NSTX Upgrade

OH Coaxial Cable and Embedded Leads

ADDENDUM to NSTXU-CALC-133-07-00

22 August 2015

Addendum 1: Note on Calculation of Lorentz Induced Stress

Addendum 2: Justification of Requirement to Fill Coax Interstitial Space

Addendum 3: Current Density Check

Michael Mardenfeld Digitally signed by Michael Mardenfeld DN: cn=Michael Mardenfeld, o=PPPL, ou=Mechanical Engineering, email=mmarden@pppl.gov, c=US Date: 2015.08.03 15:32:58 -04'00'

Michael Mardenfeld, Calculation Author

Peter H. Titus Digitally signed by Peter H. Titus DN: cn=Peter H. Titus, o, ou=Princeton Plasma Physics Laboratory, email=ptitus@pppl.gov, c=US Date: 2015.08.05 08:28:06 -04'00'

Peter Titus, Analysis Branch Head

NSTX

Addendum 1: Note on Minor Error of Lorentz Induced Stress Calculation

M. Mardenfeld

Note in Section 5.0, Updated Design Thermal Analysis, the actual current waveform of the OH Pulse was replaced with an Equivalent Square Wave (ESW). This was done in order to facilitate convergence and reduce model size. This ESW has the same total Joule Heating and occurs on a time scale faster than internal conduction within the copper, and therefore should have nearly the same temperature distribution as the actual OH Waveform. This waveform simplification should not impact the thermal stresses plotted in the calculation, which should be considered accurate.

However, the ESW has a constant current of 7425 Amps as compared to the (peak) current of 24,000 Amp peak in the actual OH Waveform. This usage of a less than peak current means that the Lorentz forces used in the calculation model are less than peak. **Correspondingly, the stresses causes by Lorentz forces, shown in Section 7.0 of the calculation, may be as much as 1/3 lower than the actual peak values which will occur during operation.**

Although this error was not caught until after the calculation had been filed and checked, the calculation author does not perceive this as having significant impact on the conclusions of the calculation due to the following factors:

1. The behavior of the Coaxial Lead is driven by thermal behavior, and even with a 3x multiplication on Lorentz Forces, the electromagnetic induced stresses are much smaller than the thermally induced stresses.

2. The details of the mechanical restraints in the region of interest (Coax Lead Support) have evolved and changed since this calculation. The new details have been re-qualified by calculation NSTXU-CALC-55-01-01, “Structural Analysis of PF1, TF and OH Bus Bars”.

Addendum 2

P. Titus

Justification of Requirement to Fill Coax Interstitial Space

Michael Mardenfeld

From: Peter Titus
Sent: Wednesday, May 20, 2015 10:12 AM
To: Stefan Gerhardt; Neway Atnafu; Lawrence Dudek; Steve Raftopoulos; Michael Mardenfeld
Subject: Fwd: about the OH coaxial lead
Attachments: Coax Calculation Figures.pdf

Follow Up Flag: Follow up
Flag Status: Completed

Presentation attached.

First, we just had a meeting with the tech's and Neway, and it is pretty easy to inject epoxy into the annular spaces between the conductors by drilling or machining grooves in the G-10 split half filler. No metal would need to be drilled. There even appears to be some advantage in "freezing" the geometry after it is well fit up and in-place. So I don't think it is a problem to have the coax meet the intended original requirements for full operating parameters.

The main load that contributed to the lift-off is the vertical field crossing the radial currents in the coax. The vertical field causes prying on the weak axis of the bolted joint. The toroidal field also adds to the moment but on the strong direction of the flange. The moment due to the toroidal field will act on the terminals inside the box and because Mike Mardenfeld modeled the coax as filled, I just want to stay consistent with the original qualifications.
---------- Forwarded message ----------
From: **Stefan Gerhardt** <sgerhard@pppl.gov>
Date: Wed, May 20, 2015 at 9:15 AM
Subject: about the OH coaxial lead
To: Peter Titus <ptitus@pppl.gov>
Cc: Jonathan Menard <jmenard@pppl.gov>, Masayuki Ono <mono@pppl.gov>, Steve Raftopoulos <sraftopo@pppl.gov>, Lawrence Dudek <ldudek@pppl.gov>, Neway Atnafu <natnafu@pppl.gov>

Hi Pete,
Do you have any presentations or information in other forms regarding this lift-off issue on the OH coaxial feed?

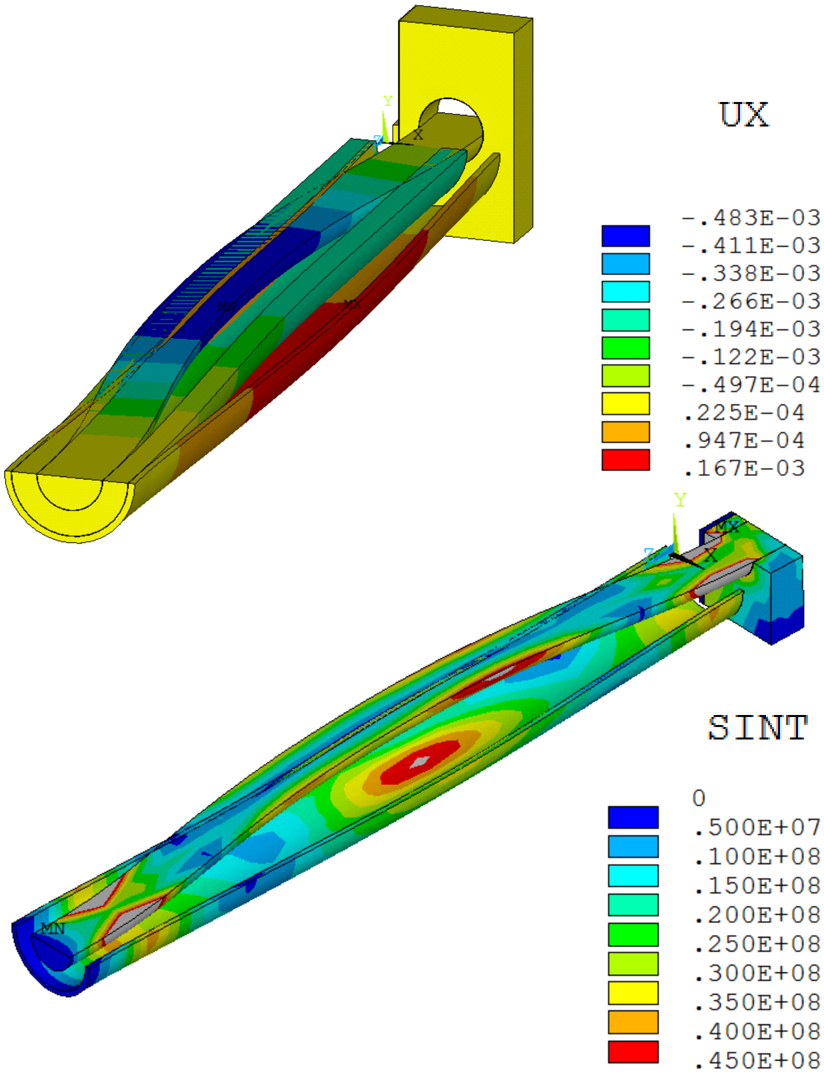
Of particular interest would be what sort of assumptions on the plasma scenario or otherwise were made? And could a simple DCPS algorithm alleviate the issue for the first year?

