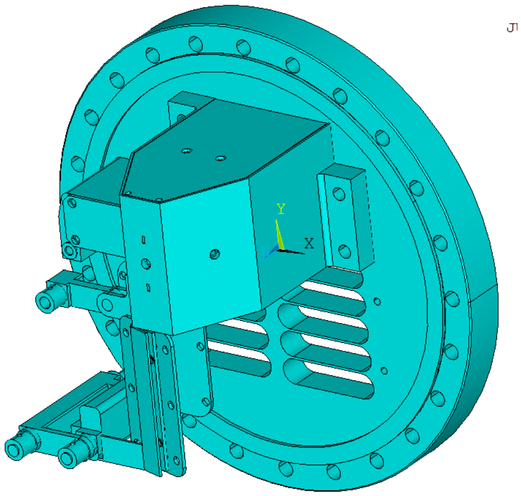
Disruption load analysis of Bay G Resistive Bolometer

NSTXU CALC-40-04-00

Date November 30 2016



Prepared by H. Zhang	Reviewed by P. Titus
Han Zhang Digitally signed by Han Zhang DN: cn=Han Zhang, o=PPPL, ou, email=hzhang@pppl.gov, c=US Date: 2016.12.06 12:50:41 -05'00'	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: 2016.12.02 17:11:15 -05'00'

PPPL Calculation Form

Calculation # **NSTXU-CALC-40-04-00** Revision # **00** ____ WP #, **xxxx**
(ENG-032)

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

The purpose of this calculation is to evaluate the disruption load and stresses on the flange.

References

These are included in the body of the calculation.

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

Centered plasma disruption (2MA) with 2000MA/s current decay is analyzed. Designed current decay rate is 1000MA/s. This should be conservative enough. Background field Br=0.31T, Bt=0.813T and Bz=-0.88T are based on the result of Peter Titus (Appendix A).

Calculation (Calculation is either documented here or attached)

These are included in the body of the following document

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

Both the eddy current and stress are quite low. Peak current and stress are at the bottom corner of the bolometer enclosure. Peak stress is 13.7MPa. For stainless steel, this is quite low and should have no problem to the structure.

Cognizant Engineer's printed name, signature, and date

Matthew L. Reinke Digitally signed by Matthew L. Reinke
Date: 2016.12.05 20:40:44 -05'00'

Matthew Reinke

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

Checker's printed name, signature, and date

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: 2016.12.02 17:10:52 -05'00'

Peter Titus

2.0 Table of Contents

Executive Summary

The 10" flange is attached at the 9 o'clock position at the Bay-G midplane port cover (E-9D1615). The resistive bolometer enclosure is a completely new design attached to this flange, which is a big piece and will have induced eddy current during plasma disruption. This analysis is to evaluate the electro-mechanical load to make sure that any disruptive loads etc. are not a problem. Note there is something special about the 10" flange in that it is not electrically connected to the Bay-G port cover. It uses a special PEEK gasket and insulated inserts for the bolts and the flange is at CAT-2 ground. This was designed by Kevin Tritz (ktritz@pppl.gov) who knows more about the details if needed.

The bolometer FEM model is from the CAD model but suppress the existing untouched ME-SXR. The changing B field dB/dt is obtained from my previous vacuum vessel disruption model and mapped to this bolometer model. Only centered plasma disruption (2MA) with 2000MA/s current decay is analyzed. Designed current decay rate is 1000MA/s. This should be conservative enough. Background field Br=0.31T, Bt=0.813T and Bz=-0.88T are based on the result of Peter Titus (Appendix A).

Eddy current pattern and EM force are provided in this document. Stresses are quite low. Peak stress is at the bottom corner of the bolometer enclosure, only 13.7 MPa, and should have no problem to the structure. Operation of the shutter shall not be impaired by thermal gradients developing in the shutter during normal operation. The shutter temperature must remain below a reasonable temperature – this was checked against criteria in [2]

Modeling

My previous vessel disruption model is a 30° model with air and centered plasma[3]. Fig. 1 shows the relative position of the flange with vessel. Flange is not included in the disruption analysis. Only the dB/dt from the vessel disruption simulation is mapping to the flange, which is electrically insulated to vessel. Fig. 2 is the background field mapped to the flange. dB/dt are calculated from 1ms plasma disruption simulation and listed in Table 1.

