Modular Coil Interface Hardware Inboard Shims AA/AB/BC PDR

Presented by
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August 2, 2007

Review Charge

- Are the requirements defined? What is the proposed design?
- What is the status of welding trials?
- Is the analysis consistent with proposed design?
- Have prior design review chits been addressed?
- Have all technical, cost, schedule, and safety risks been addressed?

Scope

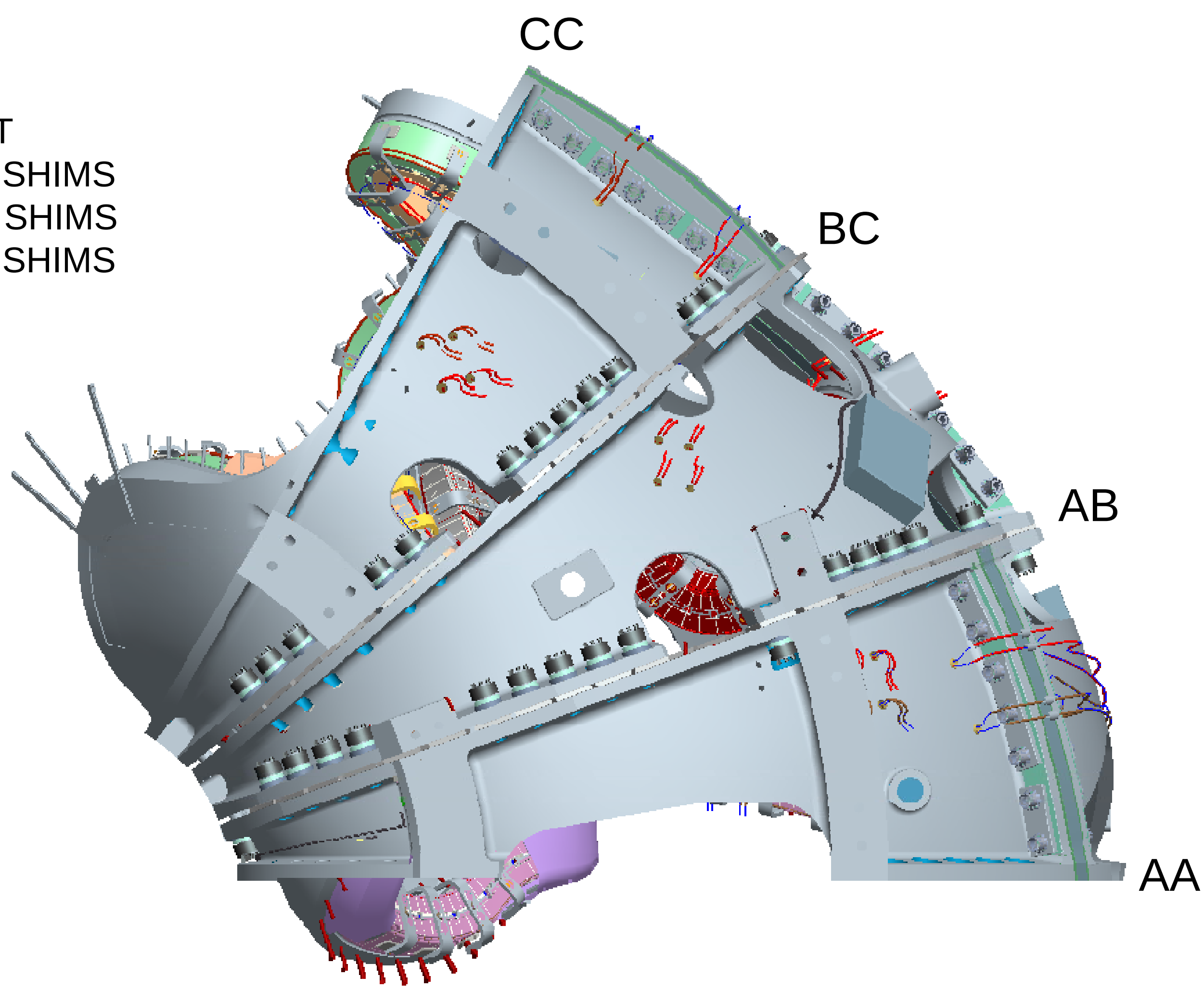
- This review-
  AA/AB/BC interface:

  SE140-046, SHIM LAYOUT
  SE140-052, AB INBOARD SHIMS
  SE140-053, BC INBOARD SHIMS
  SE140-054, AA INBOARD SHIMS

- Upcoming reviews:

  AA/AB/BC Interface
  FDR 9/4/07

  CC Interface
  PDR 8/7/07
  FDR 1/7/08



Requirements

Requirements are derived from the Modular Coil Asm Specification (NCSX-CSPEC-14-05-01) and the Station-2 Asm Specification (in progress).

Electrical

- Partial Toroidal electrical breaks shall be provided between adjacent modular coils within a field period (AA, AB, BC).
- Electrical breaks are required between adjacent modular coils in adjacent field periods (CC). [Ref. GRD Section 3.2.1.5.2b to be revised]
- Toroidal electrical breaks must be able to withstand an applied voltage of 150 V (ref. GRD Section 3.2.1.5.3.6).

Structural

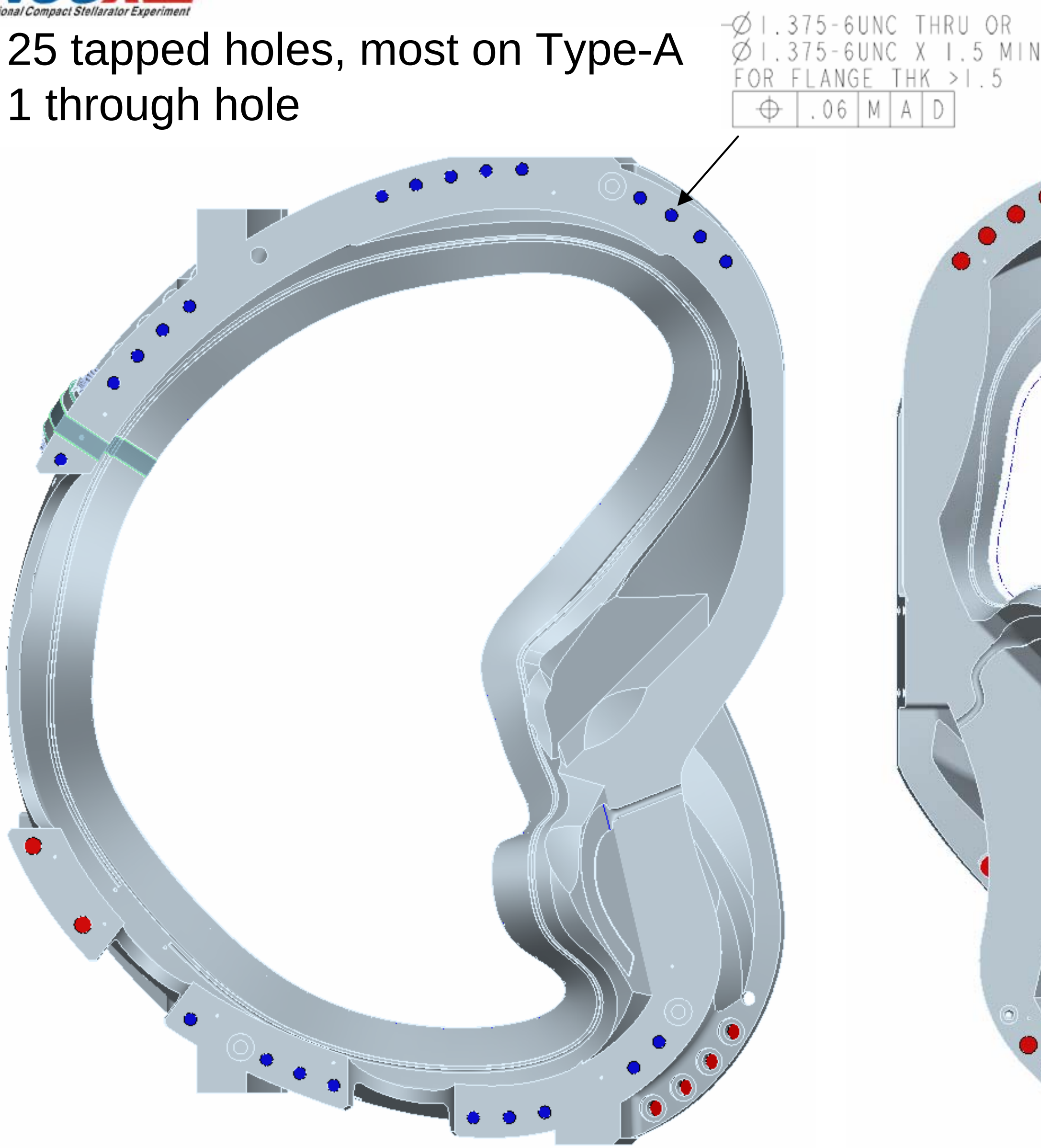
- Carry compressive loads
- Maintain a “no slip condition” under the bolts (friction joint)

Assembly

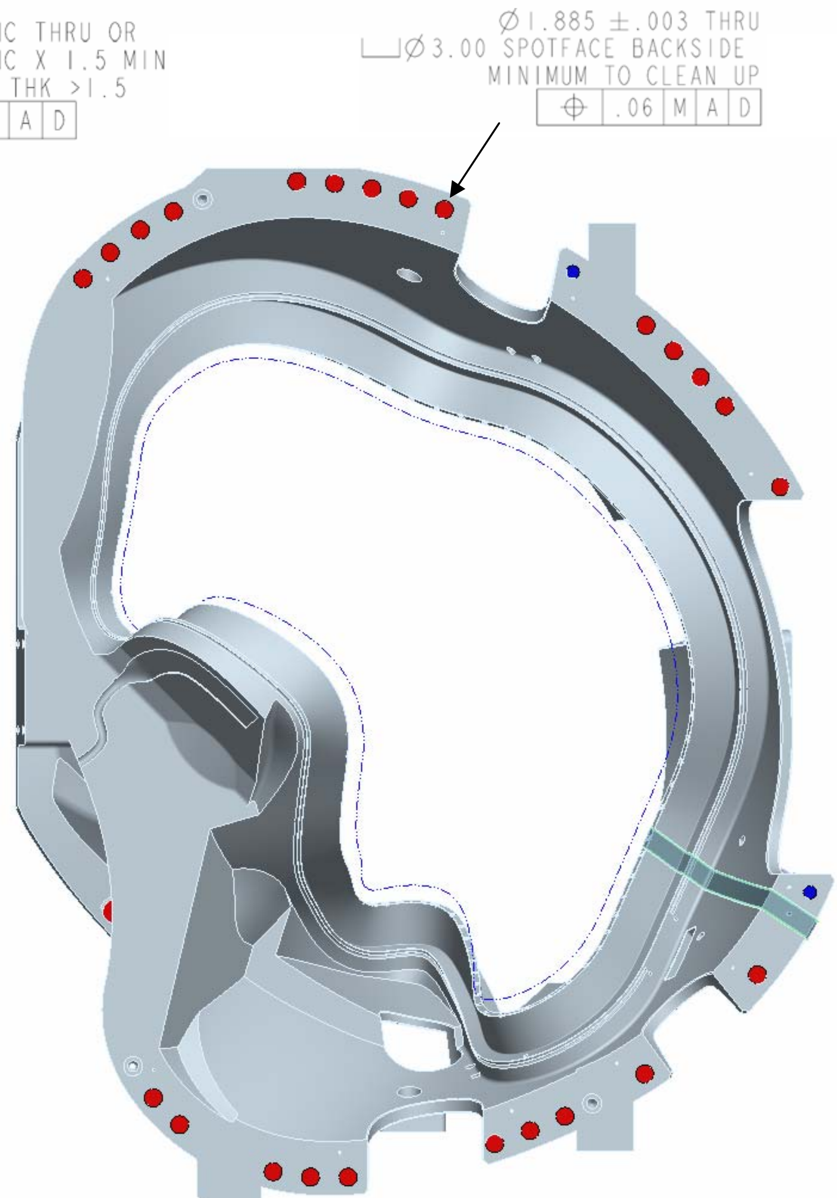
- Position the coils accurately
- Minimize gaps