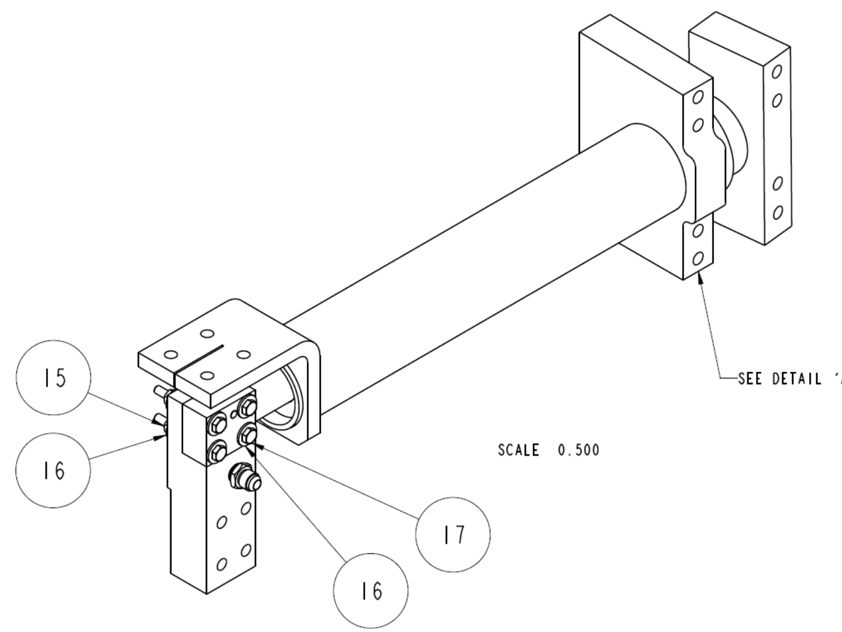
--
Stefan

Stefan Gerhardt
PPPL
609-243-2823
http://w3.pppl.gov/~sgerhard/

Coax Epoxy Fill

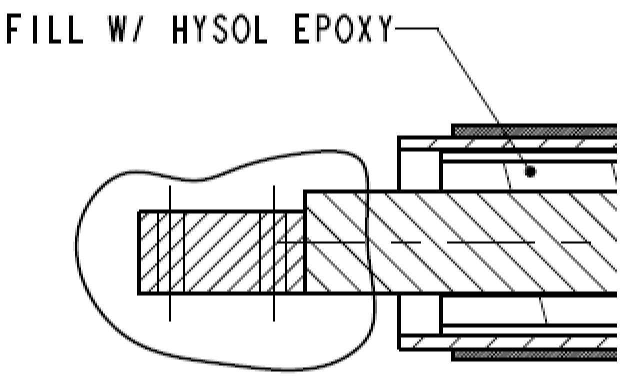
P. Titus May 13 2015





On page 28 of Mike's calculation, the following statement is made:

"In the region of the coaxial cable, the total forces on the inner and outer conductions balance each other. In this way, even though there are local compressive and tensile stresses in any plane of the coaxial cable, there is no net beam bending."



The drawing says fill with epoxy

Steve and Neway say it hasn't been filled, and
Neway says that the total radial clearance of .02 is good Enough.

My Conclusion:
To avoid lift-off on the bolted connections, it should be filled.

Nominal 96 Equilibria
algorithm # 211   SRSS of Vertical and Toroidal Field in OH Coax
Maximum Result of Algorithm 211 = 1.2509011 Tesla at EQ# 31
Minimum Result of Algorithm 211 = 1.200001 Tesla at EQ# 41
Max Limit for Algorithm 211 is 10 Tesla
Min Limit for Algorithm 211 is -10 Tesla

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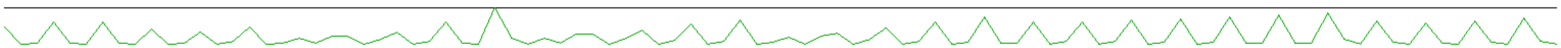
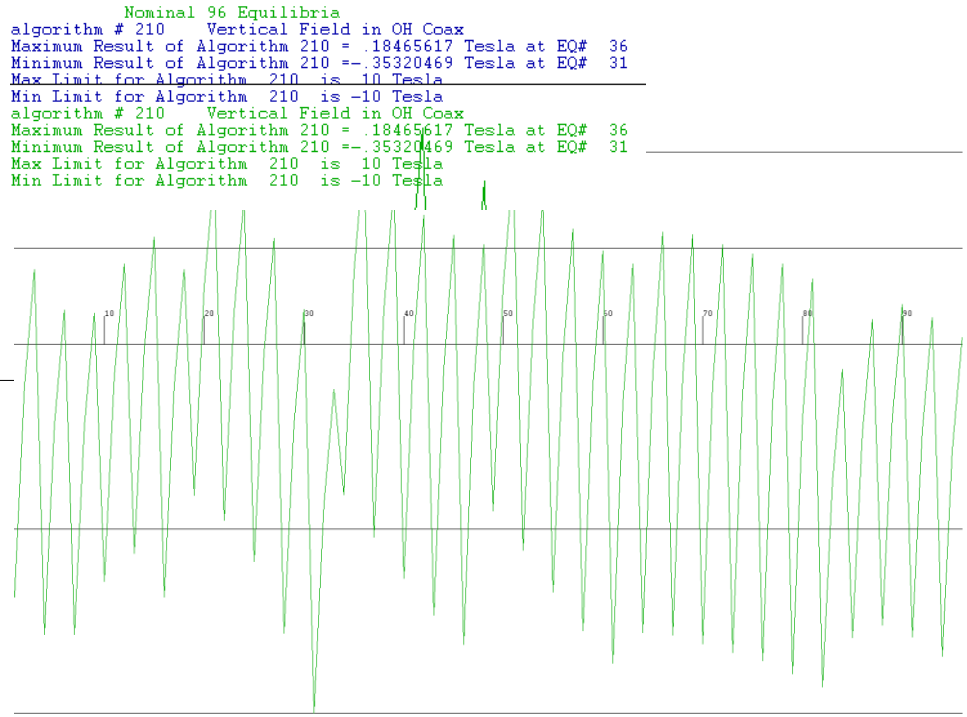
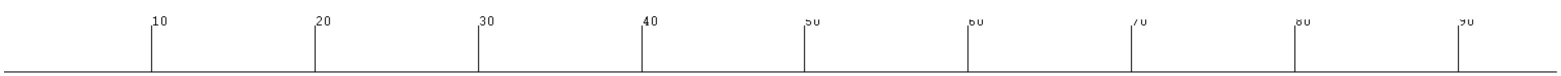
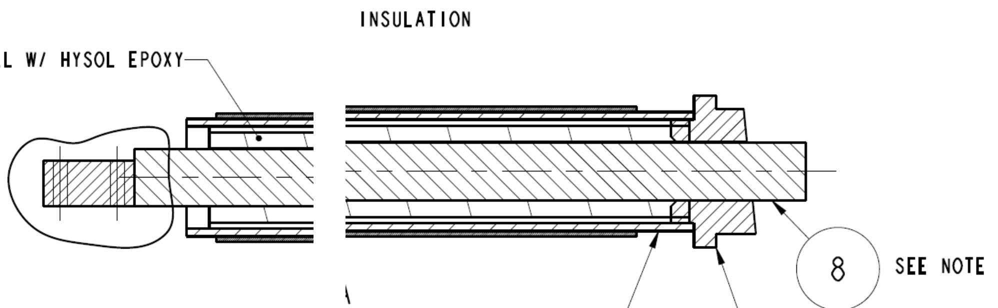