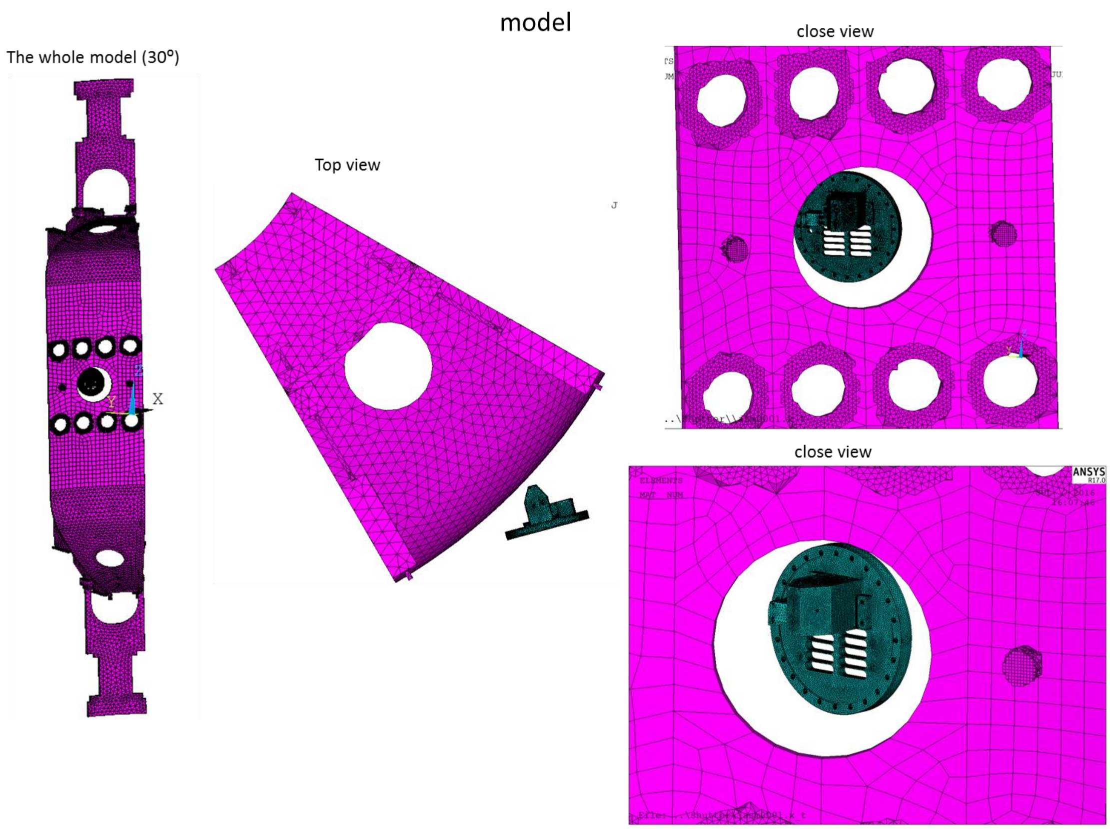

model
The whole model (30°)
Top view
close view
close view
ANSYS

Fig. 1. Model.