Interface A-B

- 25 tapped holes, most on Type-A
- 1 through hole



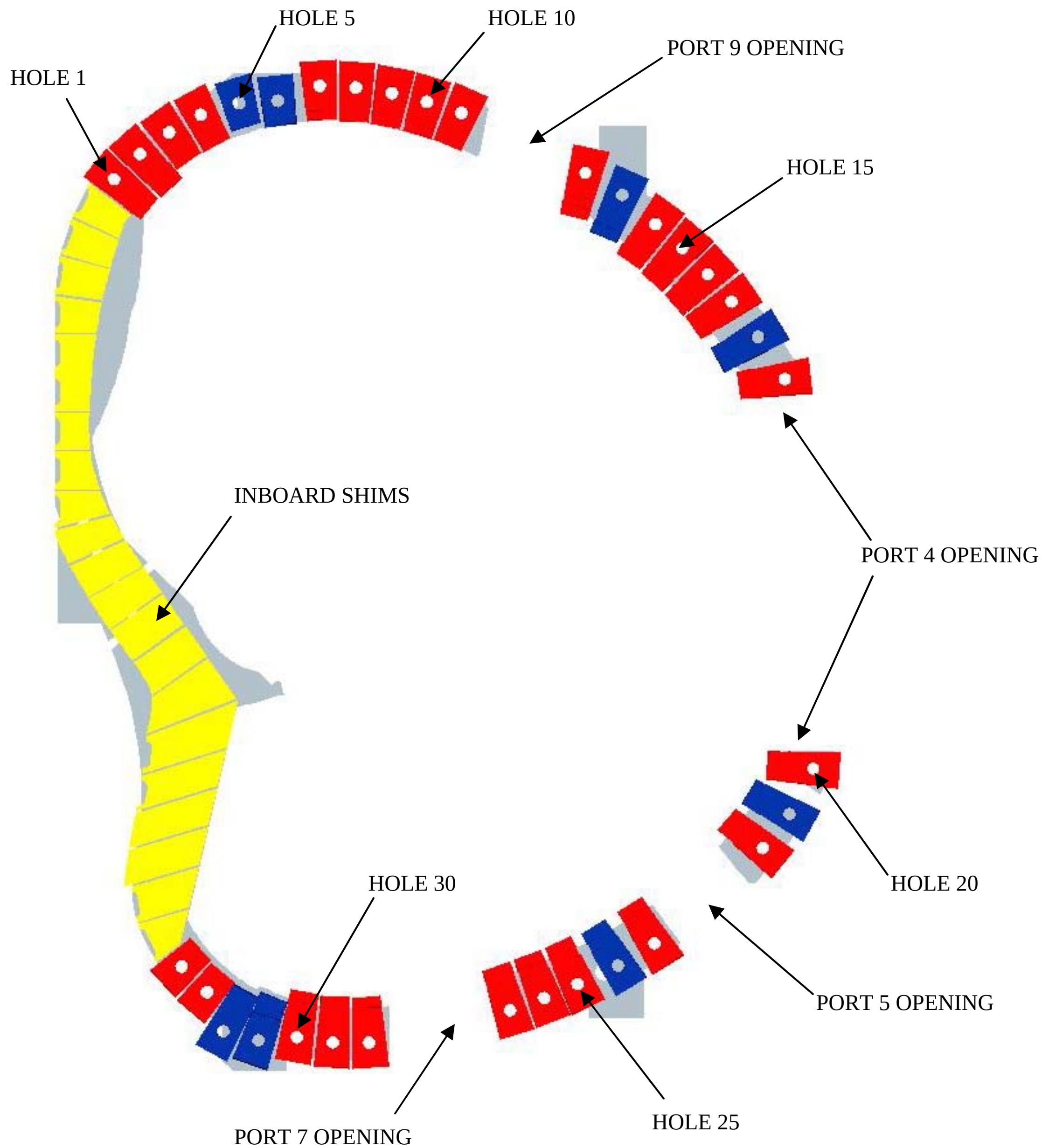
Type-A



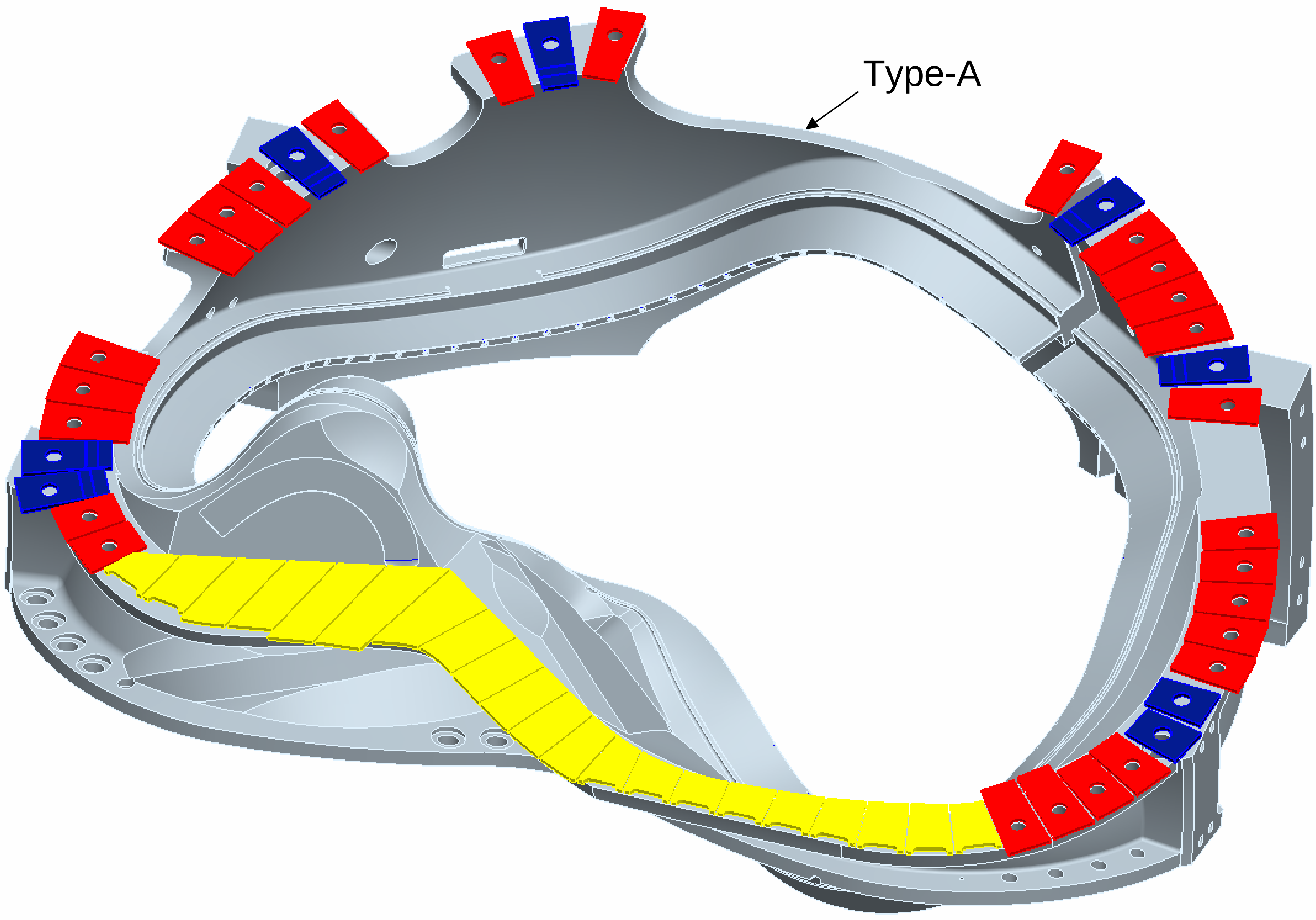
Type-B

A-B FLANGE

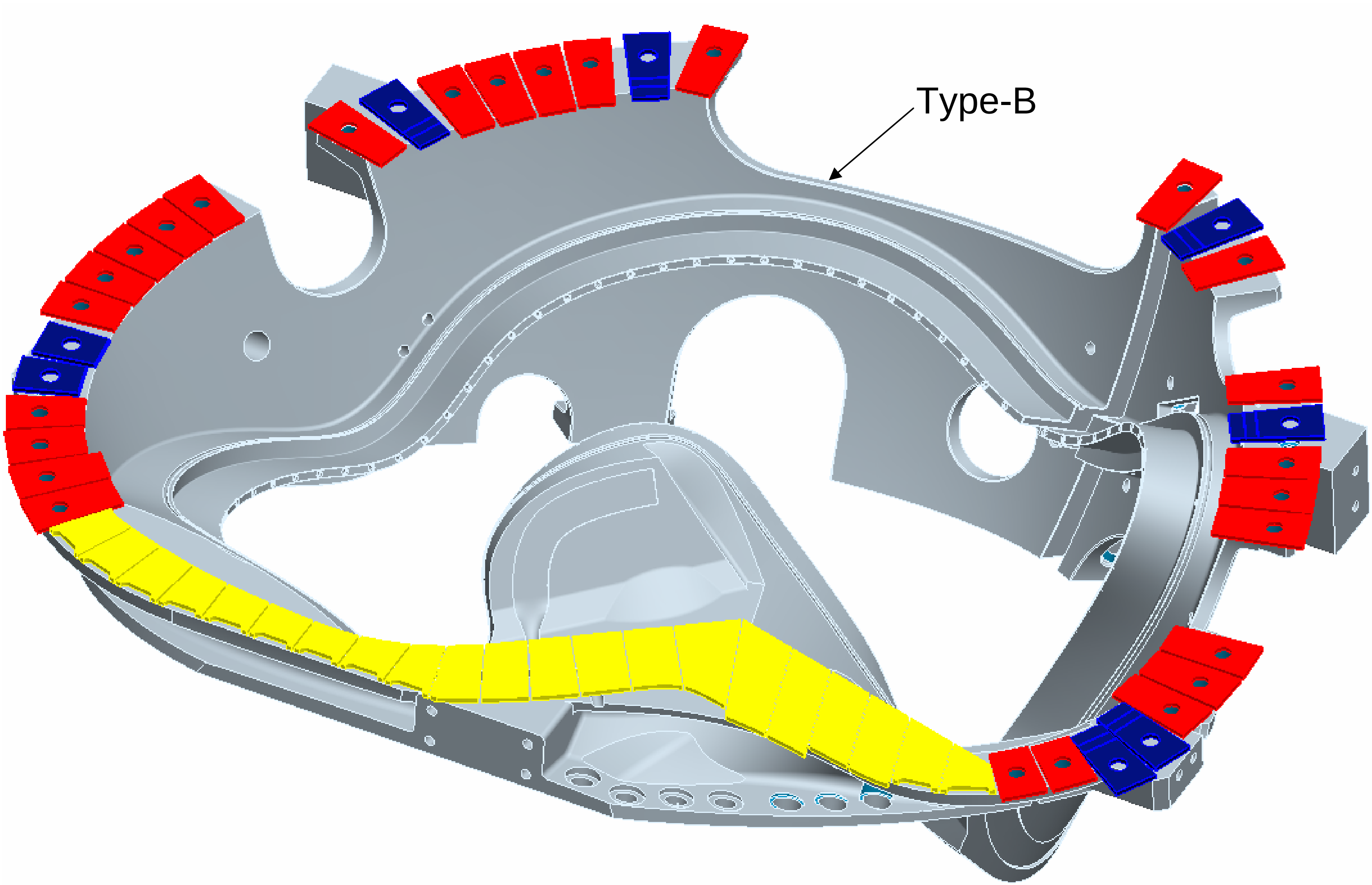
AB Hole #	Shim Length Hole to Bottom	No Bolt Shim
1	5.00	
2	5.00	
3	3.75	
4	3.75	
5		2.75
6		2.75
7	3.75	
8	3.75	
9	3.75	
10	3.75	
11	3.75	
12	5.00	
13		5.00
14	5.00	
15	5.00	
16	5.00	
17	5.00	
18		5.00
19	5.00	
20	5.00	
21		5.00
22	5.00	
23	5.00	
24		5.00
25	5.00	
26	5.00	
27	5.00	
28	5.00	
29	5.00	
30	5.00	
31		5.00
32		5.00
33	2.75	
34	2.75	



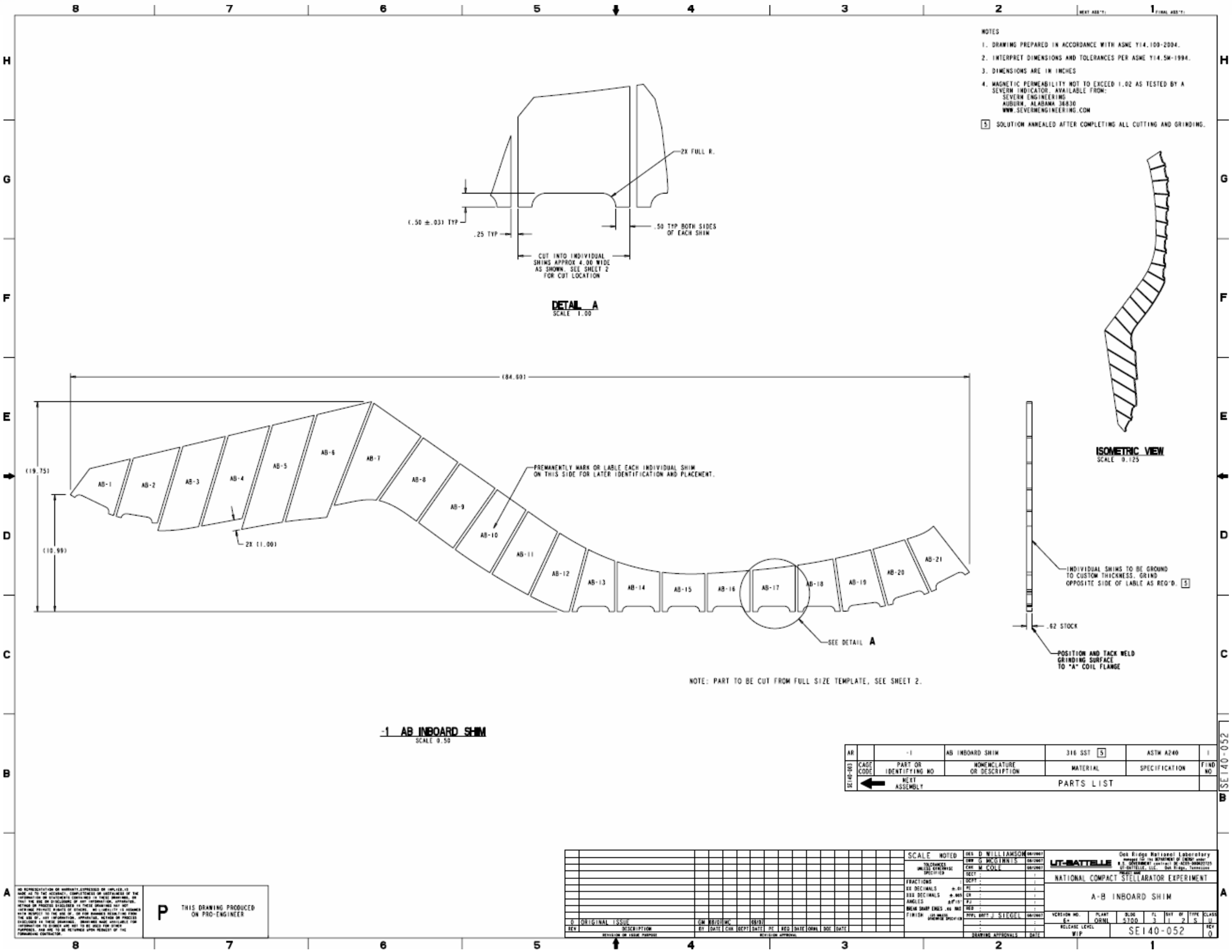
AB Inboard Welded Shims



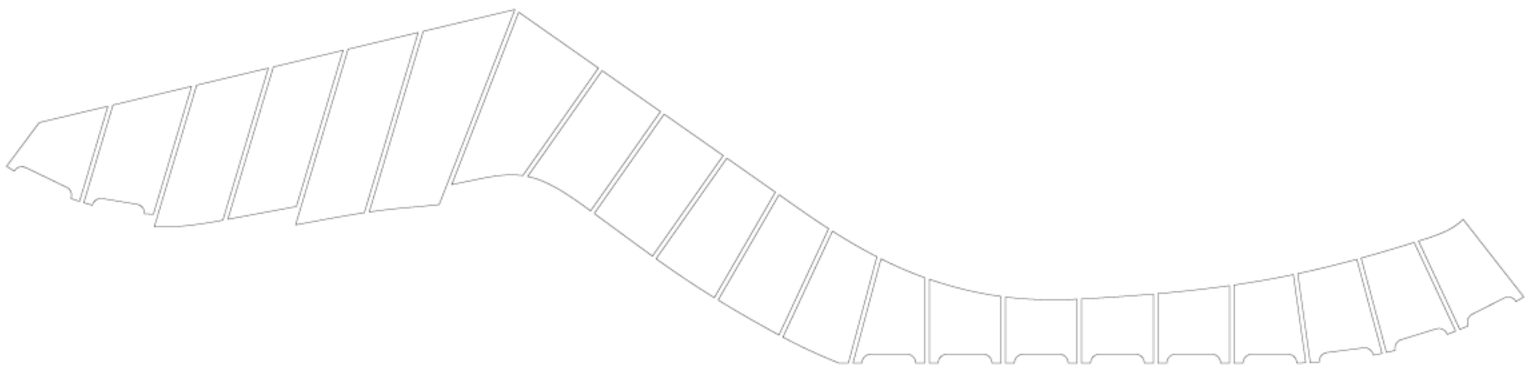
AB Inboard Welded Shims



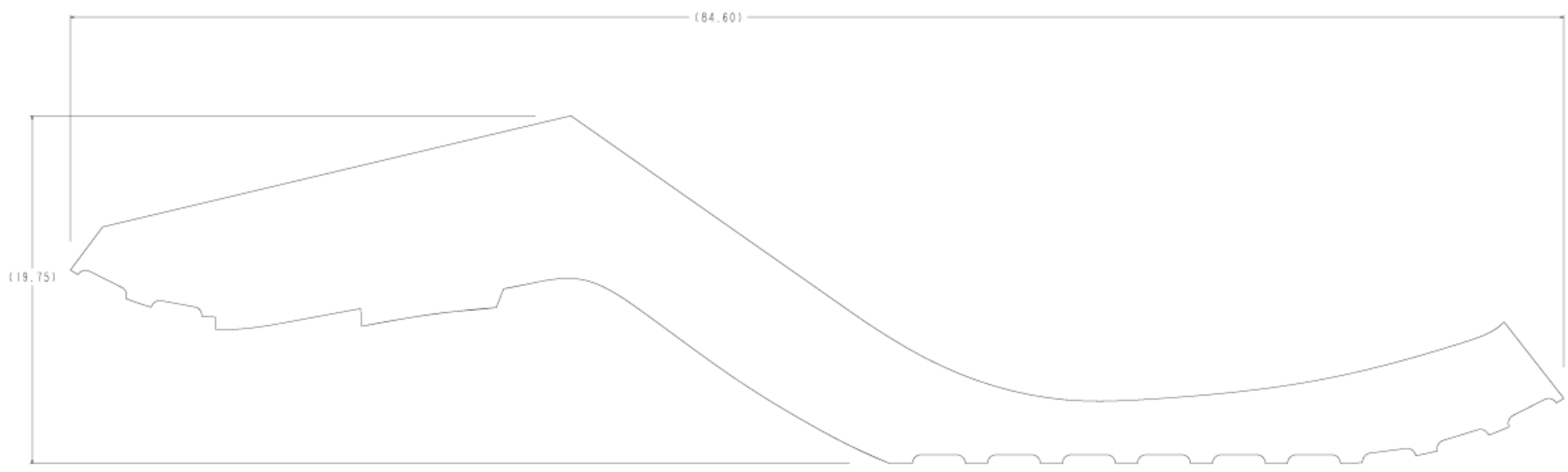
AB Inboard Welded Shims (SE140-052)