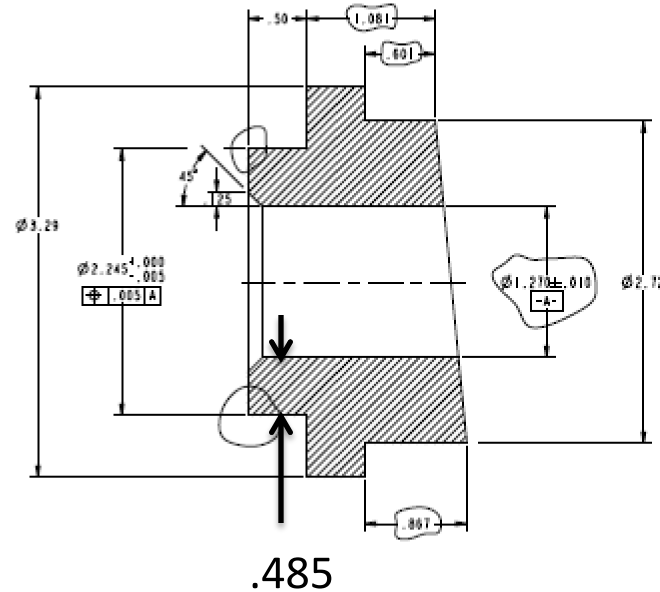


96 EQ Scan:
SRSS of toroidal and
vertical field=1.25 T
Vertical Field=-.35 T

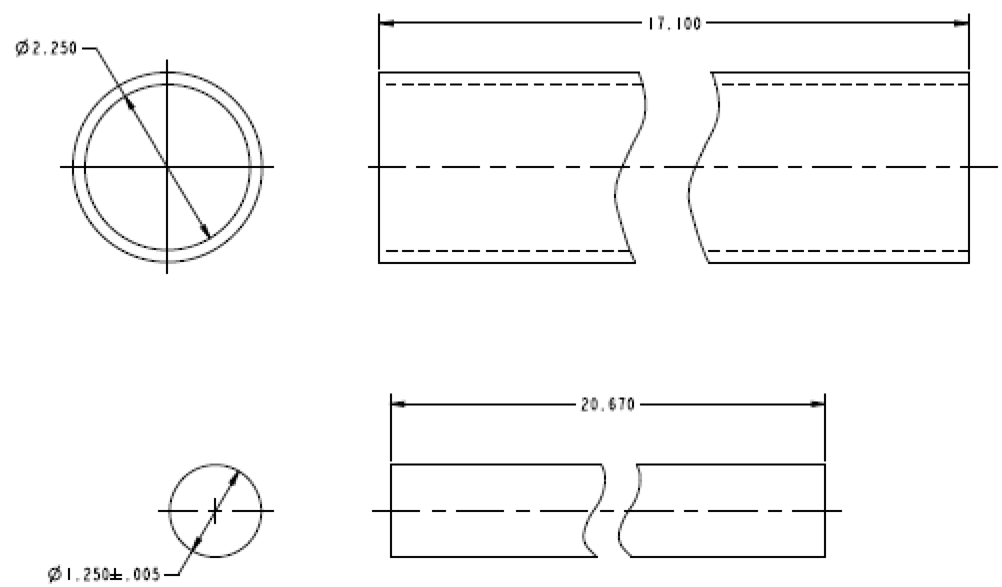


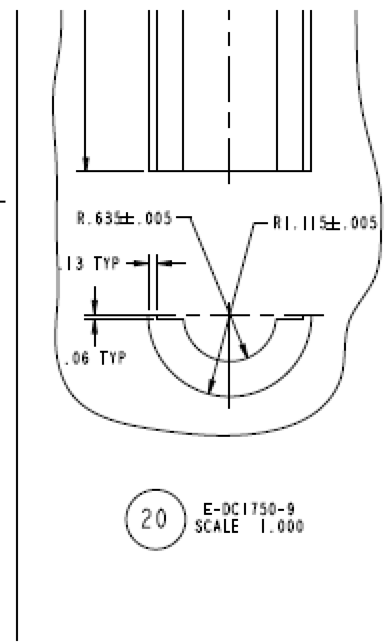


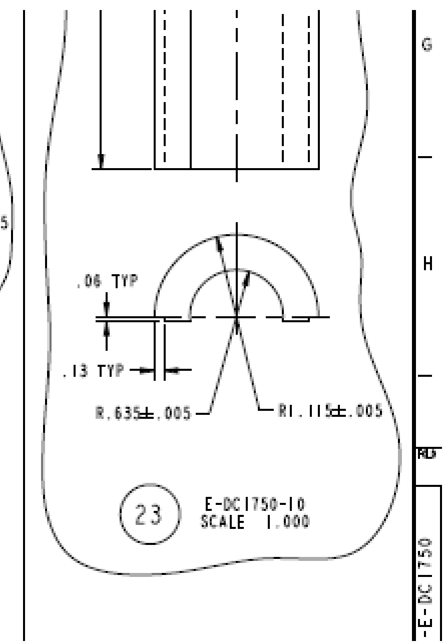
Dielectric Strength of Air is ~3 MV/m
2.Dielectric Strength of G10 is ~ 30 MV/m
.485 air gap can stand-off 36.95kV