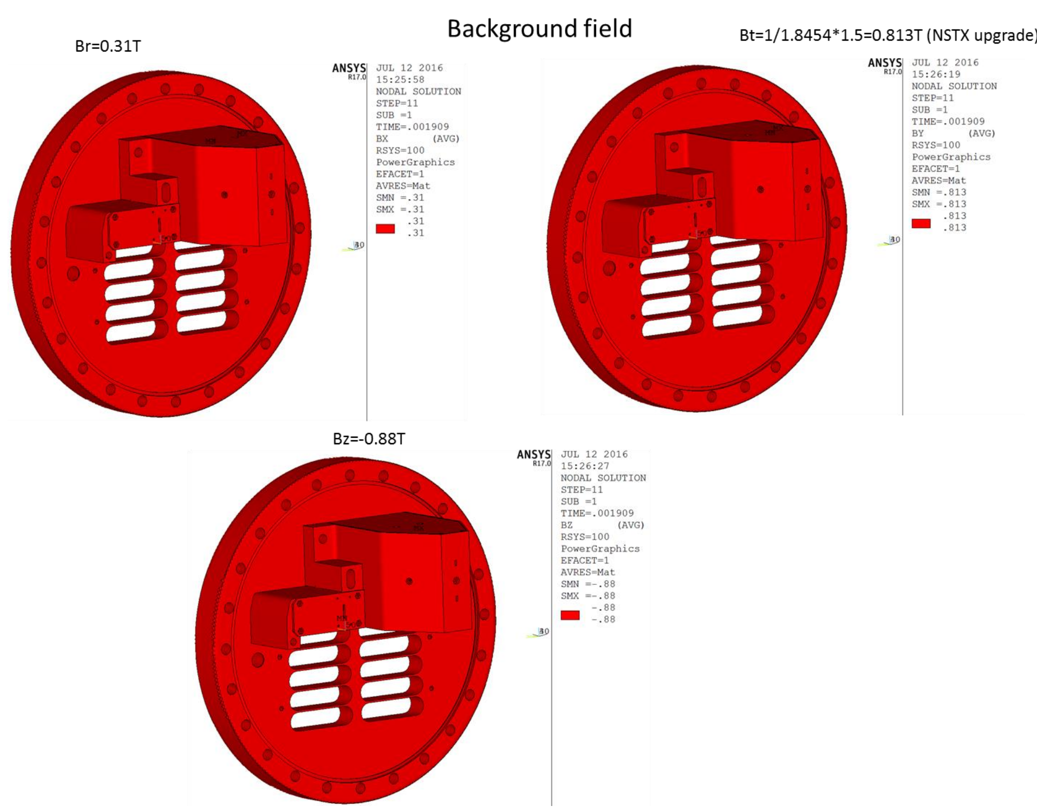

Background field
Br=0.31T
Bt=1/1.8454*1.5=0.813T (NSTX upgrade)
Bz=-0.88T
ANSYS
JUL 12 2016
15:25:58
NODAL SOLUTION
STEP=11
SUB =1
TIME=.001909
BX (AVG)
RSYS=100
PowerGraphics
EFACET=1
AVRES=Mat
SMN =.31
SMX =.31
.31
.31
ANSYS
JUL 12 2016
15:26:19
NODAL SOLUTION
STEP=11
SUB =1
TIME=.001909
BY (AVG)
RSYS=100
PowerGraphics
EFACET=1
AVRES=Mat
SMN =.813
SMX =.813
.813
.813
ANSYS
JUL 12 2016
15:26:27
NODAL SOLUTION
STEP=11
SUB =1
TIME=.001909
BZ (AVG)
RSYS=100
PowerGraphics
EFACET=1
AVRES=Mat
SMN =-.88
SMX =-.88
-.88
-.88

Fig. 2. Background field mapped to the flange.

Table 1: dB/dt are from 1ms plasma disruption simulation. The data is from the HHFW model[3]. The antenna part was set to air and it was re-run. Otherwise the dB/dt will be affected by the antenna.

No antennas (Node: 236600: mid-plane, close to vessel)			
Time (S)	Br	Bt	Bz
0.001	0.009297855	0.000271266	-0.216321283
0.001091	0.007306069	0.000322534	-0.177043923
0.001182	0.005319694	0.000373707	-0.138621882
0.001273	0.00335218	0.000421679	-0.10081377
0.001364	0.001355219	0.000472211	-0.063443163
0.001455	-0.000610927	0.000510839	-0.026409401
0.001545	-0.002576695	0.000553219	0.010276735
0.001636	-0.004517556	0.000586398	0.046735058
0.001727	-0.006459397	0.000644298	0.082942678
0.001818	-0.008373516	0.000684246	0.11889925
0.001909	-0.01027389	0.000723959	0.154631971
0.002	-0.012162011	0.000746363	0.190129282
	DBrDt	DBtDt	DBzDt
	-21.88776264	0.563383516	431.6193385
	-21.82829451	0.56233956	422.2202308
	-21.62103516	0.527165934	415.4737648
	-21.94462198	0.555297802	410.6660033
	-21.606	0.424481319	406.964422
	-21.84187111	0.470888889	407.62373
	-21.32814396	0.364602198	400.6409088
	-21.33890549	0.636265934	397.8859341
	-21.03427473	0.438992308	395.1271681
	-20.88322857	0.436401099	392.6672637
	-20.74858462	0.246207692	390.0803429
	-6.0810054	0.3731817	95.064641

Results

Fig. 3-6 shows the eddy current, EM force and stress on the flange. Peak stress is only 13.7MPa. For stainless steel, this should be no problem.