AB Inboard Welded Shims (SE140-052)

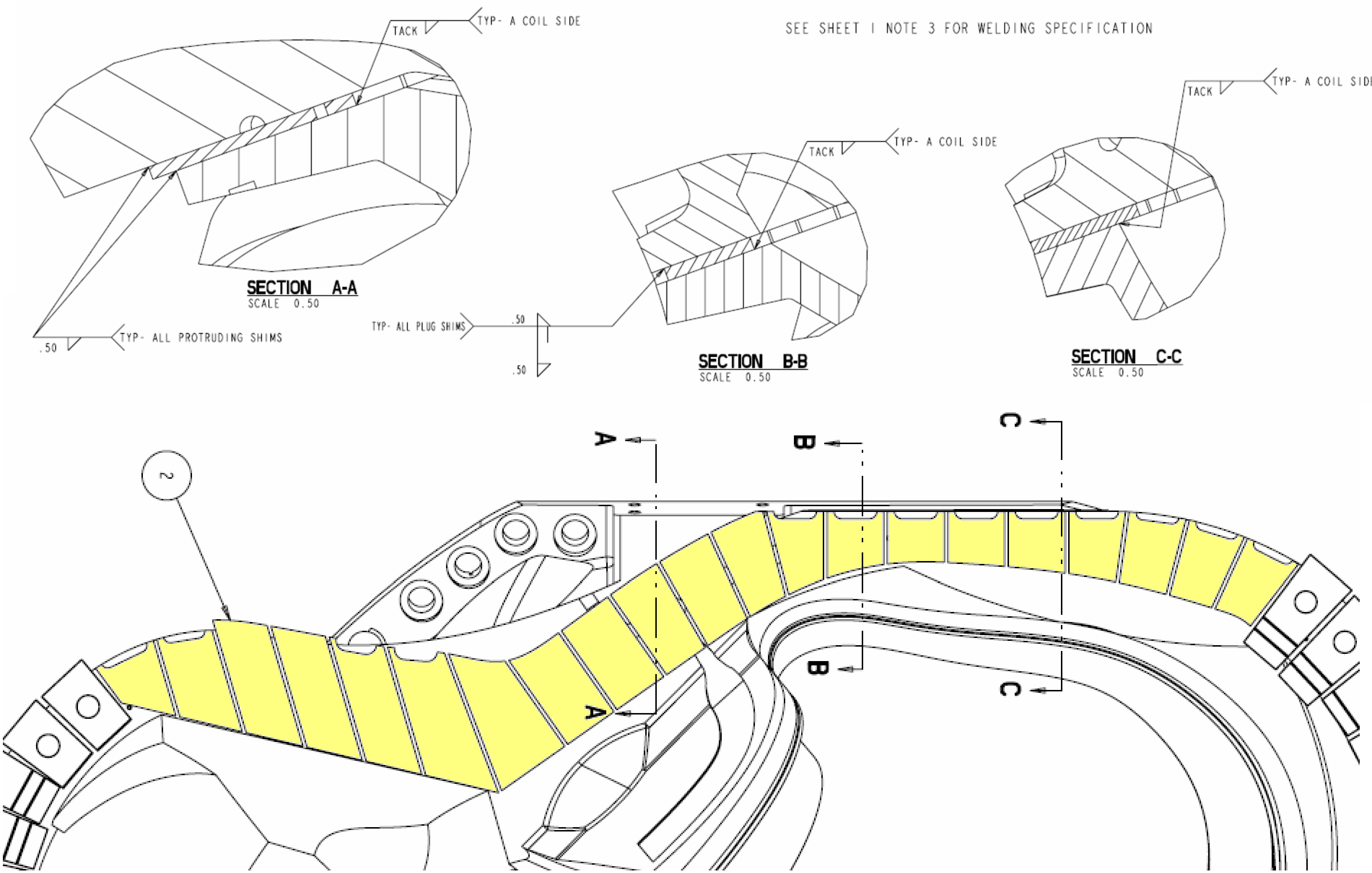


FULL SIZE TEMPLATE - SHOWN WITH INDIVIDUAL SHIM CUT LINES
SCALE 1 : 1

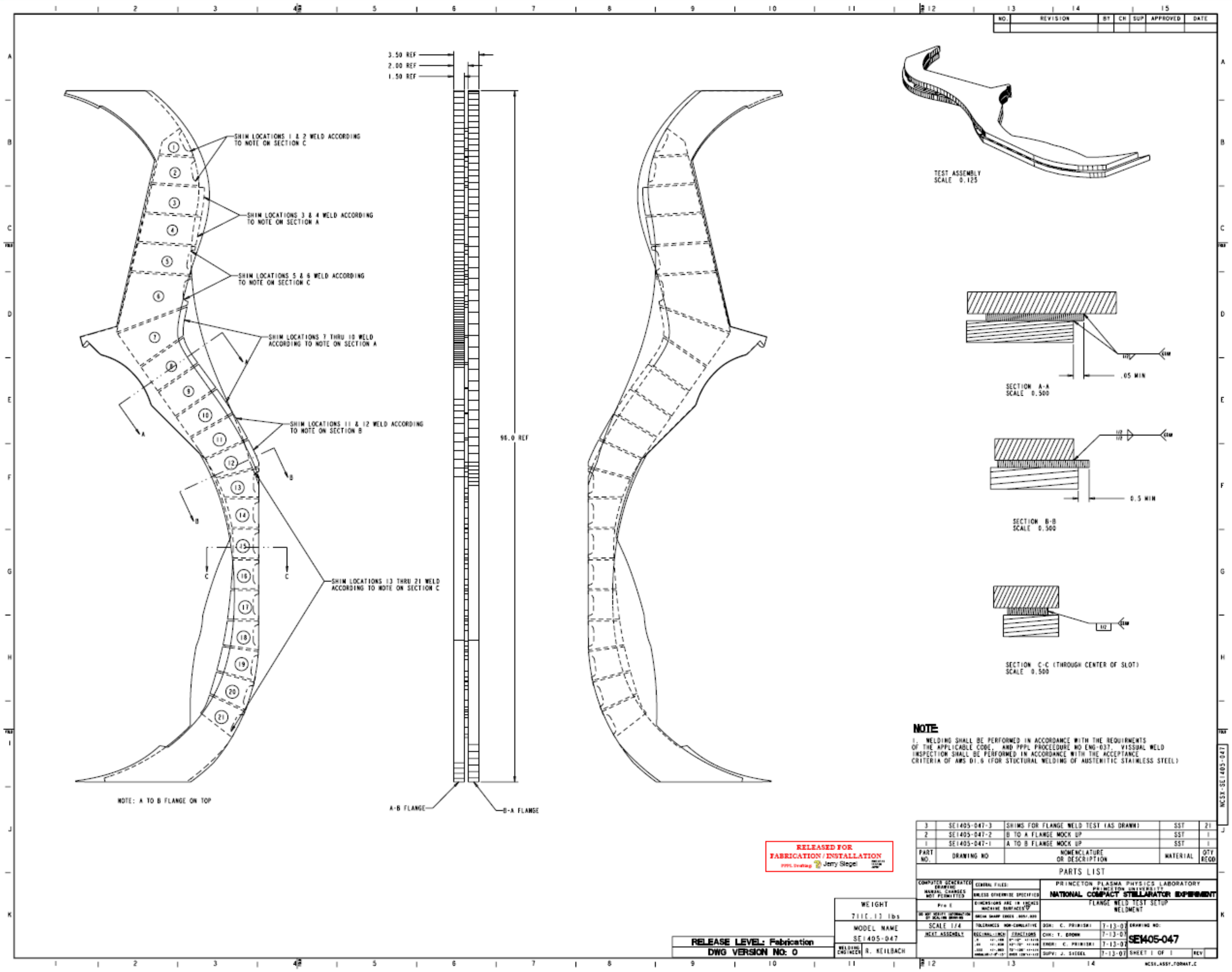


FULL SIZE TEMPLATE - CHECK REF DIMS SHOWN FOR PROPER SCALE
SCALE 1 : 1

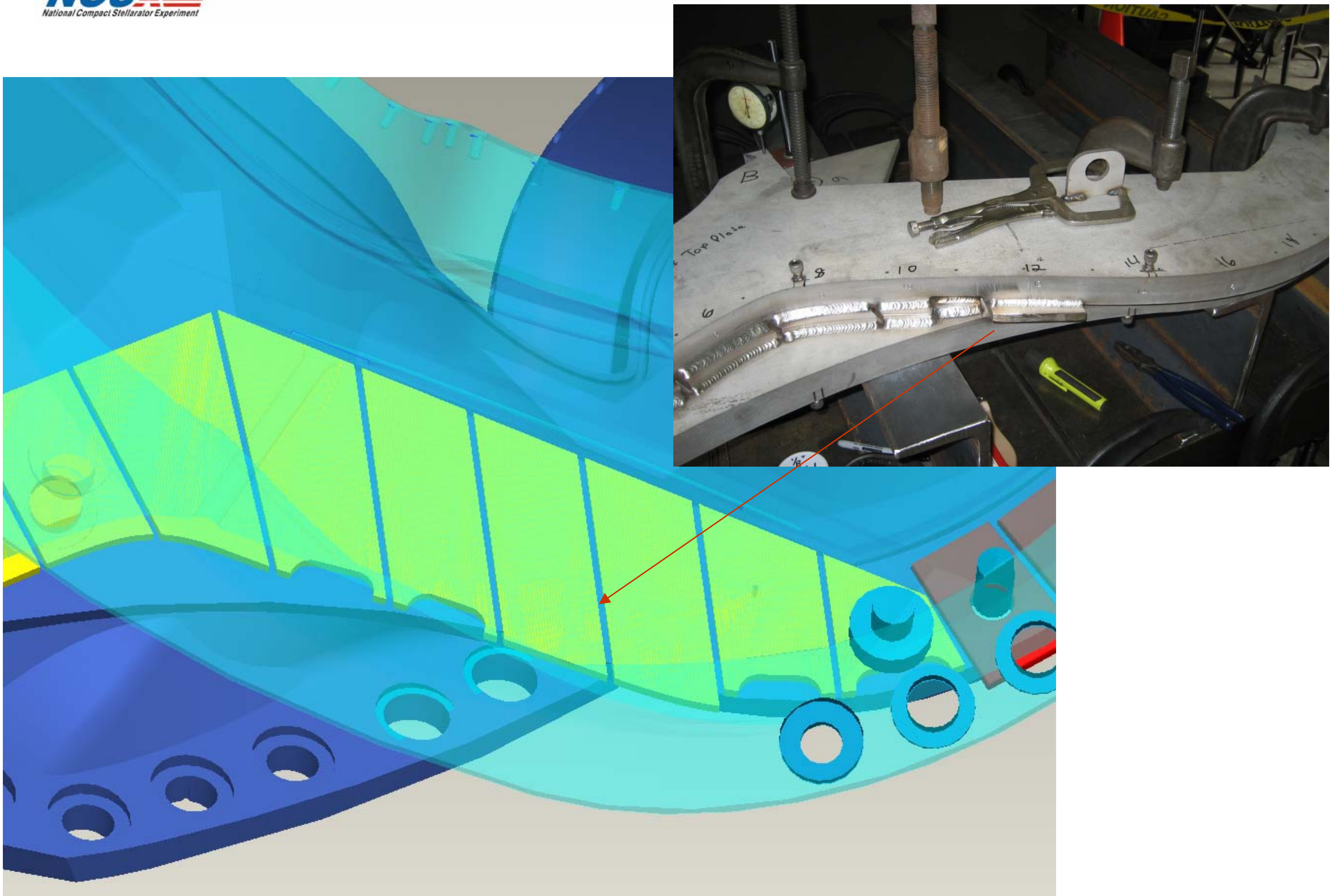
AB Inboard Welded Shims



AB Flange Mockup Weld Test

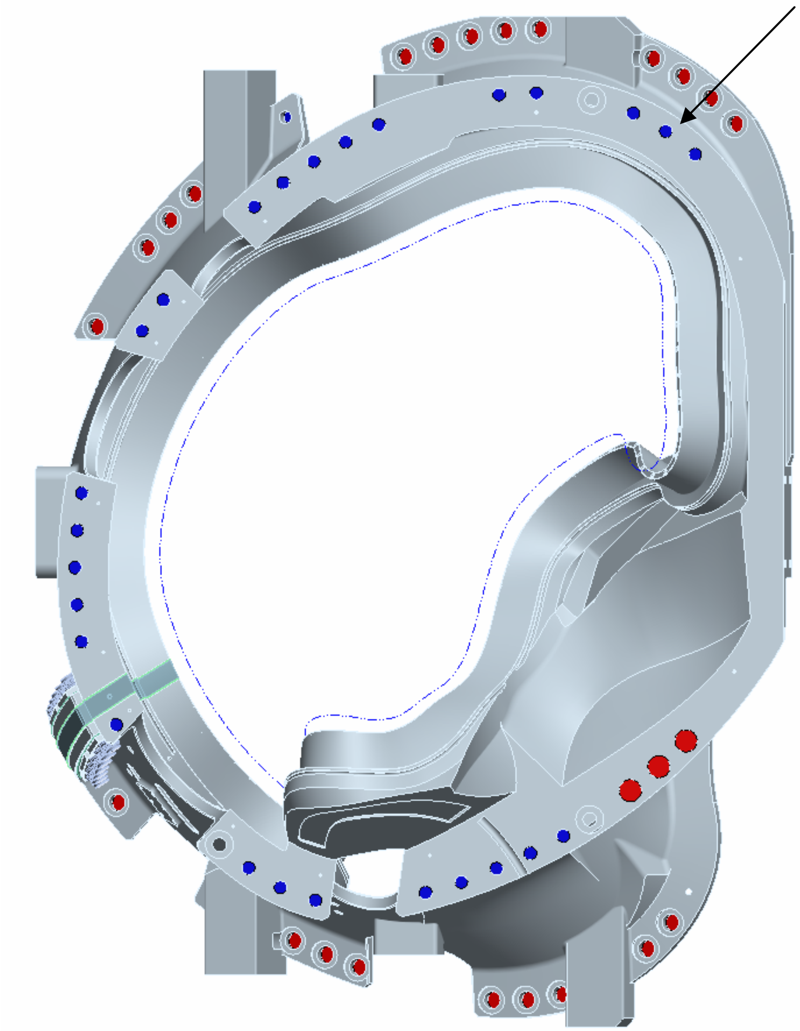


AB Flange Mockup Weld Test

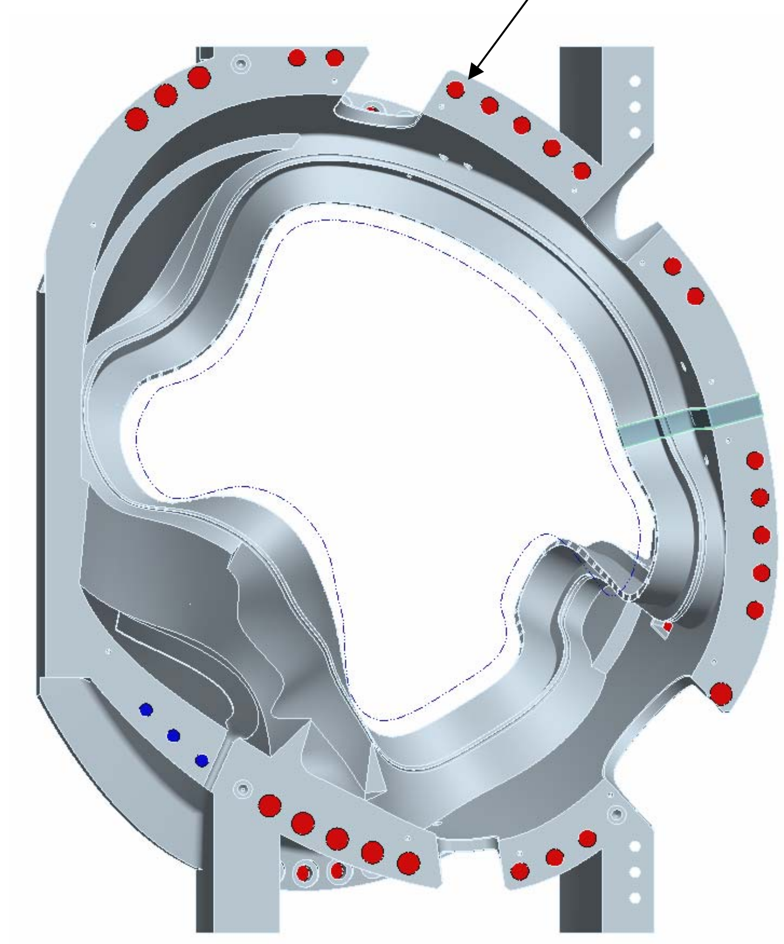


Interface B-C

- 29 tapped holes, most on Type-B