5. THE OH COAX FEED BUS IS INSULATED USING TWO HALF-LAP LAYERS OF 2 MIL KAPTON FULL LENGTH.







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3,.635,0,0,0
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n
5,1.125,0,0,0,0
n
6,1.25,0,0,0,0,0,0
mat
1
type
1
real
1
e
1,2,0,0,0,0,0,0
mat
2
real
2
type
2
e
2,3,0,0,0,0,0,0
real
5
mat
5
type
1
e
3,4,0,0,0,0,0,0,0
real
2
mat
2
type
2
e
4,5,0,0,0,0,0,0
real
4
mat
4
type
1
e
5,6,0,0,0,0,0,0
seal
0
styp
1,1
divi
1,2,1,1,1,1
snal
1
.
```

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.
merge
1,.00001
redu
todr
36,0,10
snal
1
merge
1,.00001
redu
ecor

rotx
9,90
plce
pl
!exit
todt
22,0,1

snal
1
gtrans
1,1,0,-1
bgen
1,0,1.25,0
r
1,1,333.3333
r
4,1,-333.3333
smat
4,4
smat
1,4
snal
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tmsa
coa4,2

plce
pl
exit
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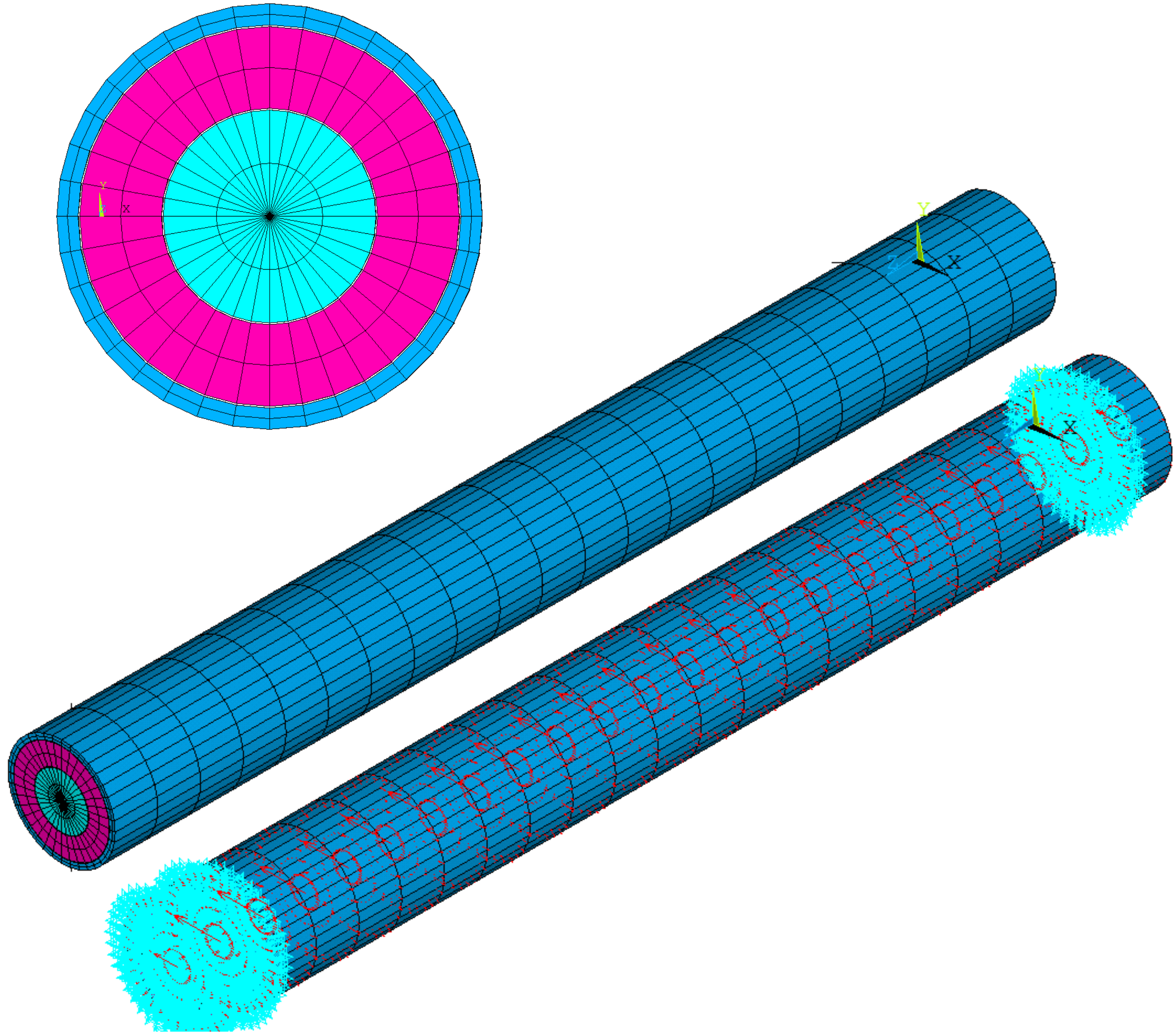
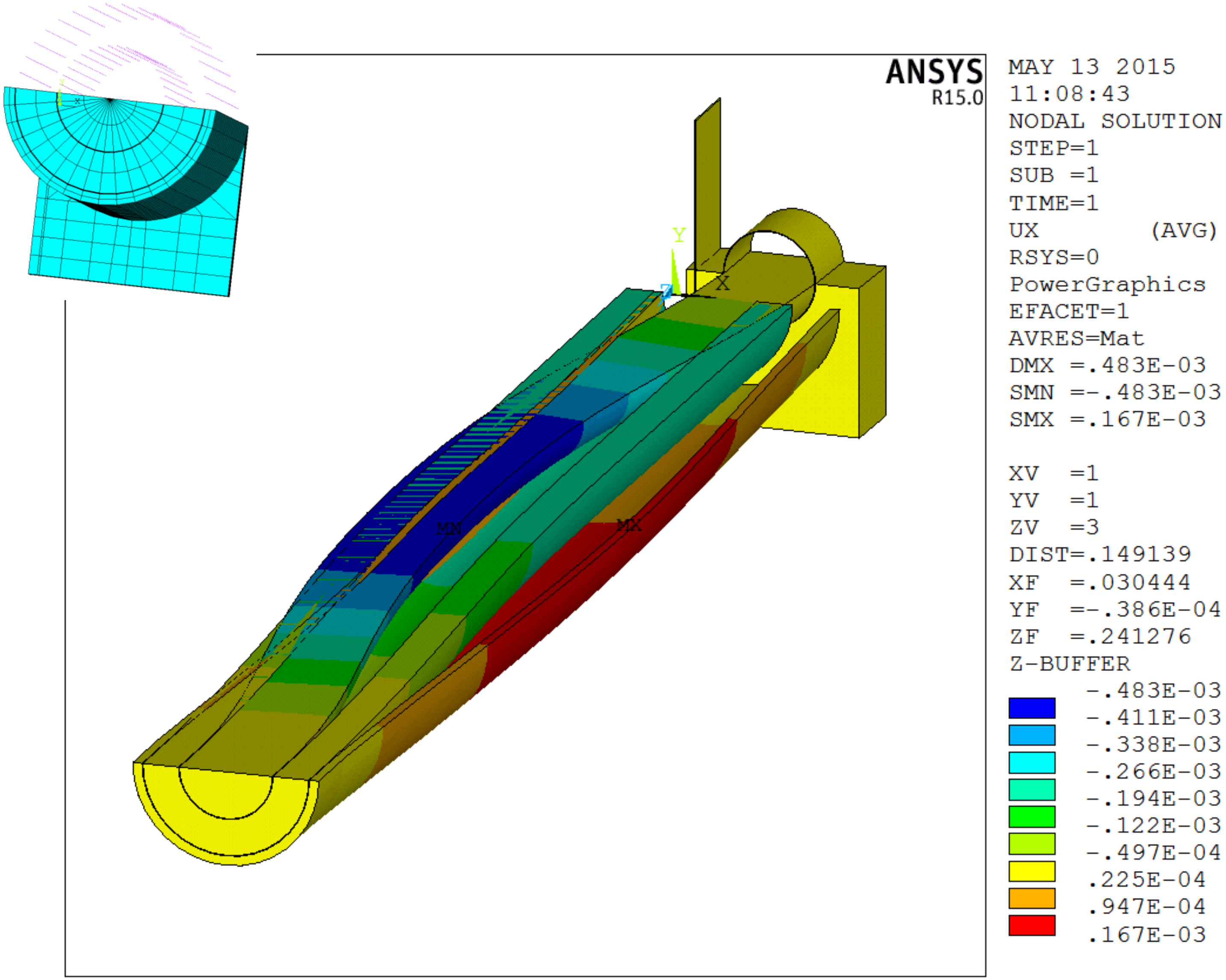
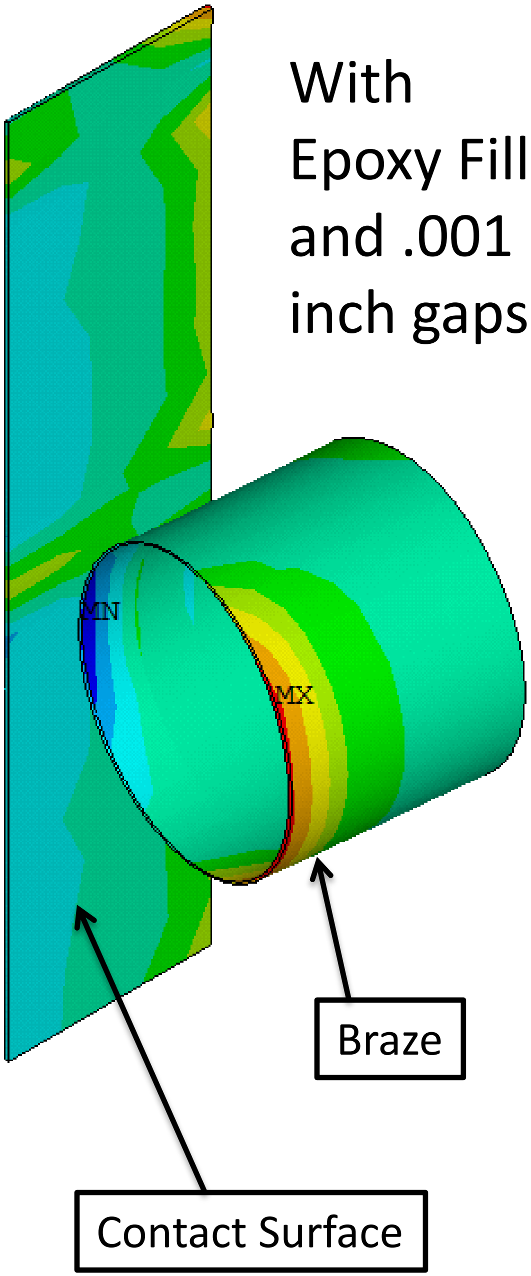