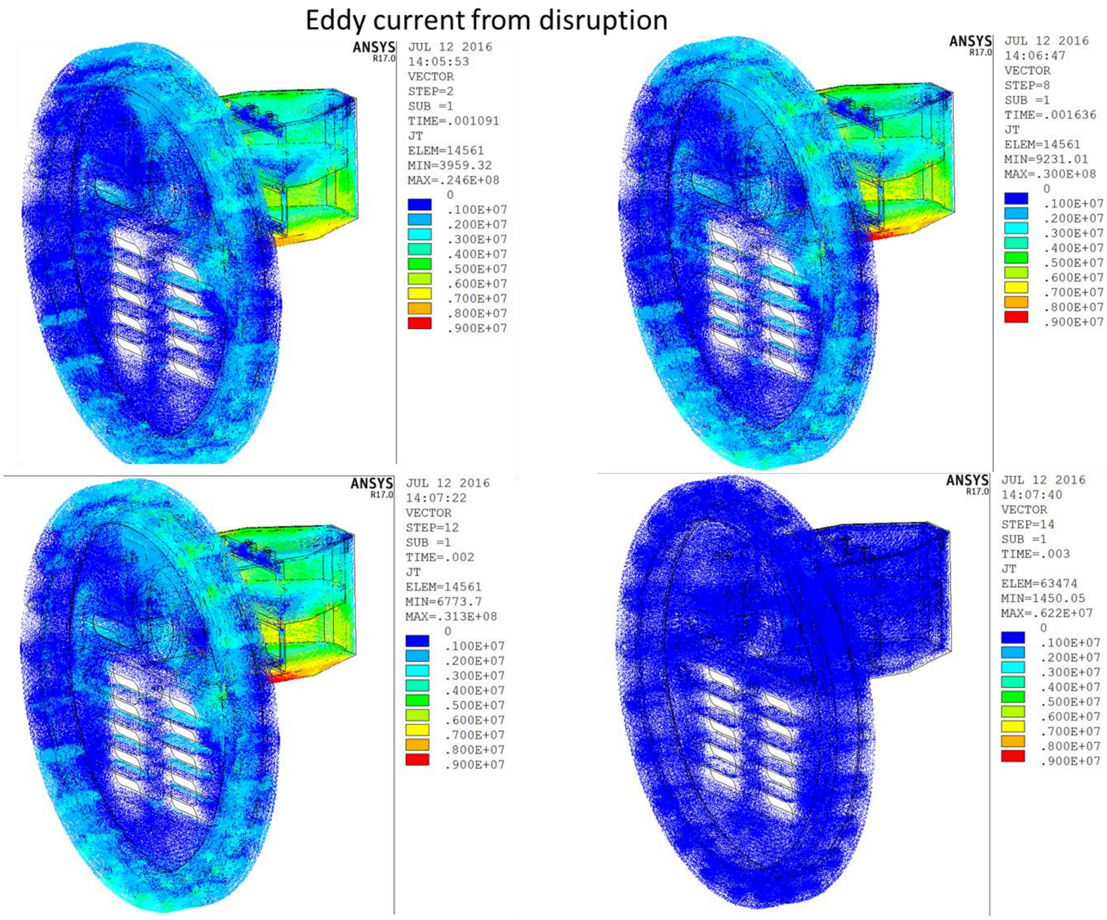


Fig. 3. Eddy current pattern on the flange.