Type-B



Type-C

B-C FLANGE

BC Hole #	Shim Length Hole to Bottom	No Bolt Shim
1	5.00	
2	5.00	
3	5.00	
4		5.00
5	5.00	
6	5.00	
7	3.75	
8	3.75	
9	3.75	
10	5.00	
11	5.00	
12	5.00	
13	5.00	
14	5.00	
15	5.00	
16	3.75	
17	3.75	
18	5.00	
19		5.00
20	5.00	
21		5.00
22	5.00	
23	3.75	
24	3.75	
25	3.75	
26	5.00	
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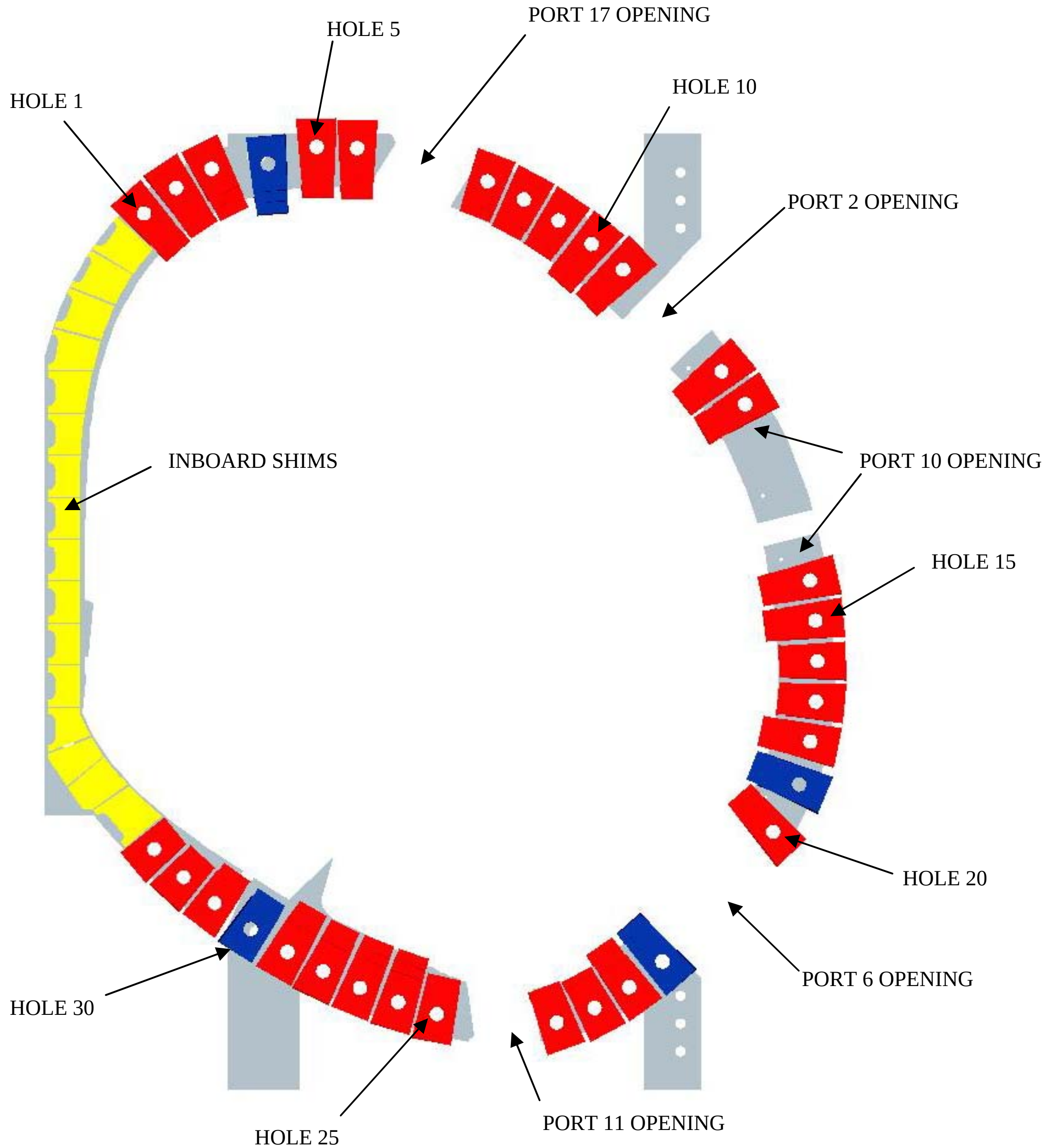
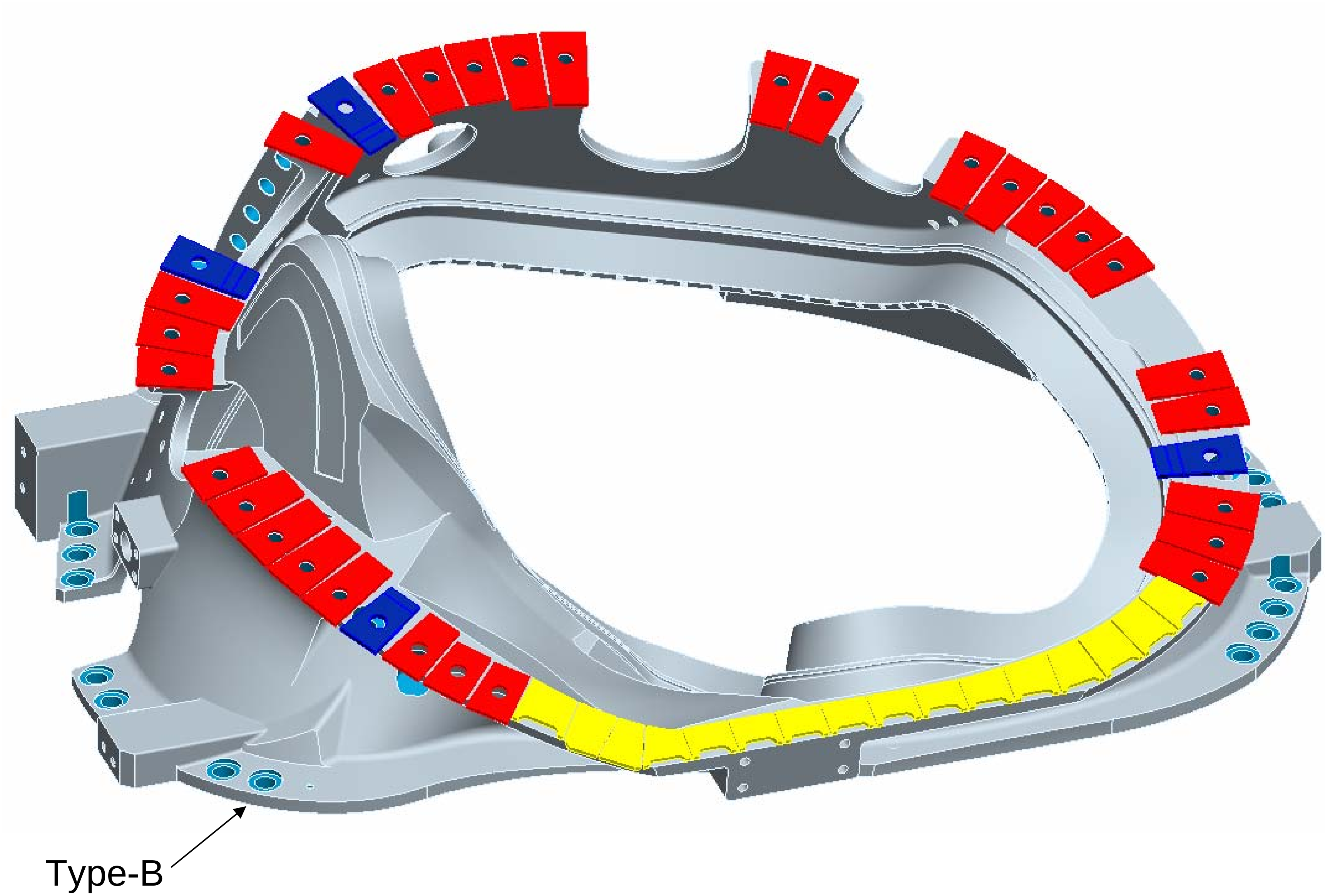
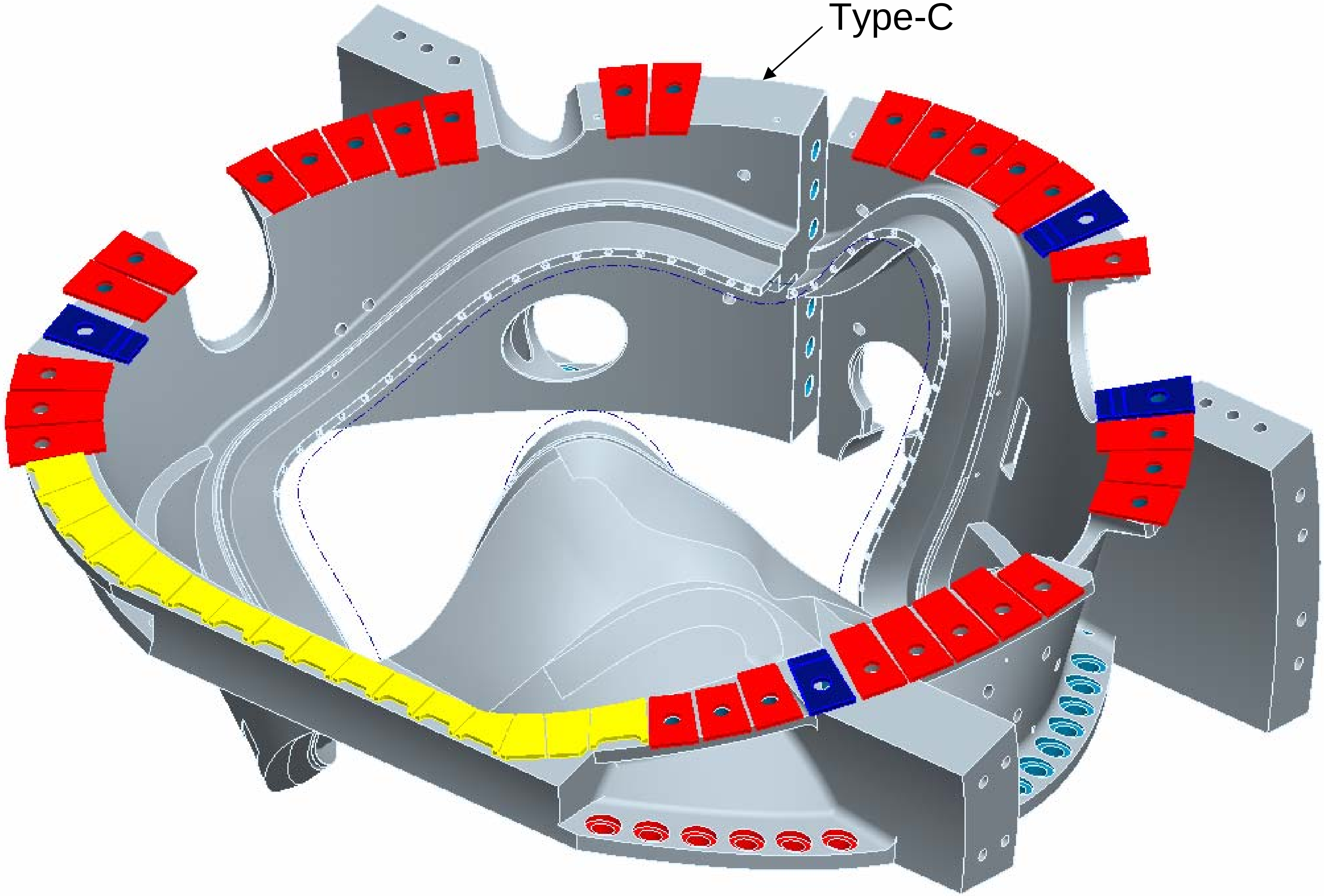
29	5.00	
30		3.75
31	3.75	
32	2.75	
33	2.75	