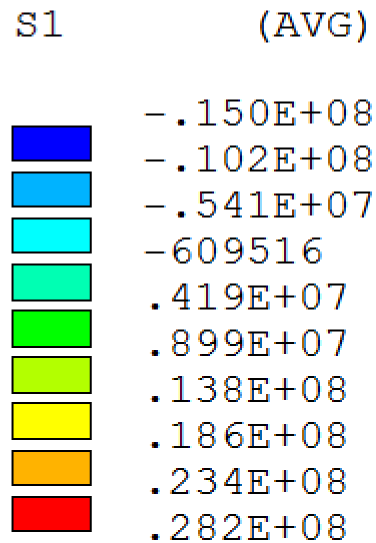


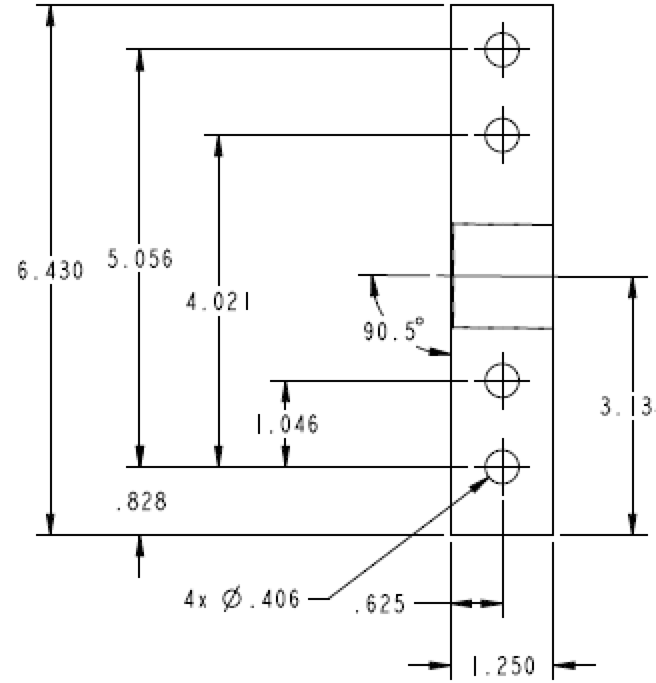
r,2,1e8,2.54e-4 ! 2.534e-4= .01 in

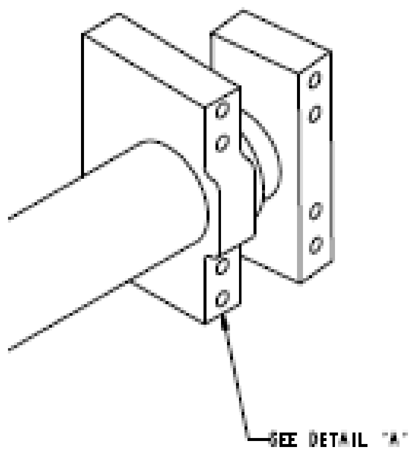


With Epoxy Fill and .001 inch gaps





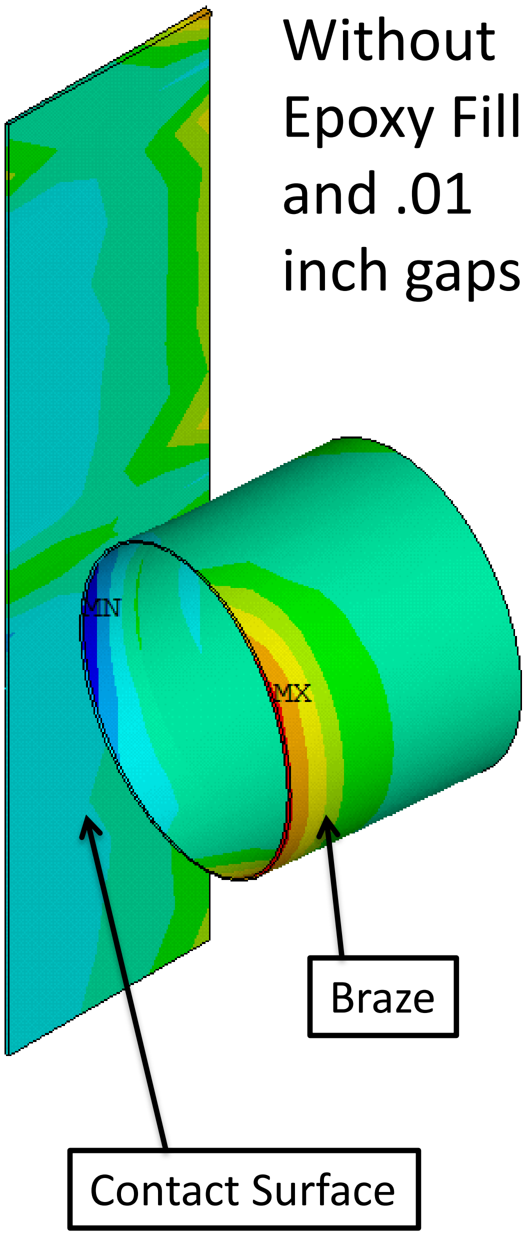


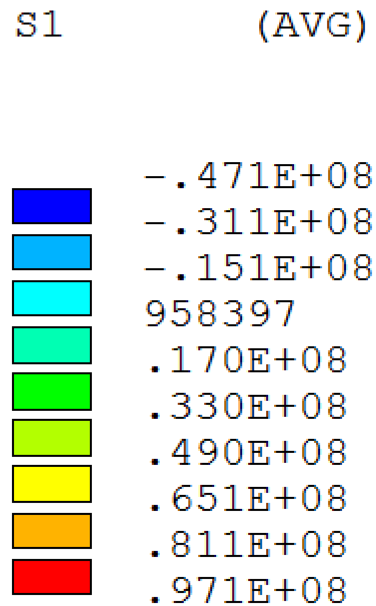


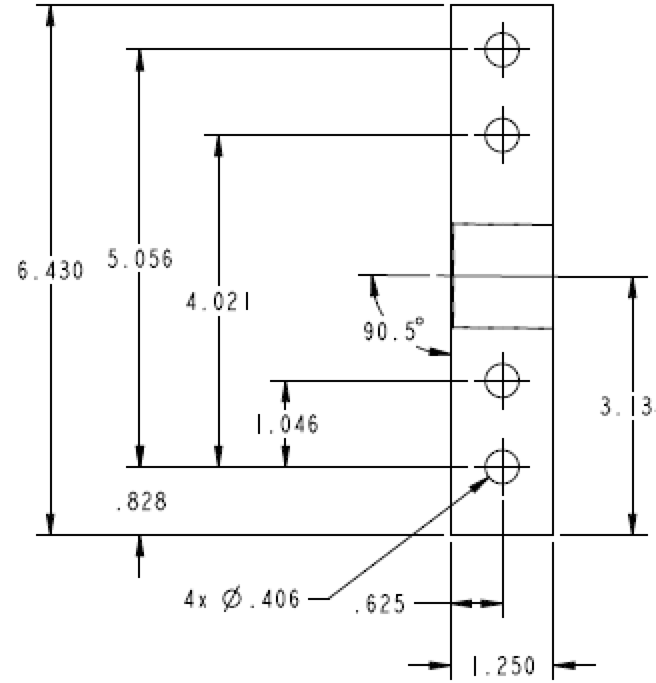
Preload Compressive stress is supplied by 4 3/8 bolts. They would be tensioned to ~20ksi*.0773in^2 =1546 lbs

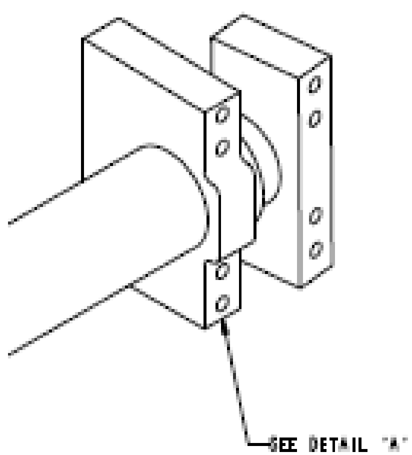
Four of them would produce a compressive pressure of 4*1546*4/1.25/6.43 = 769 psi or 5.3 MPa. The peak tension stress under load is 13.8 Mpa=2001 psi

Without Epoxy Fill and .01 inch gaps



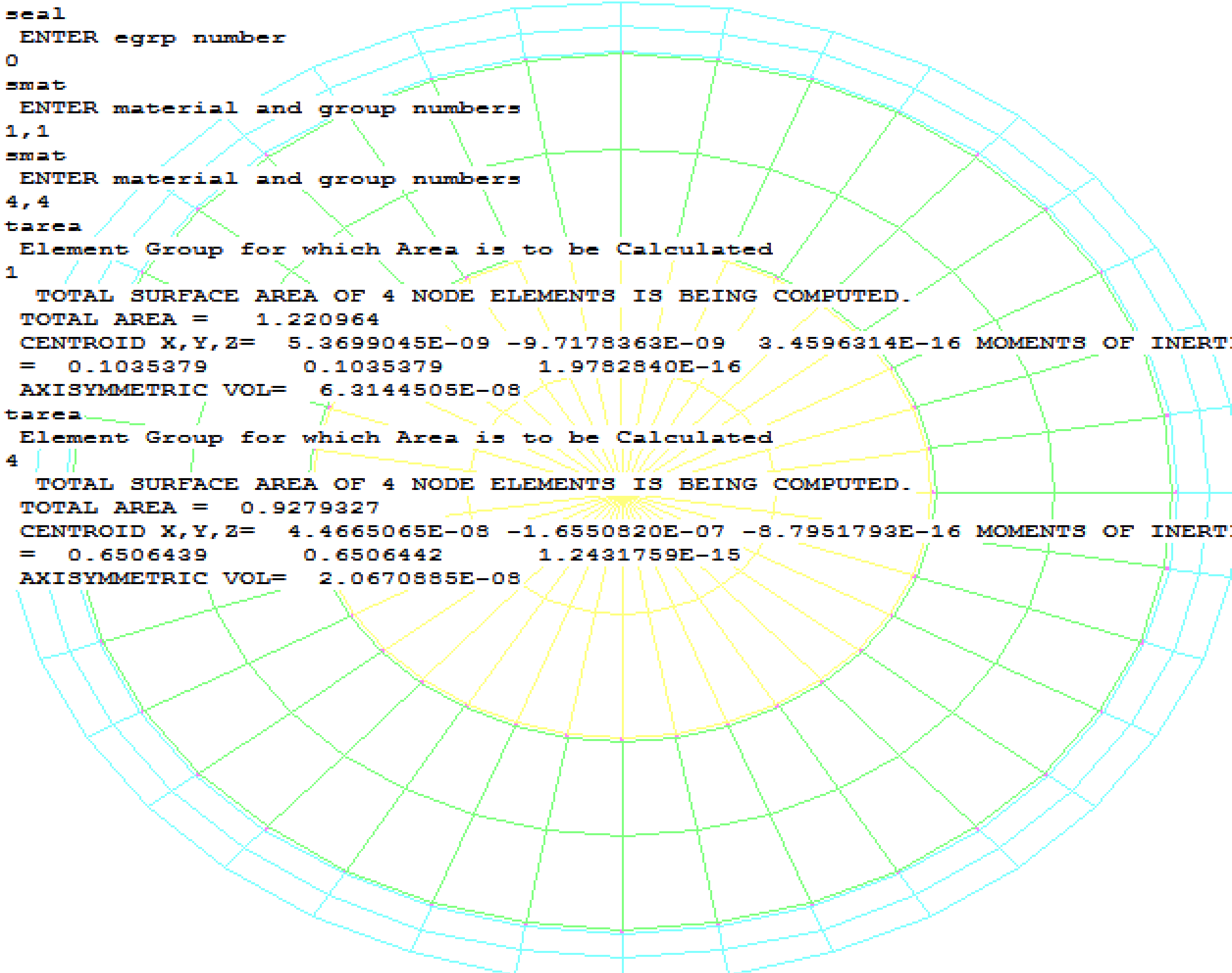






Preload Compressive stress is supplied by 4 3/8 bolts. They would be tensioned to ~20ksi*.0773in^2 =1546 lbs

Four of them would produce a compressive pressure of 4*1546*4/1.25/6.43 = 769 psi or 5.3 MPa. The peak tension stress under load is 49 Mpa=7106 psi



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seal