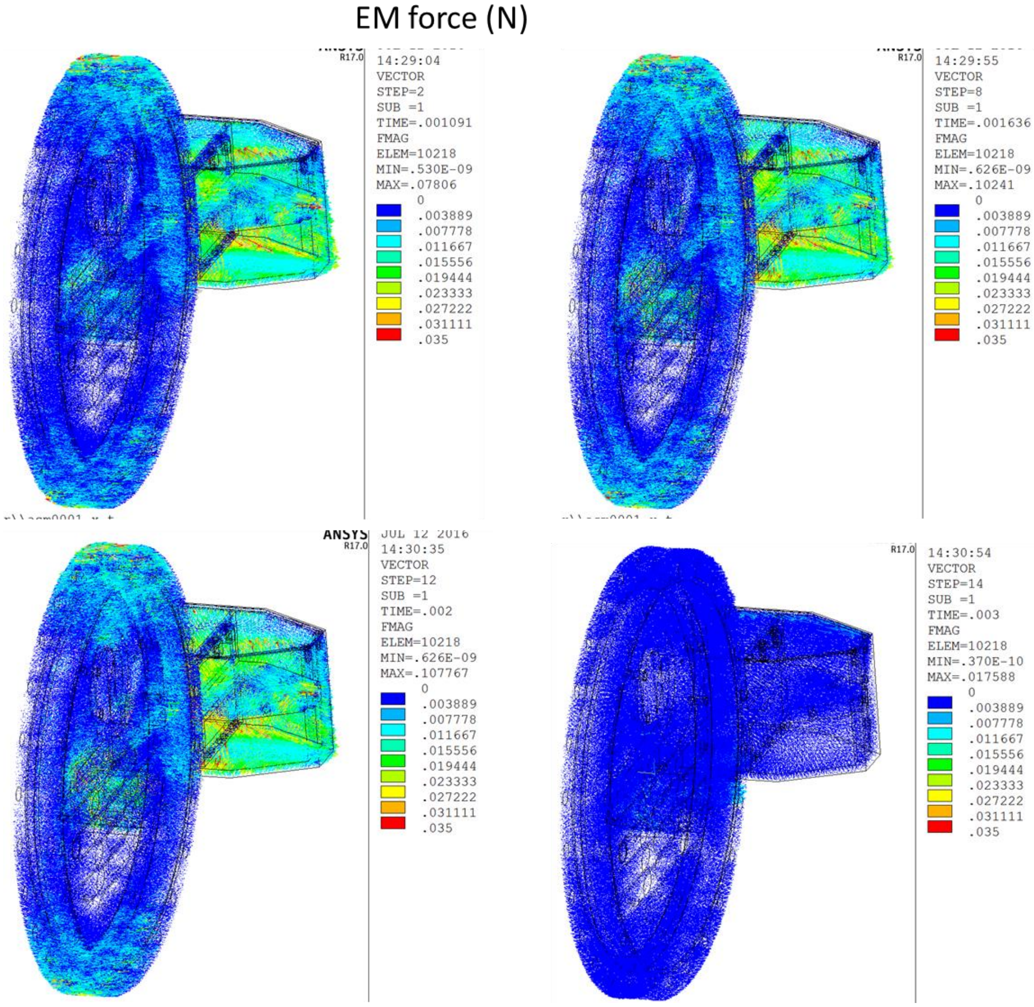


Fig. 4. Plot of EM force on the flange.

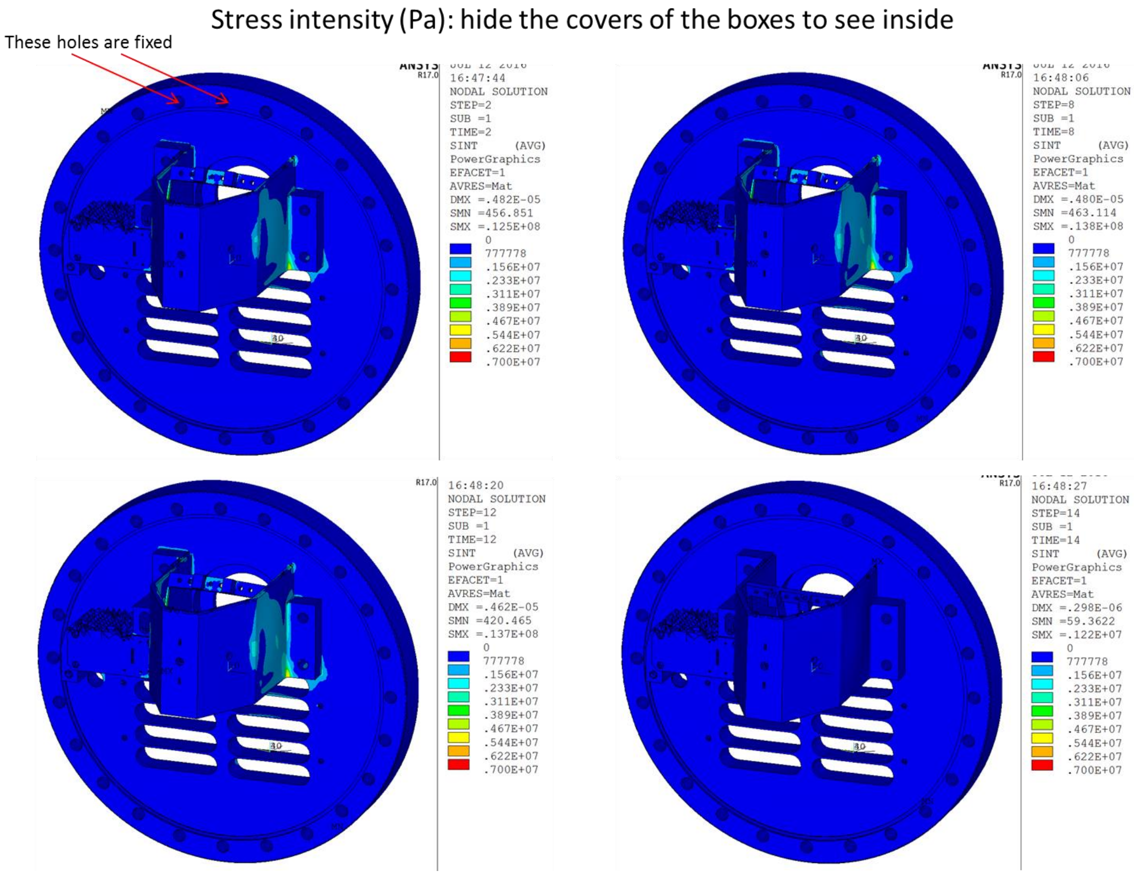


Fig. 5. Stress plot of the flange.