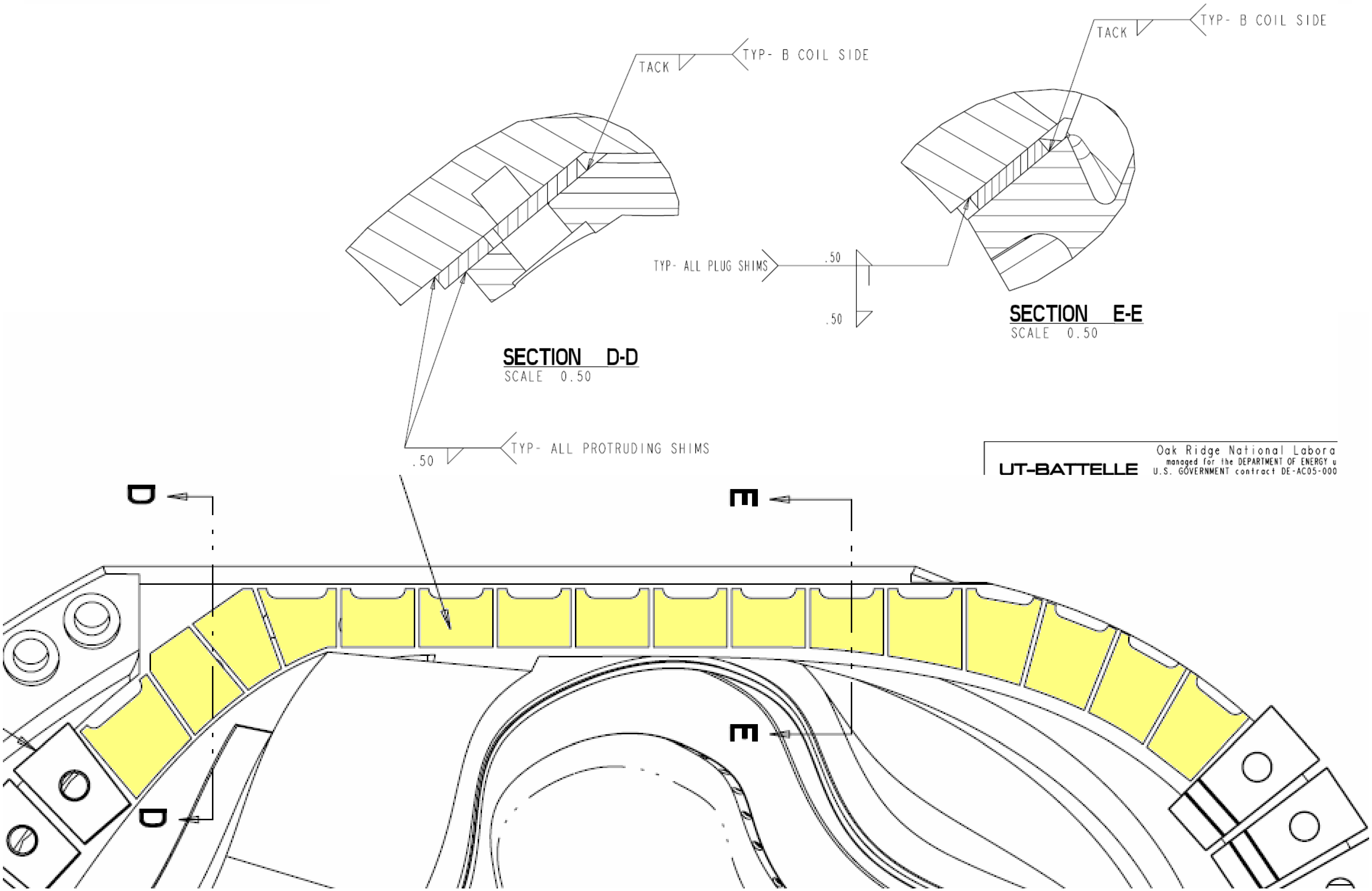
BC Inboard Welded Shims



BC Inboard Welded Shims

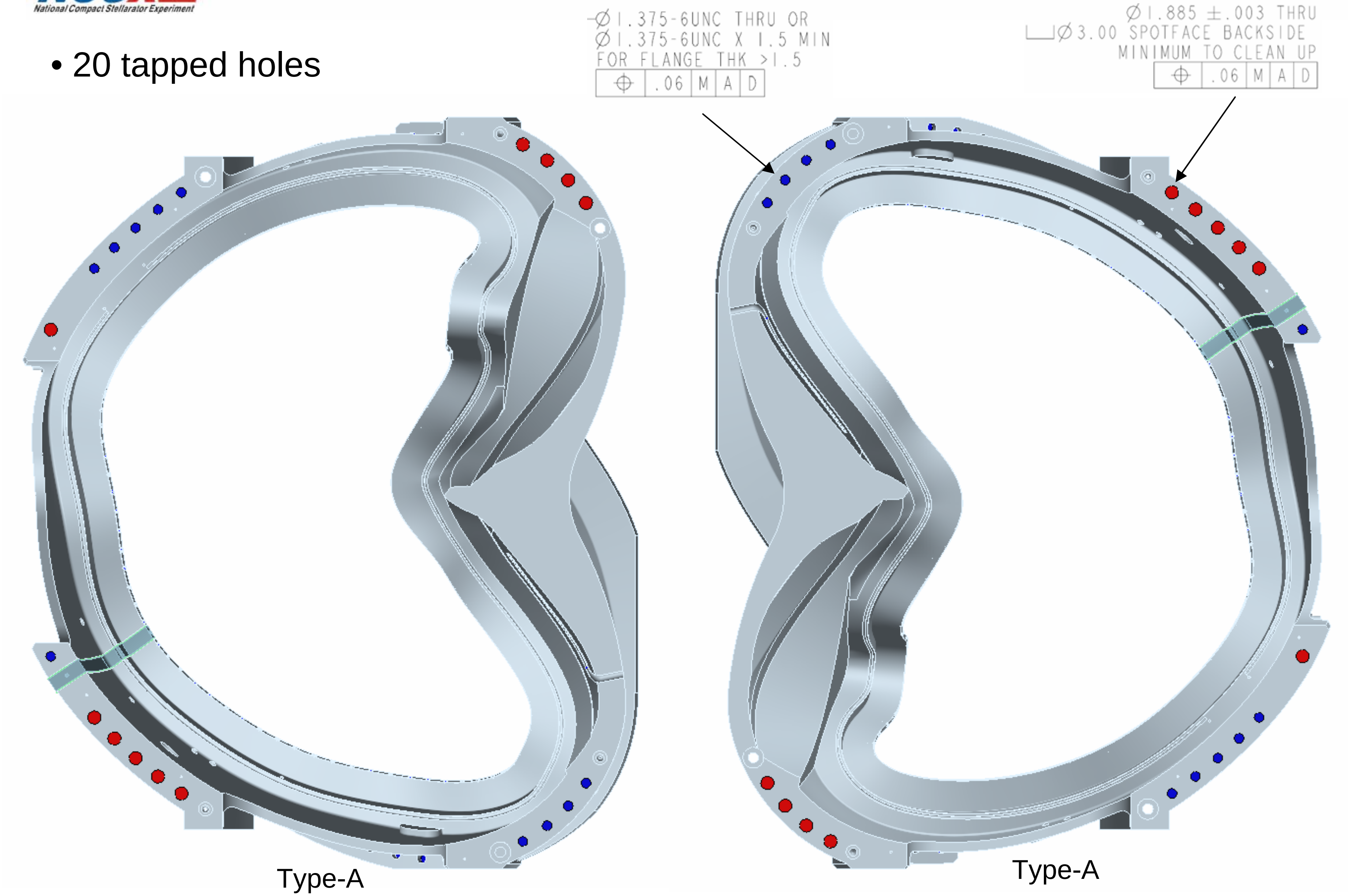


BC Inboard Welded Shims



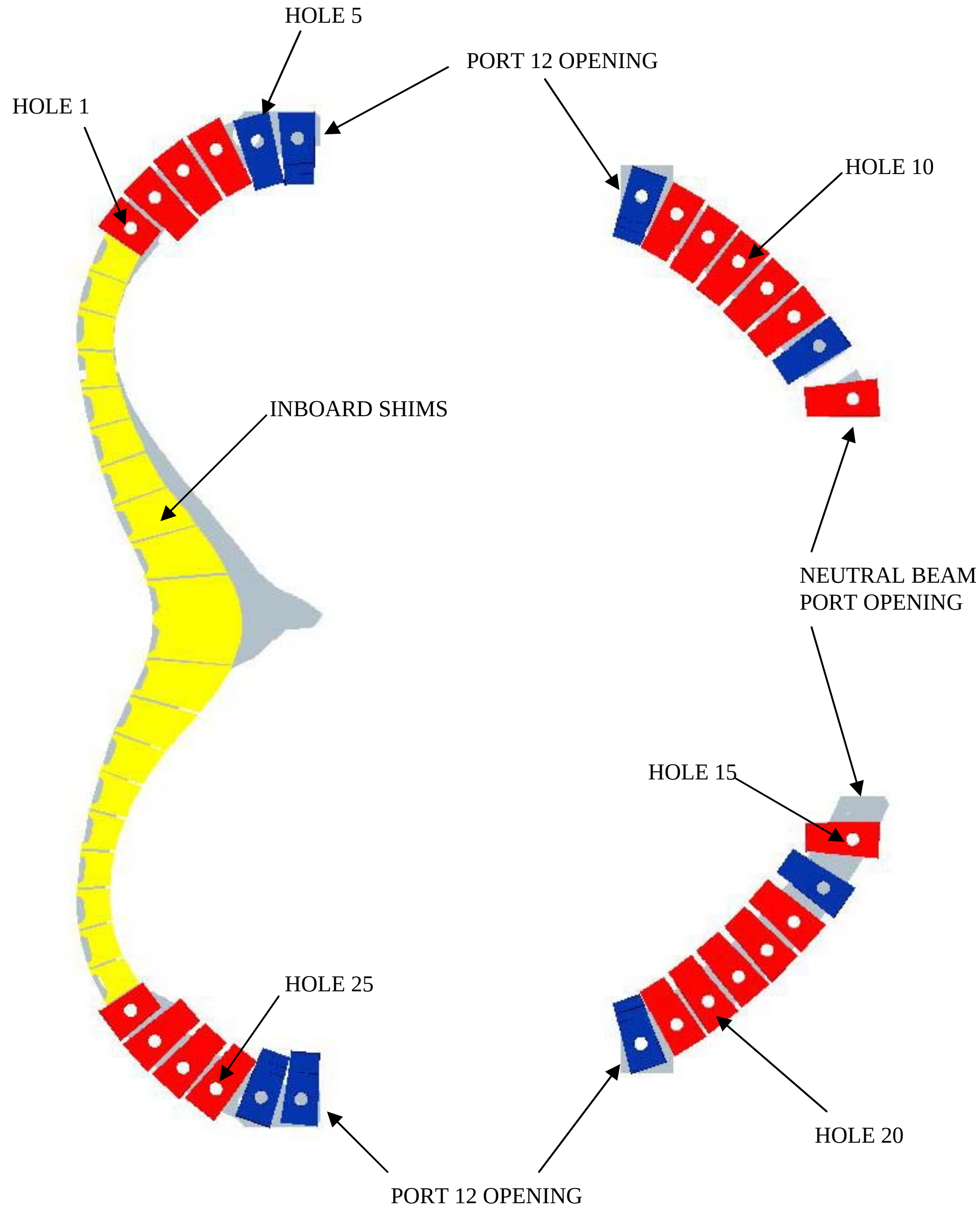
Interface A-A

- 20 tapped holes

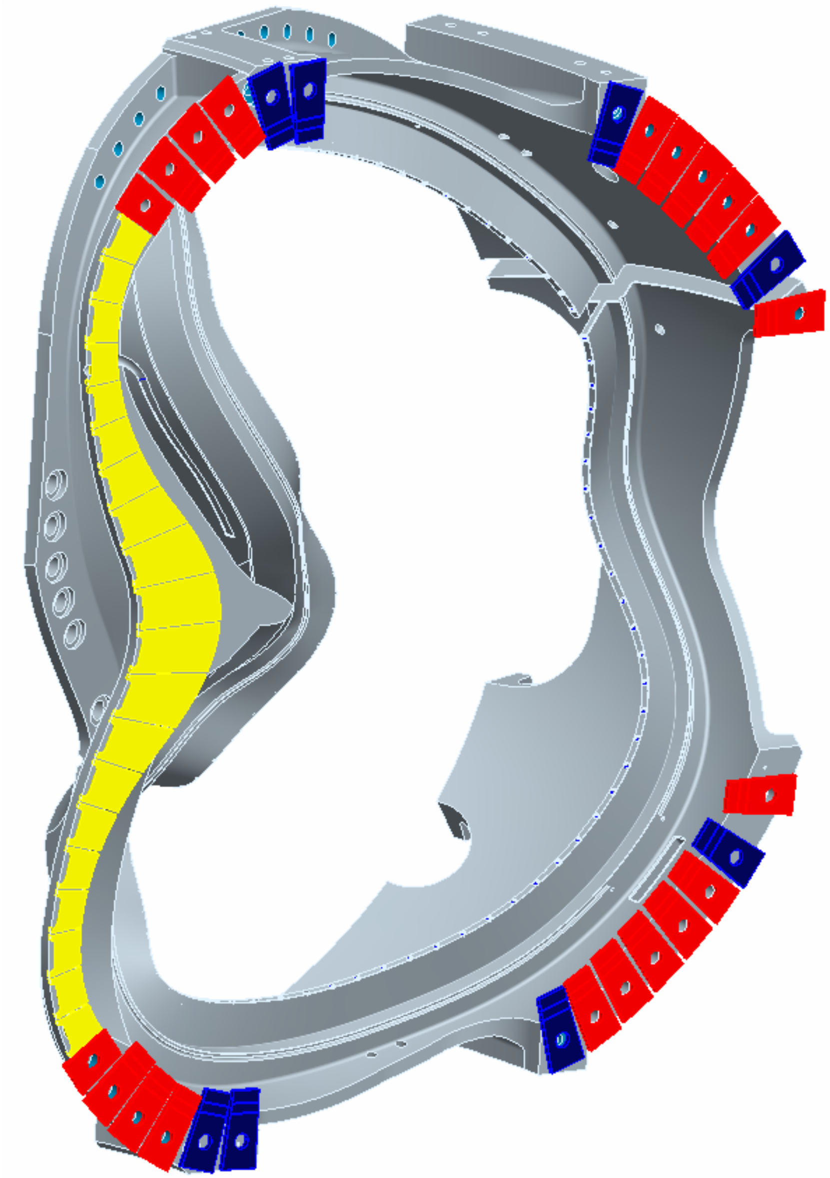


A-A FLANGE

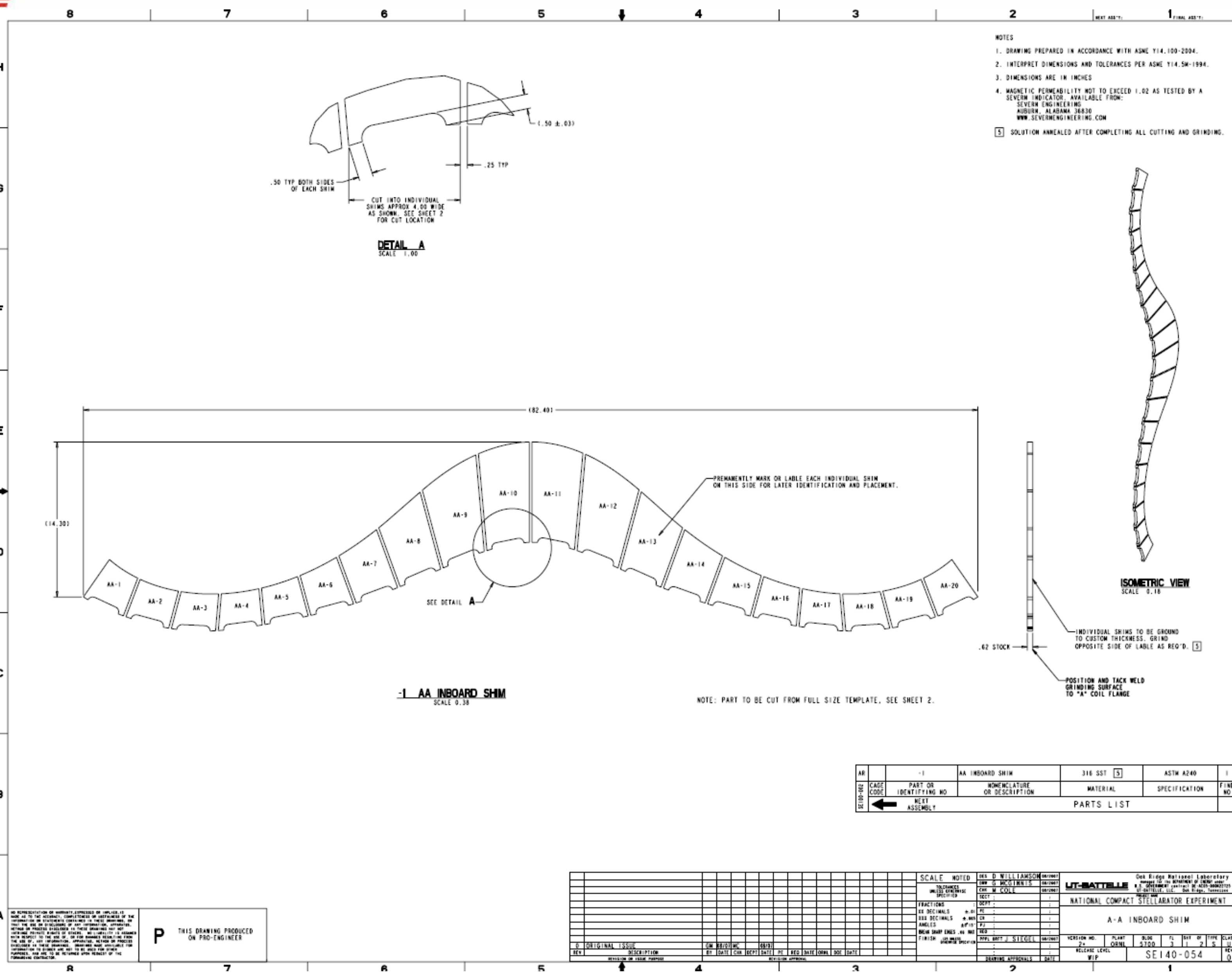
AA Hole #	Shim Length Hole to Bottom	No Bolt Shim
1	2.75	
2	5.00	
3	5.00	
4	5.00	
5		5.00
6		5.00
7		5.00
8	5.00	
9	5.00	
10	5.00	
11	5.00	
12	5.00	
13		5.00
14	5.00	
15	5.00	
16		5.00
17	5.00	
18	5.00	
19	5.00	
20	5.00	
21	5.00	
22		5.00
23		5.00
24		5.00
25	5.00	
26	5.00	
27	5.00	
28	2.75	