 ENTER egrp number
0
smat
 ENTER material and group numbers
1,1
smat
 ENTER material and group numbers
4,4
tarea
 Element Group for which Area is to be Calculated
1
  TOTAL SURFACE AREA OF 4 NODE ELEMENTS IS BEING COMPUTED.
 TOTAL AREA =    1.220964
 CENTROID X,Y,Z=  5.3699045E-09 -9.7178363E-09  3.4596314E-16 MOMENTS OF INERTIA
 =  0.1035379      0.1035379      1.9782840E-16
 AXISYMMETRIC VOL=  6.3144505E-08
tarea
 Element Group for which Area is to be Calculated
4
  TOTAL SURFACE AREA OF 4 NODE ELEMENTS IS BEING COMPUTED.
 TOTAL AREA =   0.9279327
 CENTROID X,Y,Z=  4.4665065E-08 -1.6550820E-07 -8.7951793E-16 MOMENTS OF INERTIA
 =  0.6506439      0.6506442      1.2431759E-15
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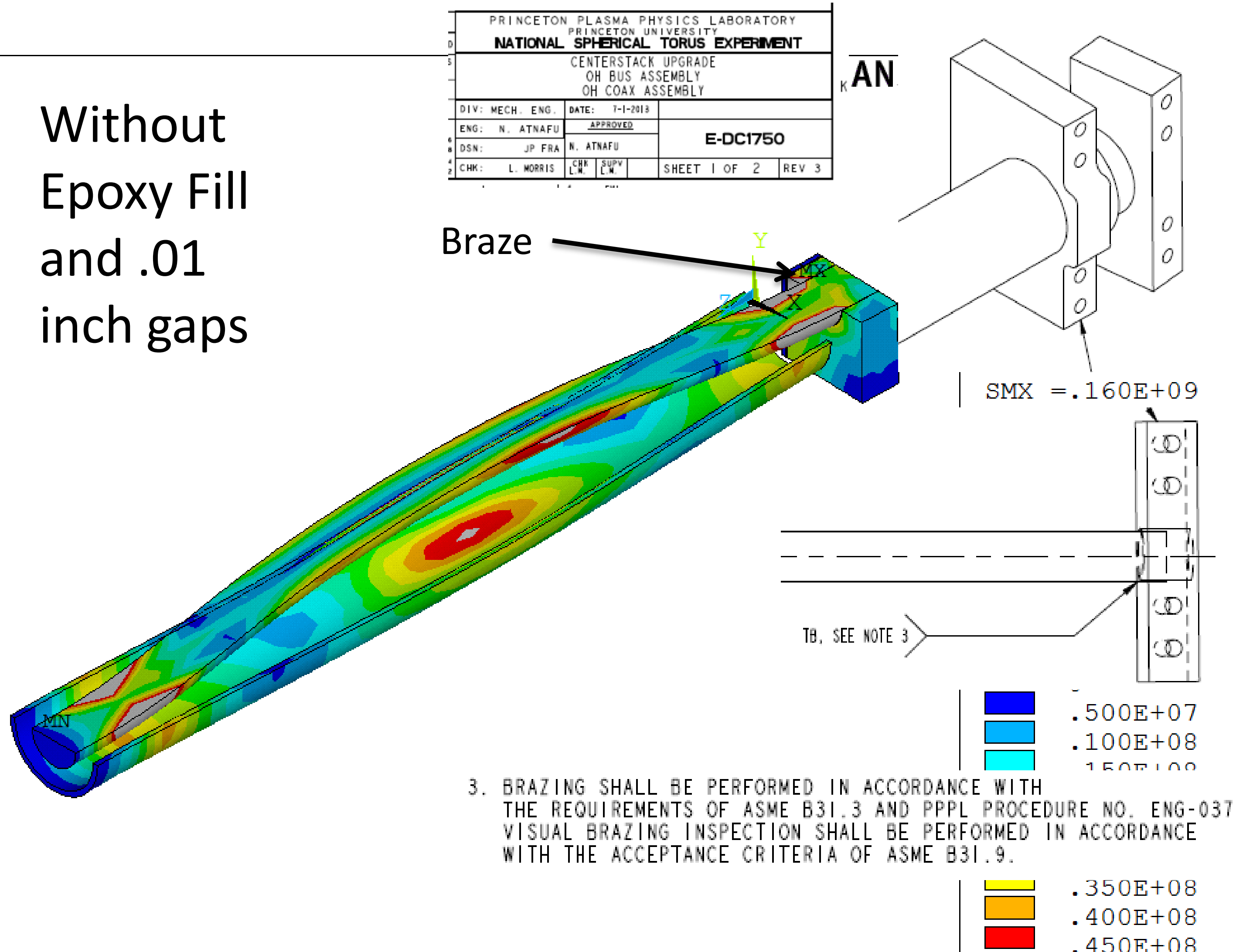
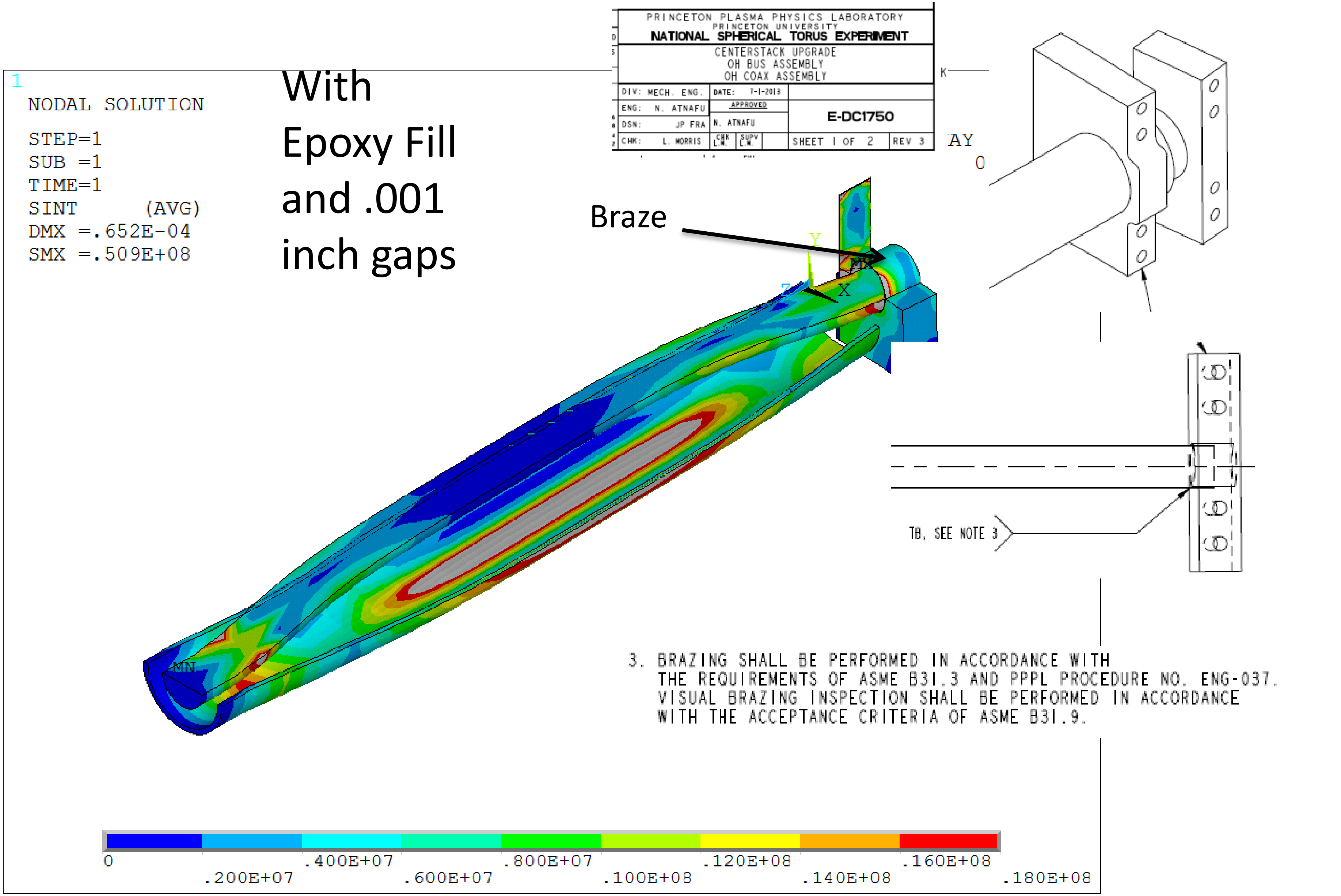
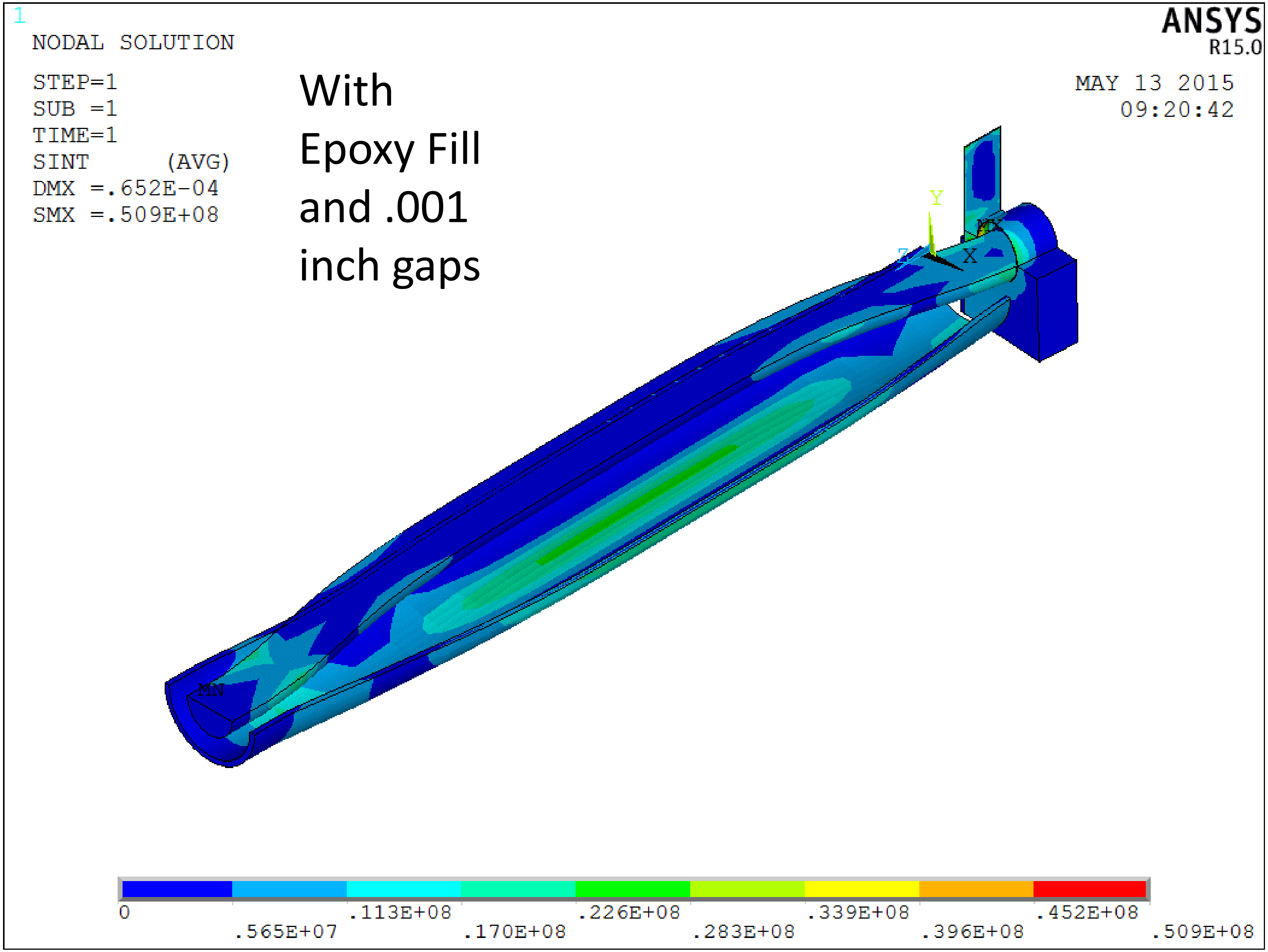
Without Epoxy Fill and .01 inch gaps





With Epoxy Fill and .001 inch gaps
Braze
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SINT (AVG)