Peak stress is 13.7MPa due to disruption

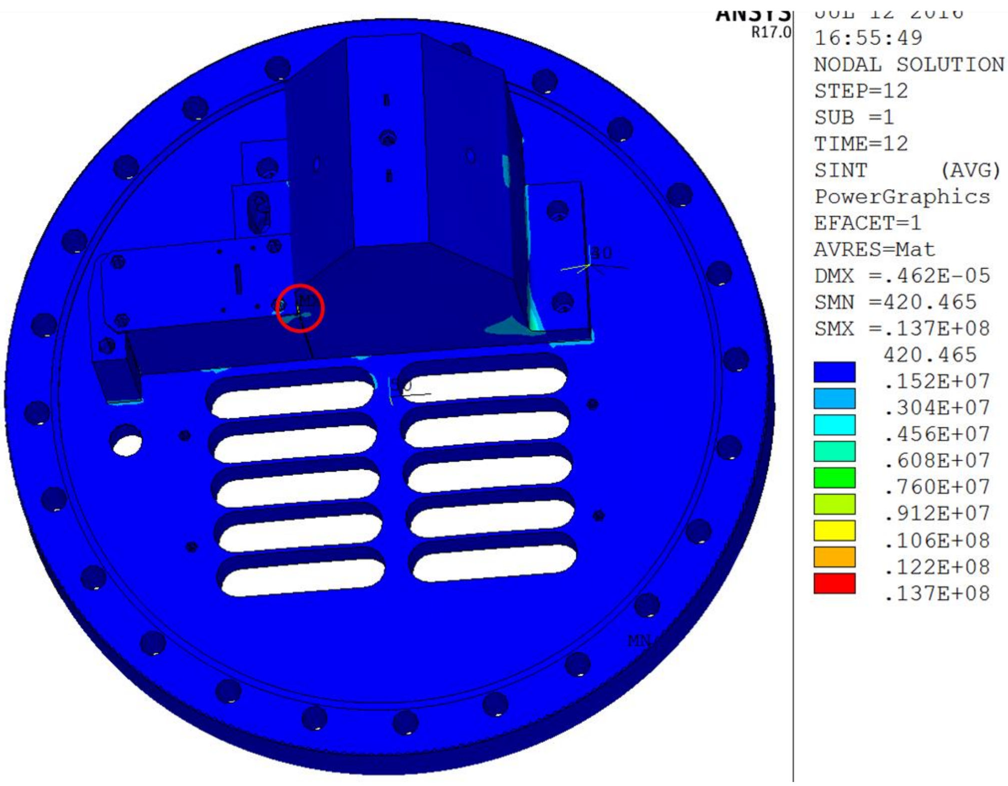


Fig. 6. Peak stress on the flange.

References

[1] NSTX-U Design Point Spreadsheet, **NSTXU-CALC-10-03-00** C. Neumeyer, http://w3.pppl.gov/~neumeyer/NSTX_CSU/Design_Point.html

[2] M.L. Reinke et. al., "Conceptual Design Review of NSTX-U Resistive Bolometer Diagnostics", https://www.dropbox.com/s/y178fcd0d3ri6v4/resbolo_fy16_cdr.pdf?dl=0

[3] NSTXU HHFW (High Harmonic Fast Wave) Eddy Current Analysis for Antenna NSTXU-CALC-24-03-01 June 1, 2011 Prepared By: Han Zhang, Reviewed by Ron Hatcher and Bob Ellis

[4] NSTX Upgrade DRAFT DCPS Check Calculations NSTXU-CALC-13-07-00 November 18 2016

[5] NSTX Upgrade Resistive Wall Mode (RWM) Coils Structural and Thermal Analysis, NSTXU CALC-12-12-00 August 27 2014 P. Titus, Reviewed by R. Wooley