AA Inboard Welded Shims

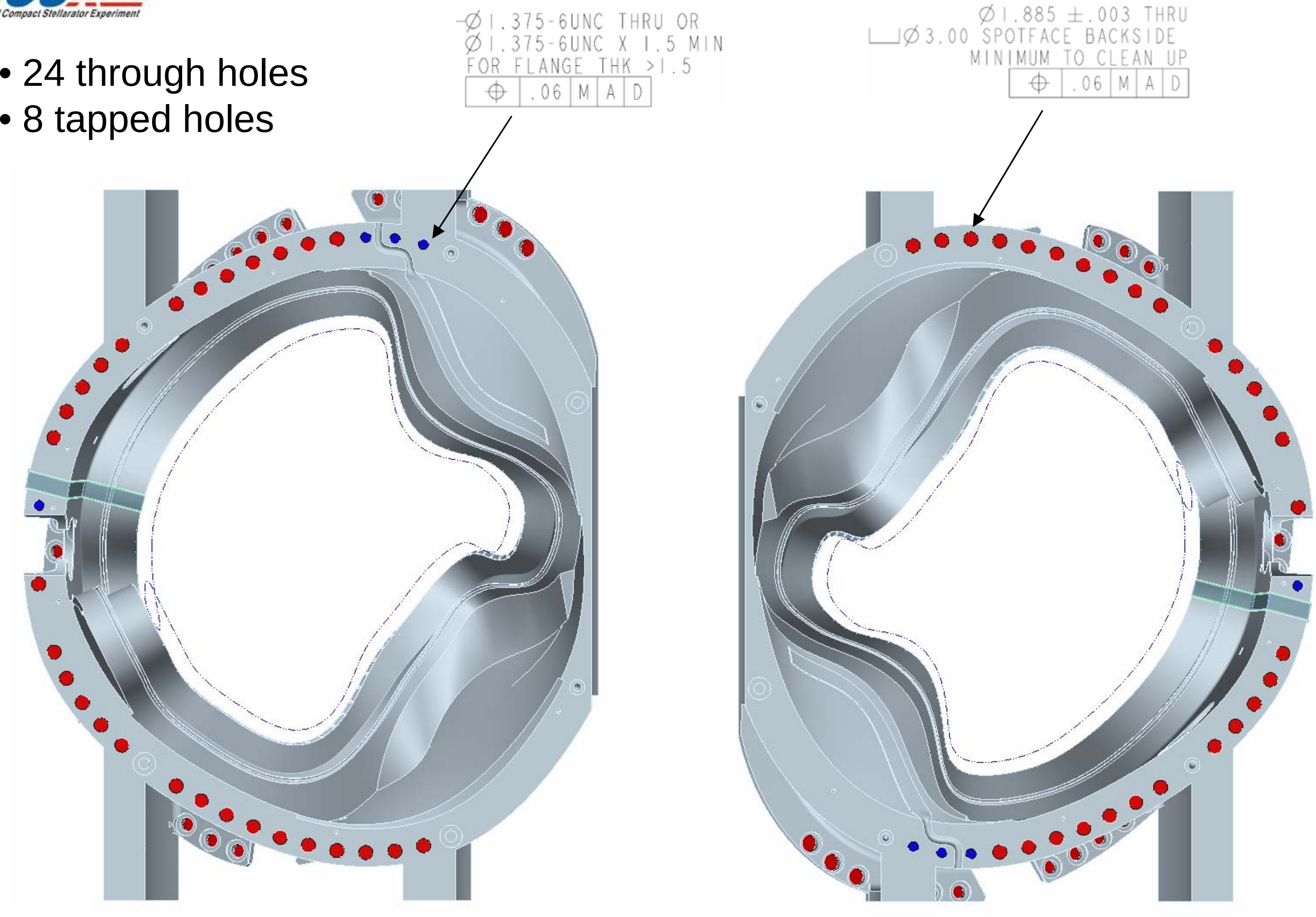


AA Inboard Welded Shims



Interface C-C

- 24 through holes
- 8 tapped holes

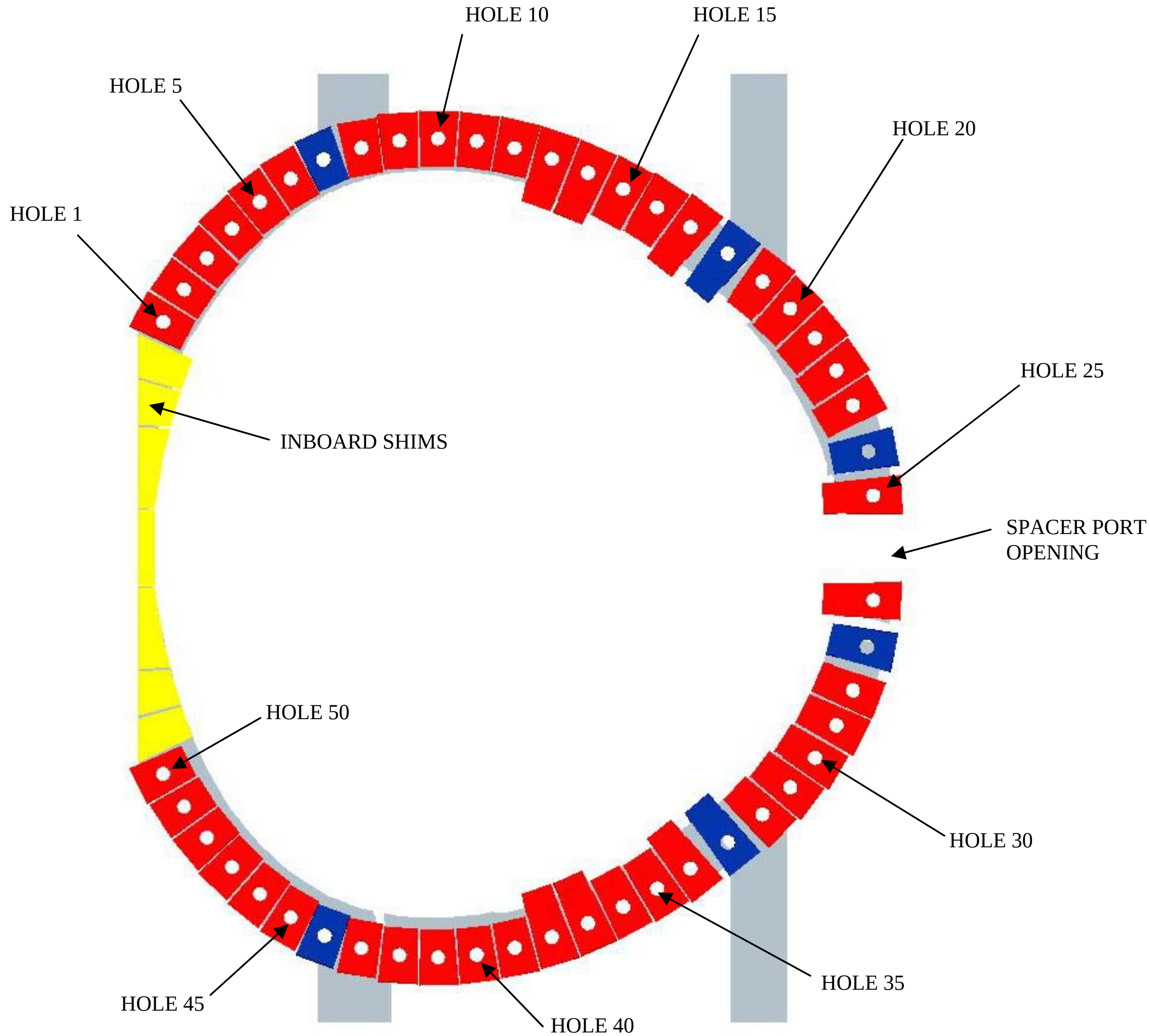


Type-C

Type-C

CC Hole #	Shim Length Hole to Bottom	No Bolt Shim
1	2.75	
2	2.75	
3	2.75	
4	2.75	
5	2.75	
6	2.75	
7		2.75
8	2.75	
9	2.75	
10	2.75	
11	2.75	
12	2.75	
13	5.00	
14	5.00	
15	3.75	
16	3.75	
17	5.00	
18		5.00
19	3.75	
20	3.75	
21	3.75	
22	3.75	
23	3.75	
24		3.75
25	5.00	
26	5.00	
27		3.75
28	3.75	
29	3.75	
30	3.75	
31	3.75	
32	3.75	
33		5.00
34	5.00	
35	3.75	
36	3.75	
37	5.00	
38	5.00	
39	2.75	
40	2.75	
41	2.75	
42	2.75	
43	2.75	
44		2.75
45	2.75	
46	2.75	
47	2.75	
48	2.75	
49	2.75	
50	2.75	

C-C FLANGE



Analysis Documentation

- Modular coil asm design basis is defined by 5 analysis reports:

  HM Fan, Nonlinear Analysis of Coil and Shell Structure, NCSX-CALC-14-001, APPROVED
  HM Fan, Analysis of Integrated Structure, NCSX-CALC-14-003, APPROVED
  K Freudenberg, Modular Coil Thermal Analysis, NCSX-CALC-14-002, DRAFT
  K Freudenberg, Nonlinear Modular Coil Analysis, NCSX-CALC-14-004, DRAFT
  D Williamson, Modular Coil Failure Modes Analysis, NCSX-FMEA-14-002, DRAFT

- Additional analysis reports are planned before Design Closeout:

  K Freudenberg, Outboard Bolted Joint Analysis, NCSX-CALC-14-006, DRAFT
  K Freudenberg, Modular Coil Inboard Shims Analysis, IN PROGRESS
  D Williamson, Modular Coil Leads Structural Analysis, PLANNED

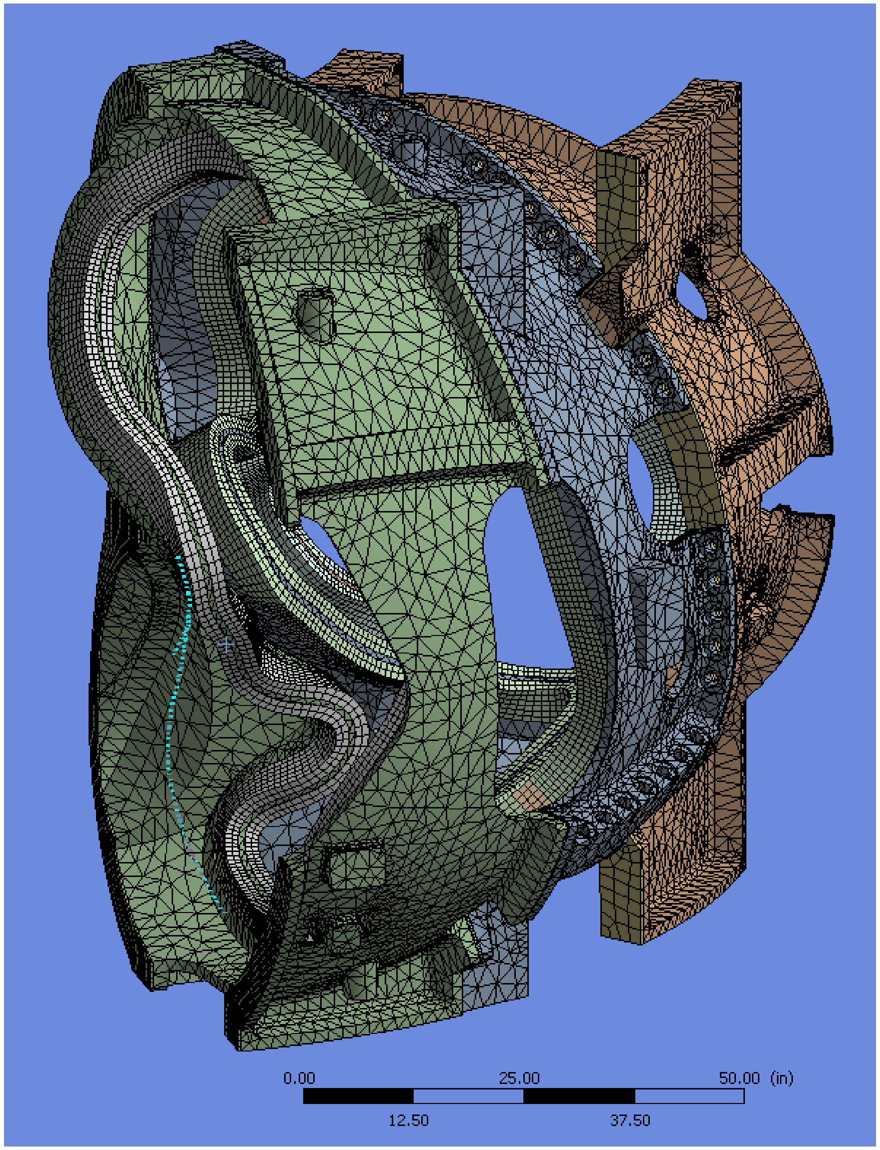
Quick weld allowable calculation

NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT

- Sm = 2/3 Sy at temp or 1/3 Sult for all materials
- Sy = 93.2 ksi for stellaloy but weld since Sult is 157.5 -> Sm = 52.5 based on weld wire.
- Knockdown factor of .6 applied for visual inspected welds. → **31.5 ksi**. Which is our max stress intensity we can incur statically.