DMX =.652E-04
SMX =.509E+08
MX
MN
Y
Z
X
0
.200E+07
.400E+07
.600E+07
.800E+07
.100E+08
.120E+08
.140E+08
.160E+08
.180E+08
PRINCETON PLASMA PHYSICS LABORATORY
PRINCETON UNIVERSITY
NATIONAL SPHERICAL TORUS EXPERIMENT
CENTERSTACK UPGRADE
OH BUS ASSEMBLY
OH COAX ASSEMBLY
DIV: MECH. ENG.
DATE: 7-1-2013
ENG: N. ATNAFU
APPROVED
DSN: JP FRA
N. ATNAFU
CHK: L. MORRIS
E-DC1750
SHEET 1 OF 2
REV 3
TB, SEE NOTE 3
3. BRAZING SHALL BE PERFORMED IN ACCORDANCE WITH THE REQUIREMENTS OF ASME B31.3 AND PPPL PROCEDURE NO. ENG-037. VISUAL BRAZING INSPECTION SHALL BE PERFORMED IN ACCORDANCE WITH THE ACCEPTANCE CRITERIA OF ASME B31.9.


1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SINT (AVG)
DMX =.652E-04
SMX =.509E+08
With
Epoxy Fill
and .001
inch gaps
ANSYS
R15.0
MAY 13 2015
09:20:42
Y
Z
X
MX
MN
0
.565E+07
.113E+08
.170E+08
.226E+08
.283E+08
.339E+08
.396E+08
.452E+08
.509E+08

Addendum 3

P. Titus

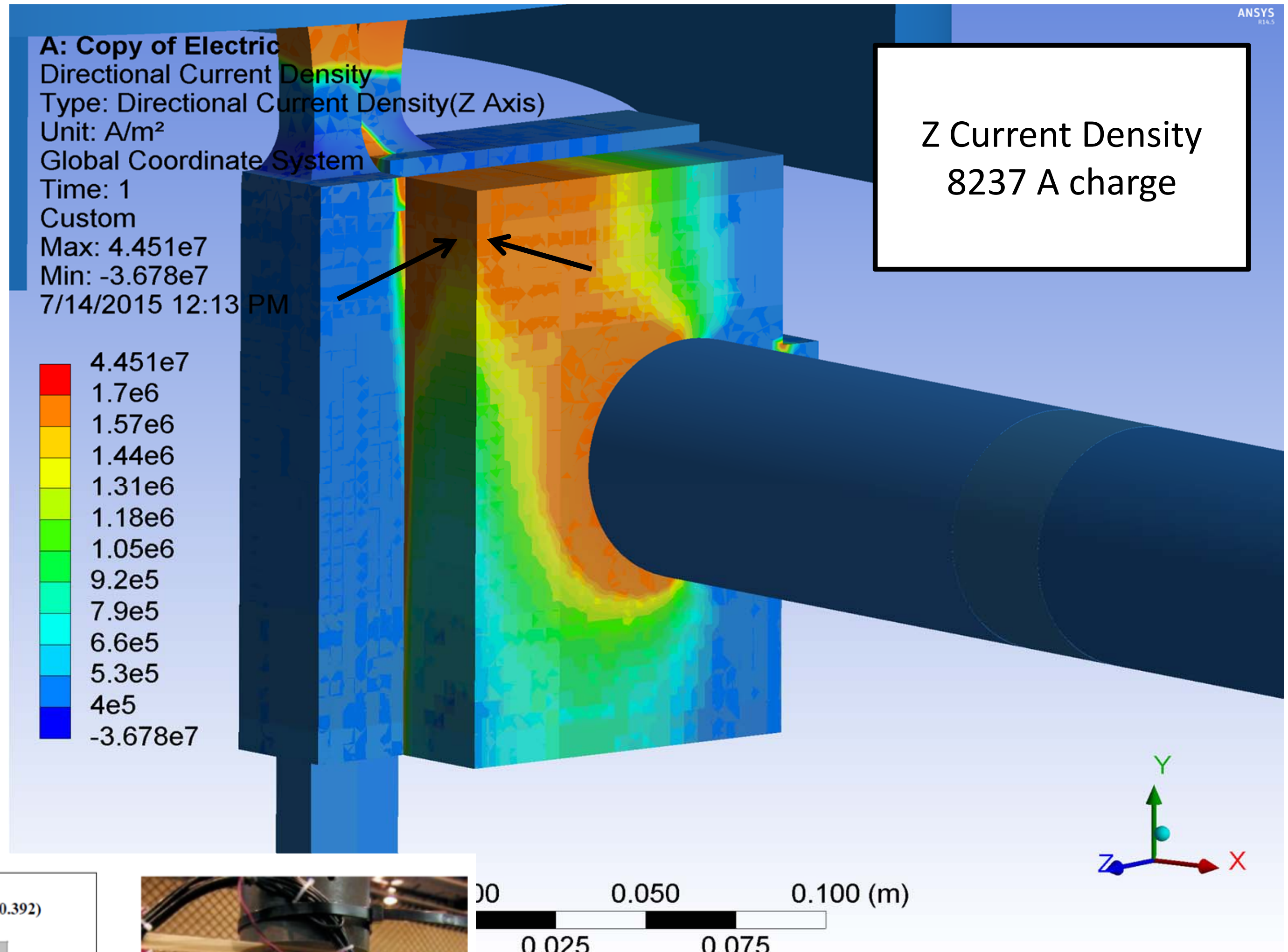
Current Density Check