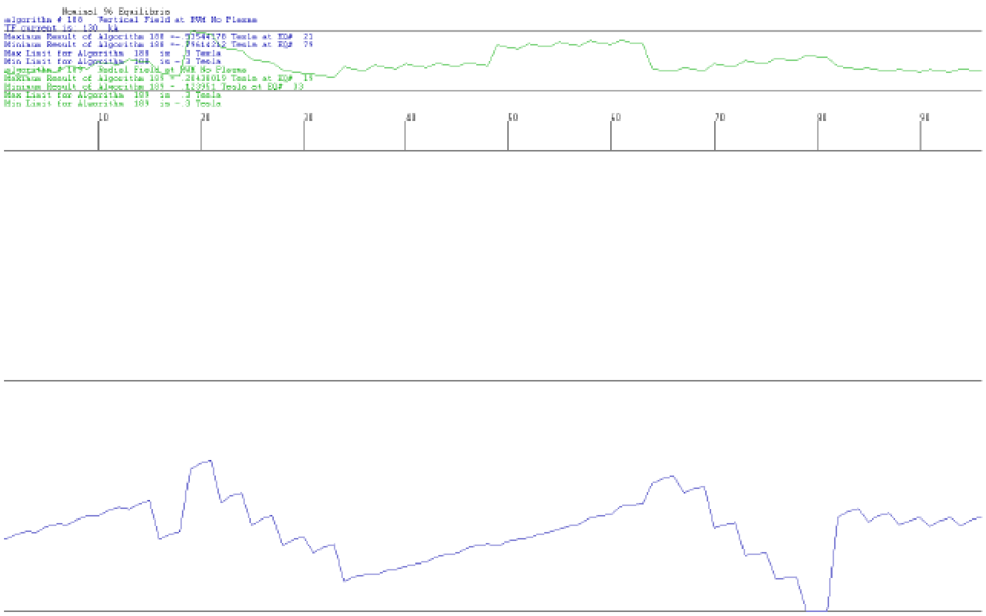
[6] ' Analysis of Diagnostic and Diagnostic Shutter " NSTXU-CALC-40-01-00 Rev 0 July 2011 Prepared By: Joseph Boales (Drexel Co-op Student, Signed by P. Titus for J. Boales

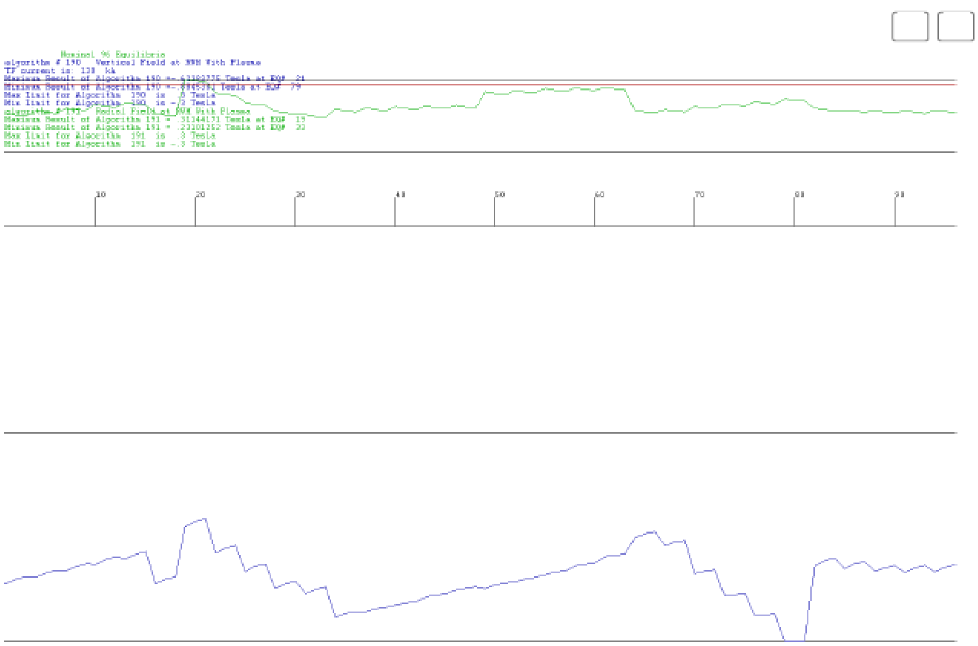
Appendix A
Email Transmitting Background Fields from [4], [5]

11/30/2016 the flange model. - hzhang@pppl.gov - PPPL Mail

Peter Titus <ptitus@pppl.gov>
to me, Matthew

I have the RWM coil location set up - which should be representative of a mid-plane port. I would use -.88T vertical and .31 Radial from the "with Plasma" result, below. -Peter