New Global Model for welds

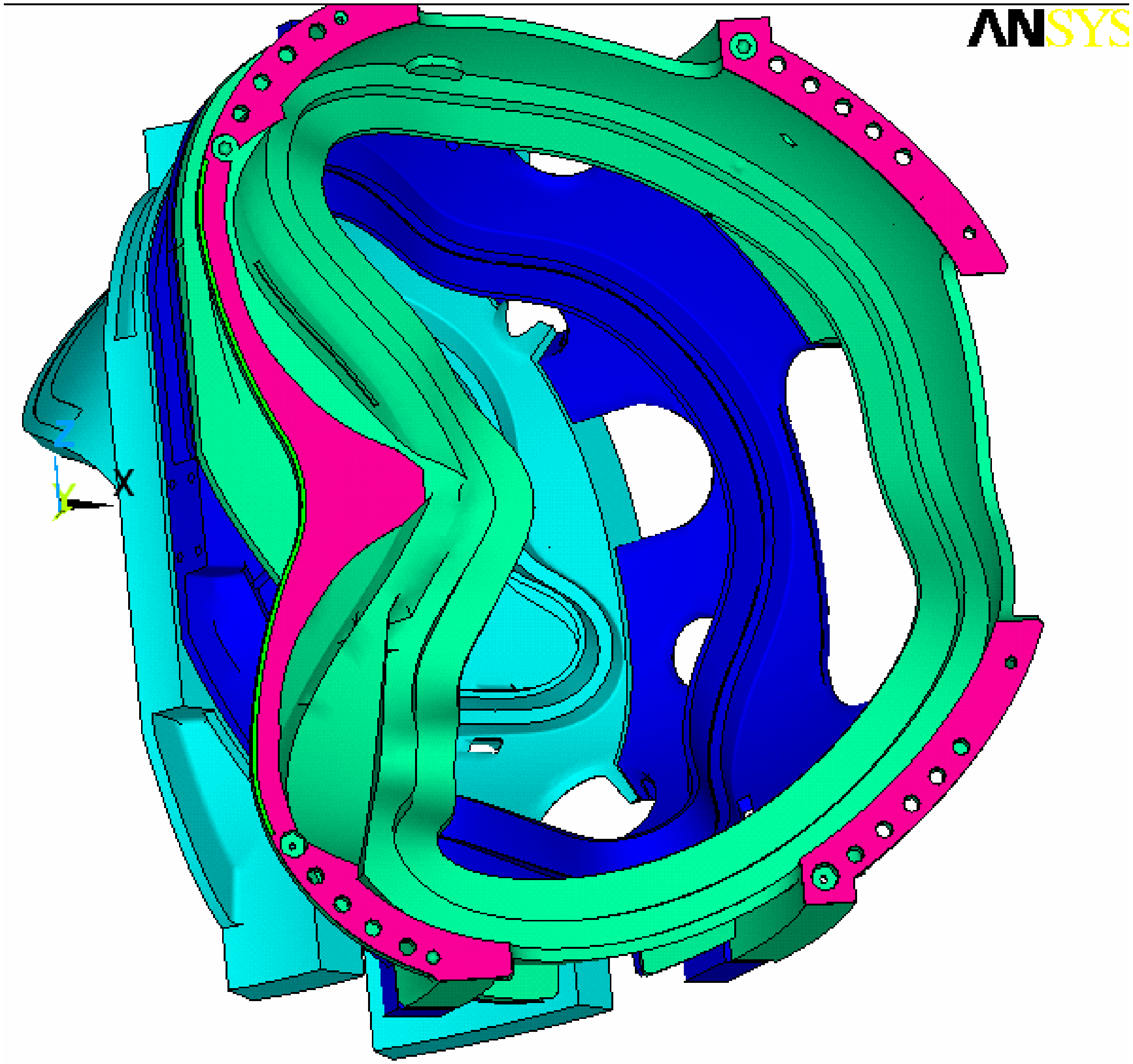
NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT

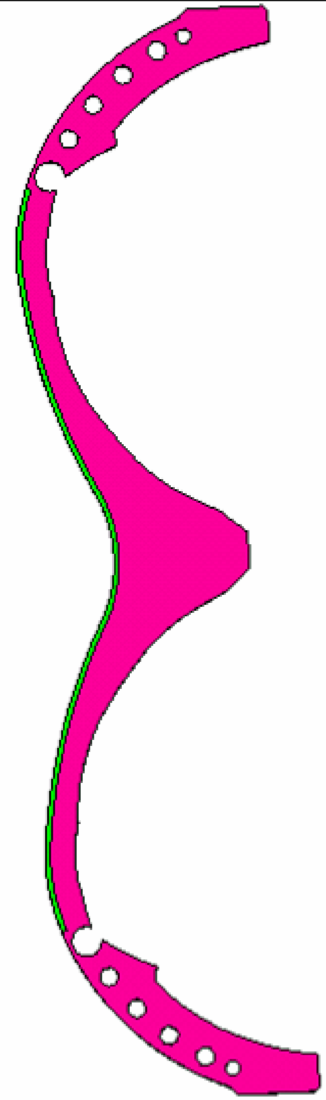


Modeling Approach

- Weld Elements are placed in the model on the each flange of interest. (AA, AB, BC)
- Bolt holes and bolts taken out of all flanges except the one being studied.
- This method locks up the outboard side of the global model with bonded contact but has the inboard leg run frictionless sliding (Keyopt 12 = 0) with the weld taking the shear and tension from the flanges.
- Material Props of weld match that of shim and castings.
- The analysis has only examined the 2T high beta case. (supposedly the worst EM load case.)
- A detailed sub-model of the in-board leg, including proper segmentation and filet welds, is then constructed on flanges where stress is deemed an issue. Deflections are mapped from the global to the sub-model.

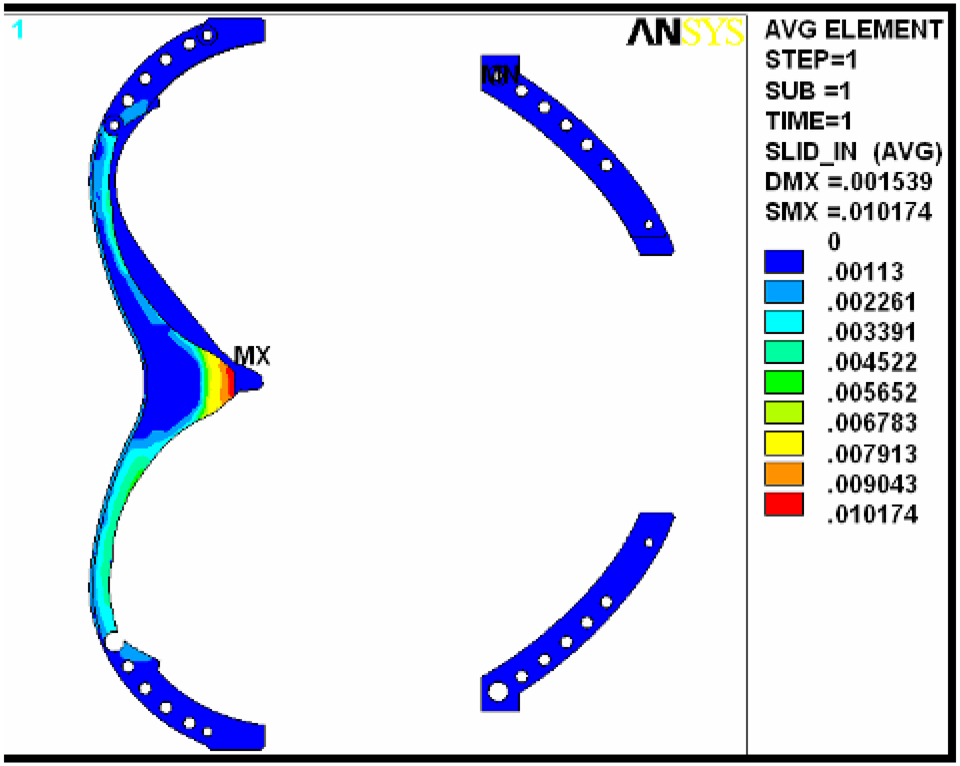
AA Weld (Global Model)

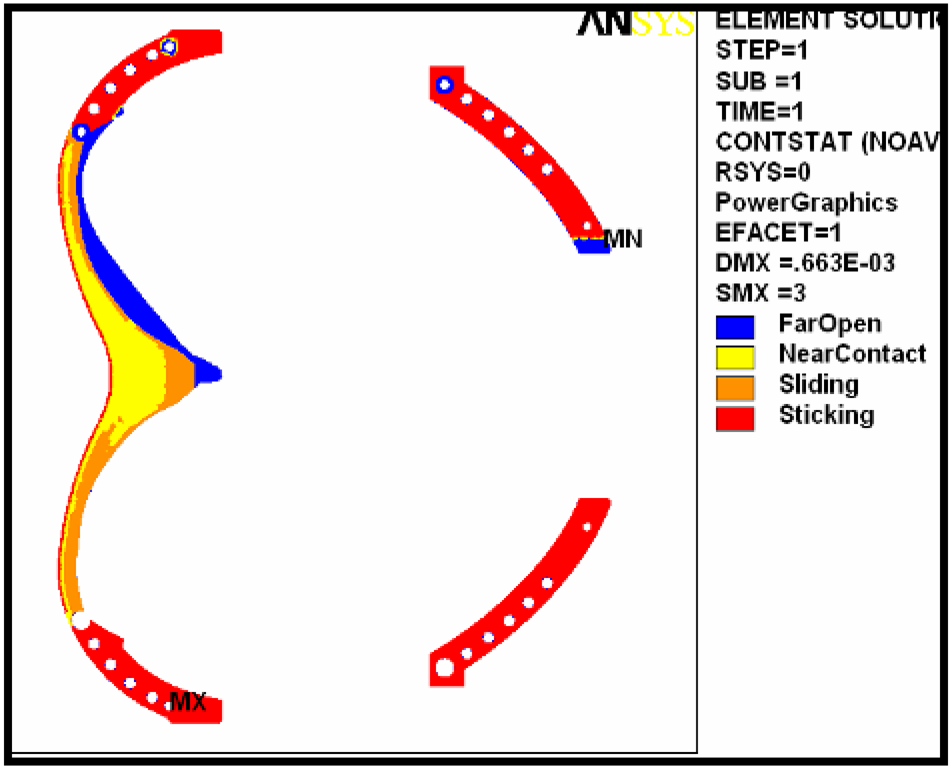




AA Sliding and contact status (inches)

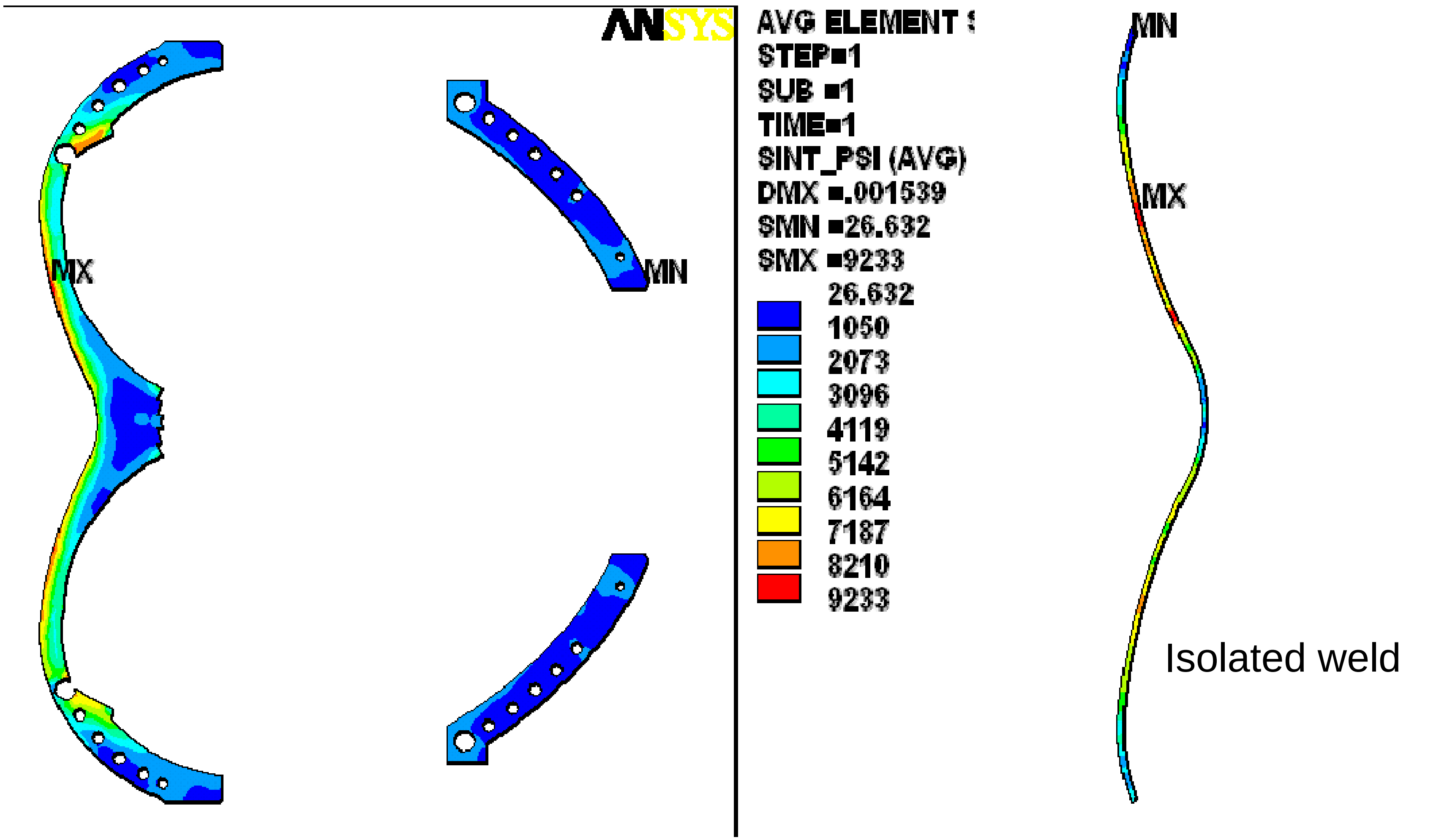
NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT





AA Stress Intensity of Weld

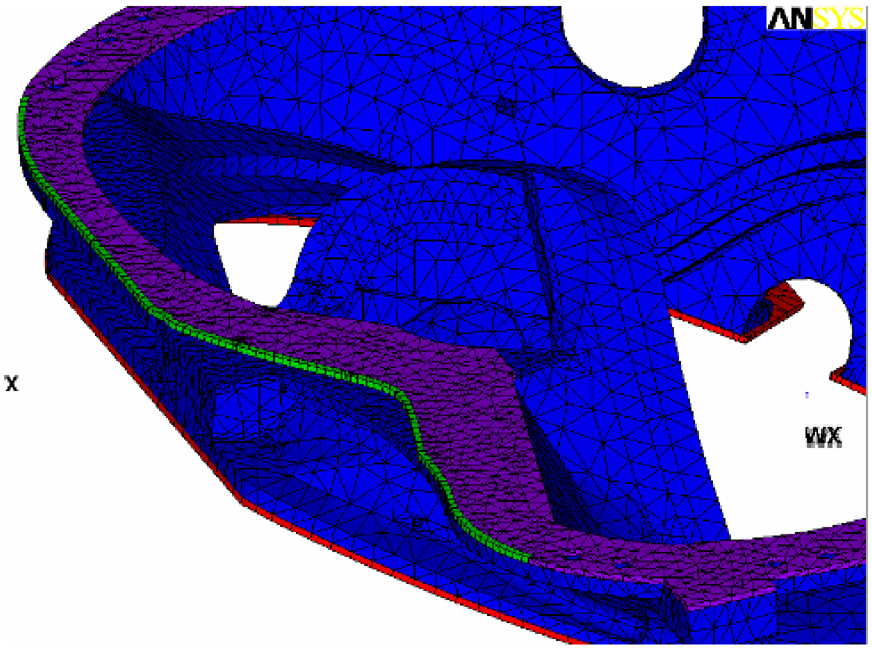
NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT