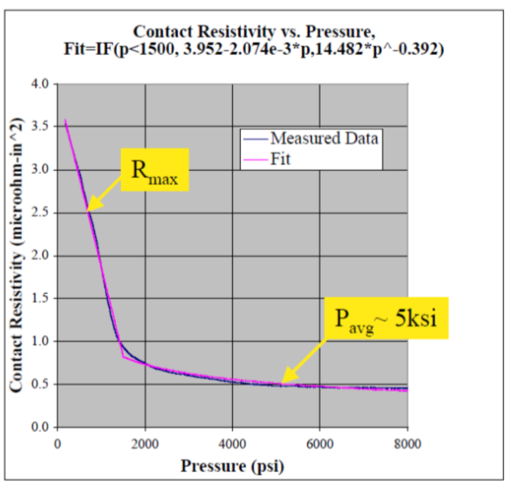
Michael Mardenfeld

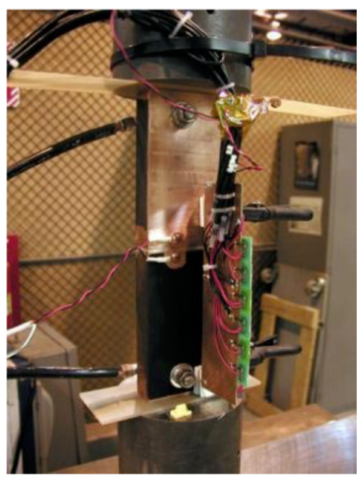
From: Peter Titus
Sent: Tuesday, July 14, 2015 2:15 PM
To: Hans Schneider; Steve Raftopoulos; Erik Perry; Michael Mardenfeld; Arthur Brooks
Subject: voltage at OH Joint
Attachments: Coax Joint Voltage.pptx

Follow Up Flag: Follow up
Flag Status: Flagged

Andrei took Mike Mardenfeld's electromagnetic model and plotted up the current density at the upper corner of the contact surface. I assumed the contact was good and the pressure was just beyond the "knee" of the contact resistance curve. That gave me a voltage across the contacts (the two arrows) of 6.36e-6V for 69 amps. In the contour plot, the OH side block is shown removed. From the bluing, we may not have full contact where the measurements is being made, but the contact is good around the bolts very near where your measurement is being made. -Peter







V=1.57e6 A/m^2*.75e-6 Ohm-in^2/39.37^2

=7.597e-4 Volts for 8237amps

=6.36e-6V for 69 amps