Appendix B
The script to apply B and dB/dt to the flange model

```
/clear,start
resume,flange_pos,db
FileNam='Flange'
FileNamTYPE='EM_Bxyz'
/filnam, %FileNam%%FileNamTYPE%
/solu
*afun,deg
allsel,all
antype,trans                ! transient solution
TRNOPT,FULL                 ! full transiant

t_init=1E-3       ! initialize time for static solution
EQSLV,ICCG,1e-6,2                 ! toler=1e-6
! ***********************************************************************
! ***********************************************************************
timint,OFF      ! time integration effects off for static solution
KBC,1         ! Stepped loads
time,t_init
outres,,LAST
allsel,all
csys,0
/input,Axyz_t1,cbdo

B_r=0.31
B_t=0.813         !1T*1.5/1.8454
B_z=-0.88
DCUM,ADD
*get,n_num,node,,count
n_str=0
csys,0
*do,k,1,n_num,1
  n_nxt=ndnext(n_str)
  n_x=nx(n_nxt)
  n_y=ny(n_nxt)
  n_z=nz(n_nxt)
  theta=45
  Bn_x=B_r*cos(theta)-B_t*sin(theta)
  Bn_y=B_r*sin(theta)+B_t*cos(theta)
  Bn_z=B_z
  d,n_nxt,ax,Bn_y*n_z
  d,n_nxt,ay,Bn_z*n_x
  d,n_nxt,az,Bn_x*n_y
  n_str=n_nxt
*enddo
DCUM,REPL

allsel,all
*get,n_min,node,,num,min
d,n_min,volt,0
allsel,all
csys,0
solve
```

```
! ***************************************************************************
! ***************************************************************************
timestep=0.09091e-3
risetime=t_init
timint,ON       ! time-integration effects on for transient solution
KBC,0           !  ramp load KBC,0
deltim,timestep
outres,,last
*do,t_stp,2,11,1
risetime=risetime+timestep
time,risetime        ! step down within "risetime"
/input,Axyz_t%t_stp%,cbdo

B_r=0.31
B_t=0.813         !1T*1.5/1.8454
B_z=-0.88
DCUM,ADD
*get,n_num,node,,count
n_str=0
csys,0
*do,k,1,n_num,1
  n_nxt=ndnext(n_str)
  n_x=nx(n_nxt)
  n_y=ny(n_nxt)
  n_z=nz(n_nxt)
  theta=45
  Bn_x=B_r*cos(theta)-B_t*sin(theta)
  Bn_y=B_r*sin(theta)+B_t*cos(theta)
  Bn_z=B_z
  d,n_nxt,ax,Bn_y*n_z
  d,n_nxt,ay,Bn_z*n_x
  d,n_nxt,az,Bn_x*n_y
  n_str=n_nxt
*enddo
DCUM,REPL

allsel,all
*get,n_min,node,,num,min
d,n_min,volt,0
allsel,all
csys,0
solve
*enddo

! ***************************************************************************
! ***************************************************************************
risetime=2e-3
timint,ON       ! time-integration effects on for transient solution
KBC,0           ! ramp load KBC,0
deltim,timestep
outres,,last
time,risetime        ! step down within "risetime"
/input,Axyz_t12,cbdo

B_r=0.31
```

```
B_t=0.813          !1T*1.5/1.8454
B_z=-0.88
DCUM,ADD
*get,n_num,node,,count
n_str=0
csys,0
*do,k,1,n_num,1
  n_nxt=ndnext(n_str)
  n_x=nx(n_nxt)
  n_y=ny(n_nxt)
  n_z=nz(n_nxt)
  theta=45
  Bn_x=B_r*cos(theta)-B_t*sin(theta)
  Bn_y=B_r*sin(theta)+B_t*cos(theta)
  Bn_z=B_z
  d,n_nxt,ax,Bn_y*n_z
  d,n_nxt,ay,Bn_z*n_x
  d,n_nxt,az,Bn_x*n_y
  n_str=n_nxt
*enddo
DCUM,REPL

allsel,all
*get,n_min,node,,num,min
d,n_min,volt,0
allsel,all
csys,0
solve

! ************************************************************************
! ************************************************************************
timestep=0.5e-3
timint,ON       ! time-integration effects on for transient solution
KBC,0              !  ramp load KBC,0
deltim,timestep
outres,,last
*do,t_stp,13,22,1
risetime=risetime+timestep
time,risetime       ! step down within "risetime"
/input,Axyz_t%t_stp%,cbdo

B_r=0.31
B_t=0.813          !1T*1.5/1.8454
B_z=-0.88
DCUM,ADD
*get,n_num,node,,count
n_str=0
csys,0
*do,k,1,n_num,1
  n_nxt=ndnext(n_str)
  n_x=nx(n_nxt)
  n_y=ny(n_nxt)
  n_z=nz(n_nxt)
  theta=45
  Bn_x=B_r*cos(theta)-B_t*sin(theta)
  Bn_y=B_r*sin(theta)+B_t*cos(theta)
```

```
  Bn_z=B_z
  d,n_nxt,ax,Bn_y*n_z
  d,n_nxt,ay,Bn_z*n_x
  d,n_nxt,az,Bn_x*n_y
  n_str=n_nxt
*enddo
DCUM,REPL

allsel,all
*get,n_min,node,,num,min
d,n_min,volt,0
allsel,all
csys,0
solve
*enddo

finish
```