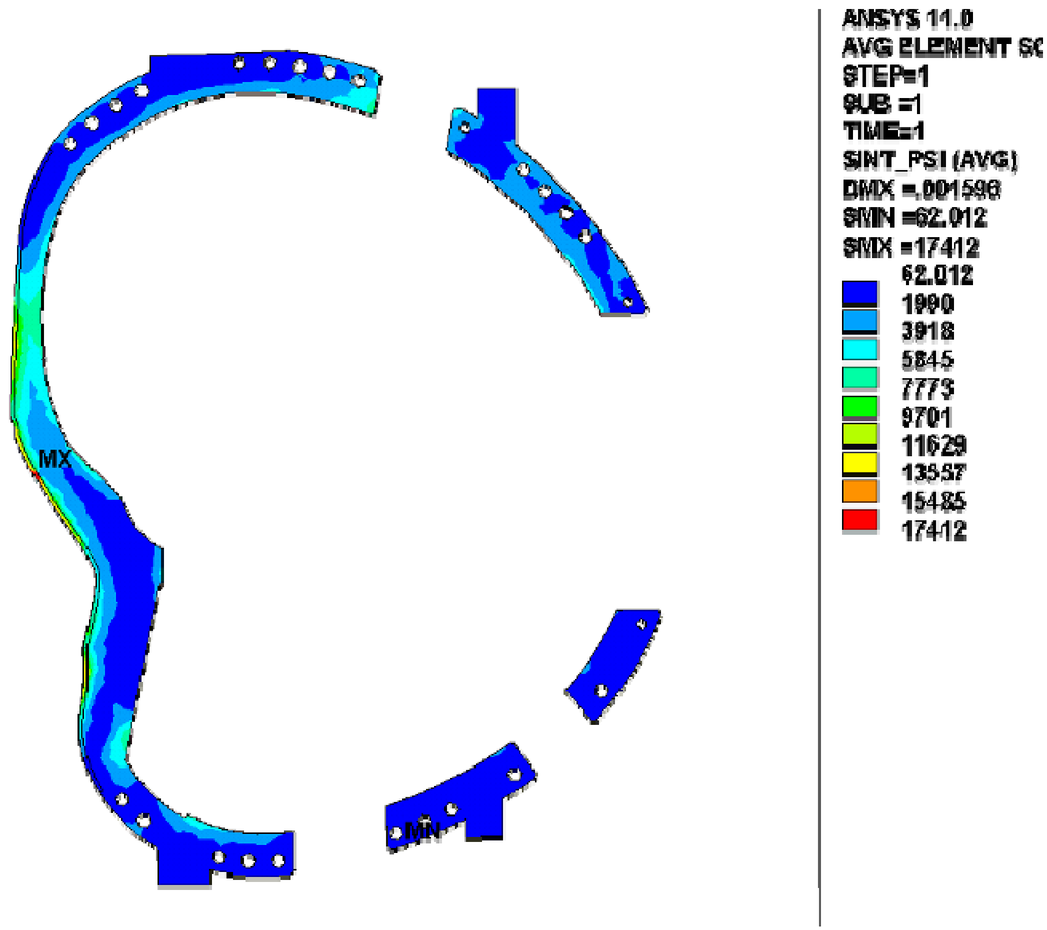
Weld Stresses on AA are the lowest of those studied. Even with segmentation, the weld stresses will not approach the 31.5 Ksi limit or even 20 Ksi. <u>No Sub-model for AA is needed. AA weld is adequate</u>

AB Weld Analysis

AB Global Model weld

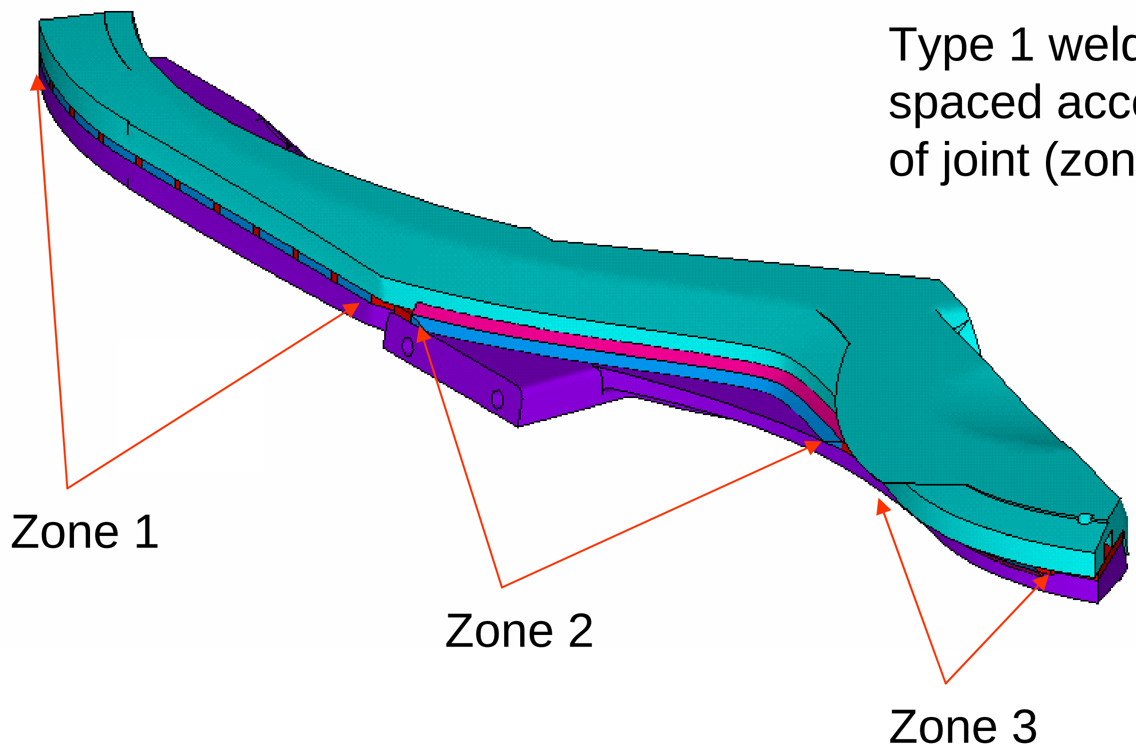


One line of elements 0.5” thick

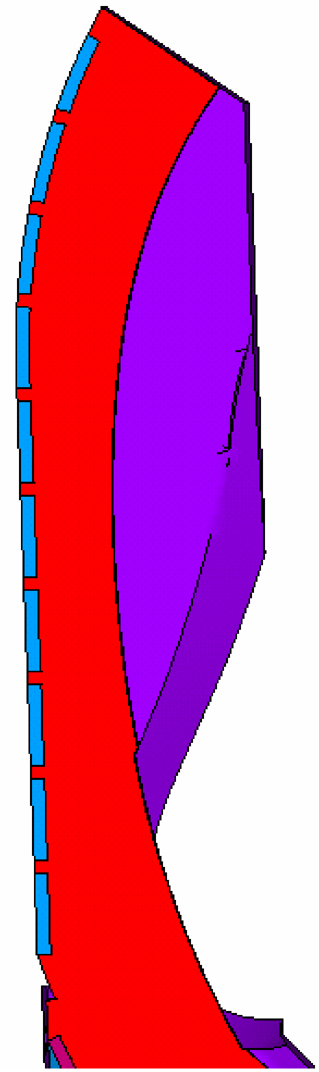


The peak stress is 17.4 ksi and the average stresses are greater than 12 ksi in places. Sub mode is warranted here to determine safety margin.

AB Weld Sub-model



Type 1 welds (3" long) spaced accordingly at top of joint (zone 1)



Red = shim

Blue and pink = welds

Purple = B casting flange

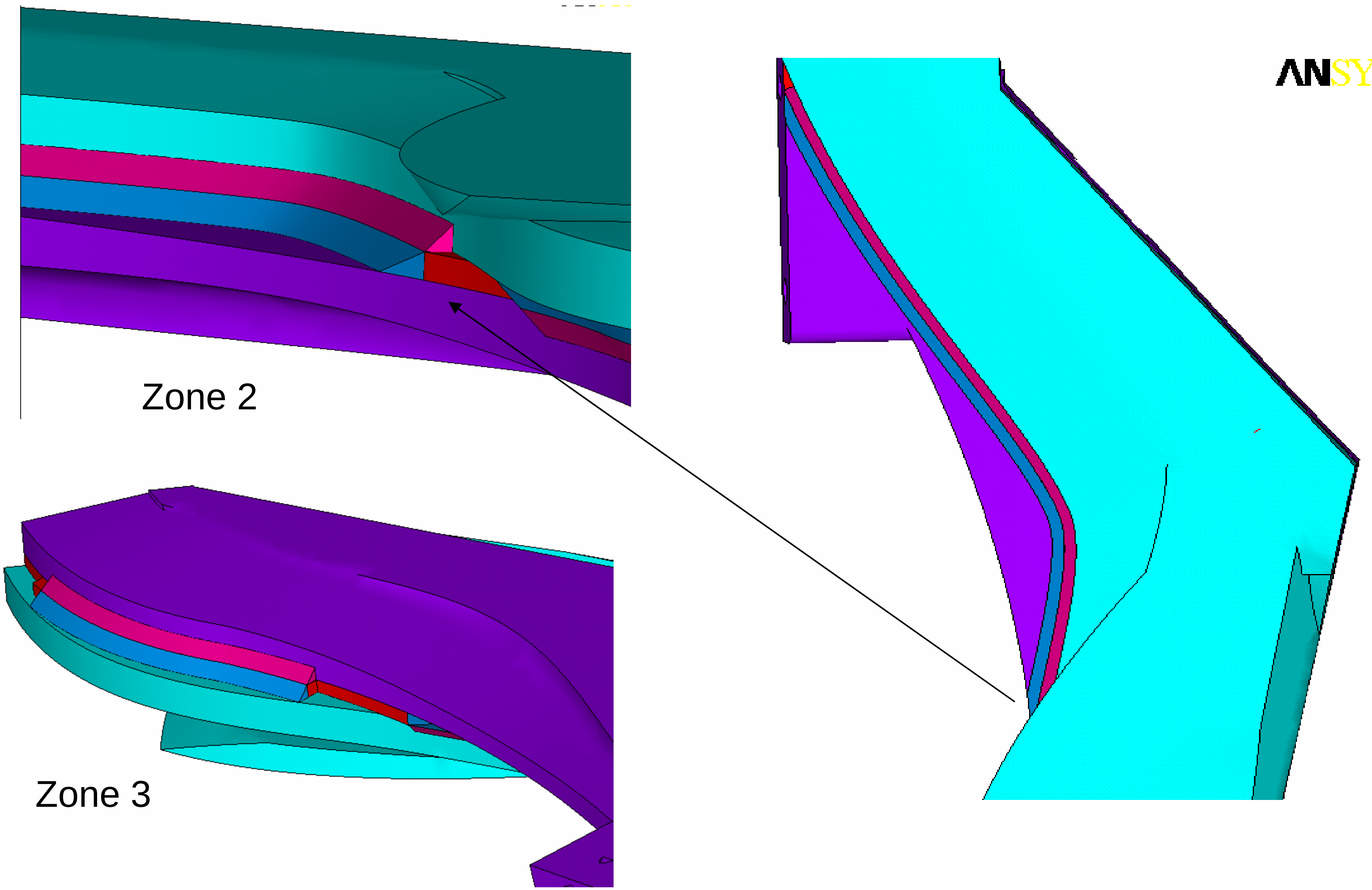
Cyan = A casting flange

There is a small gap in welding between zone transitions

The shim has been stuck out 0.5" in the fillet areas.

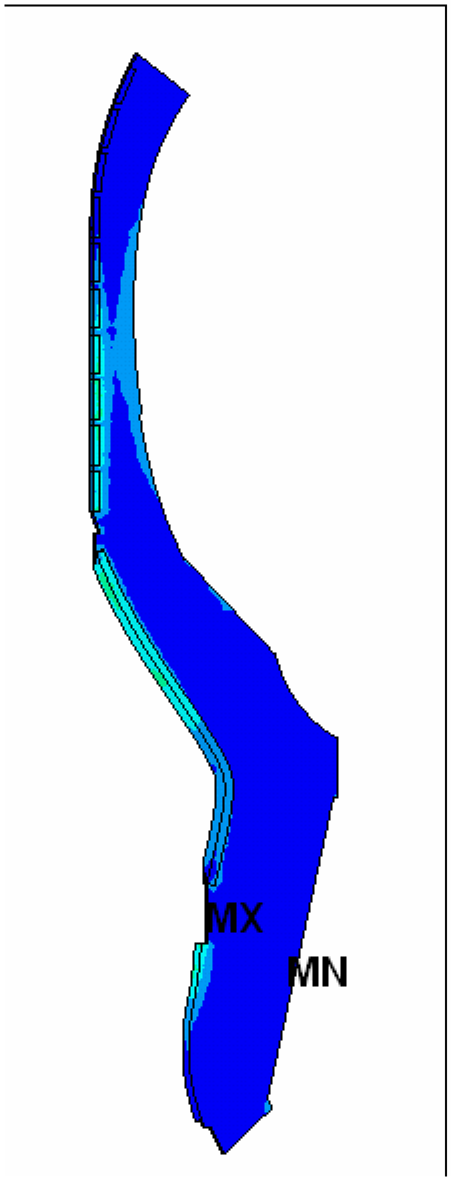
Fillet welds are 0.5" (0.35" throat)

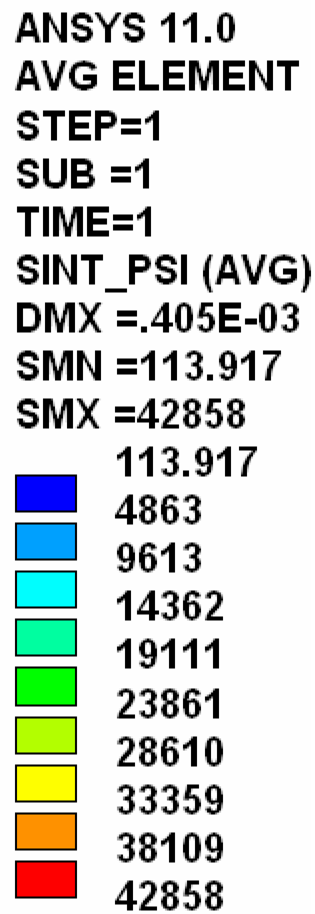
Fillet welds are modeled in AB

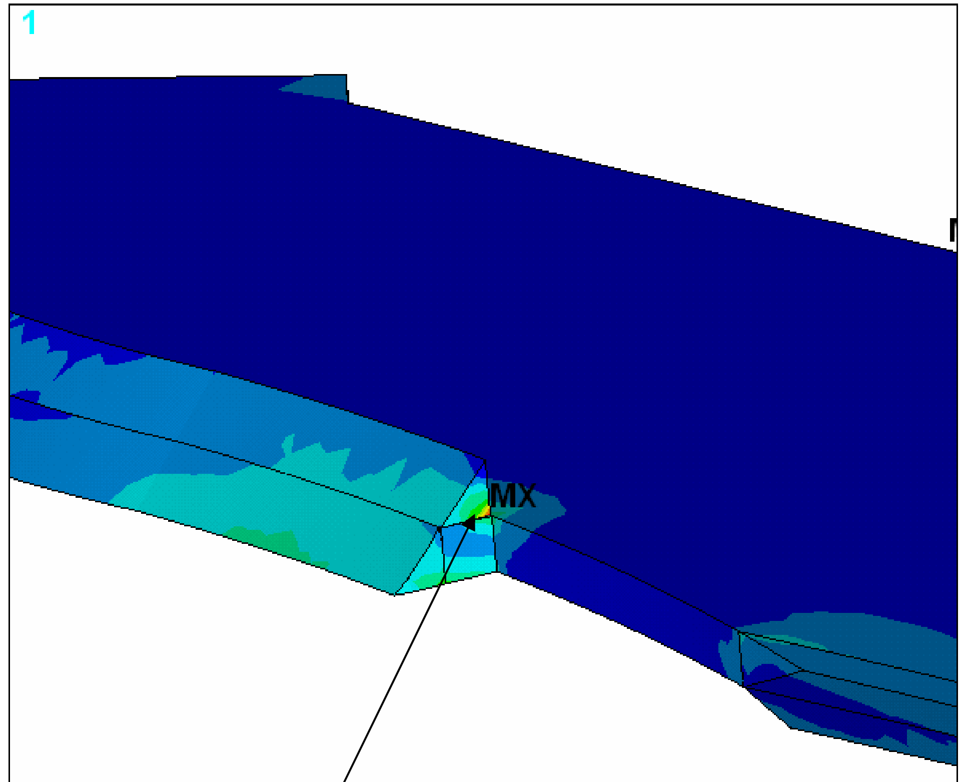


Stress Intensity of weld and shim

NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT

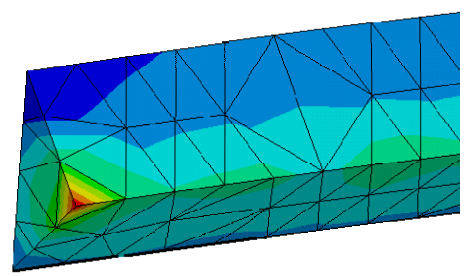






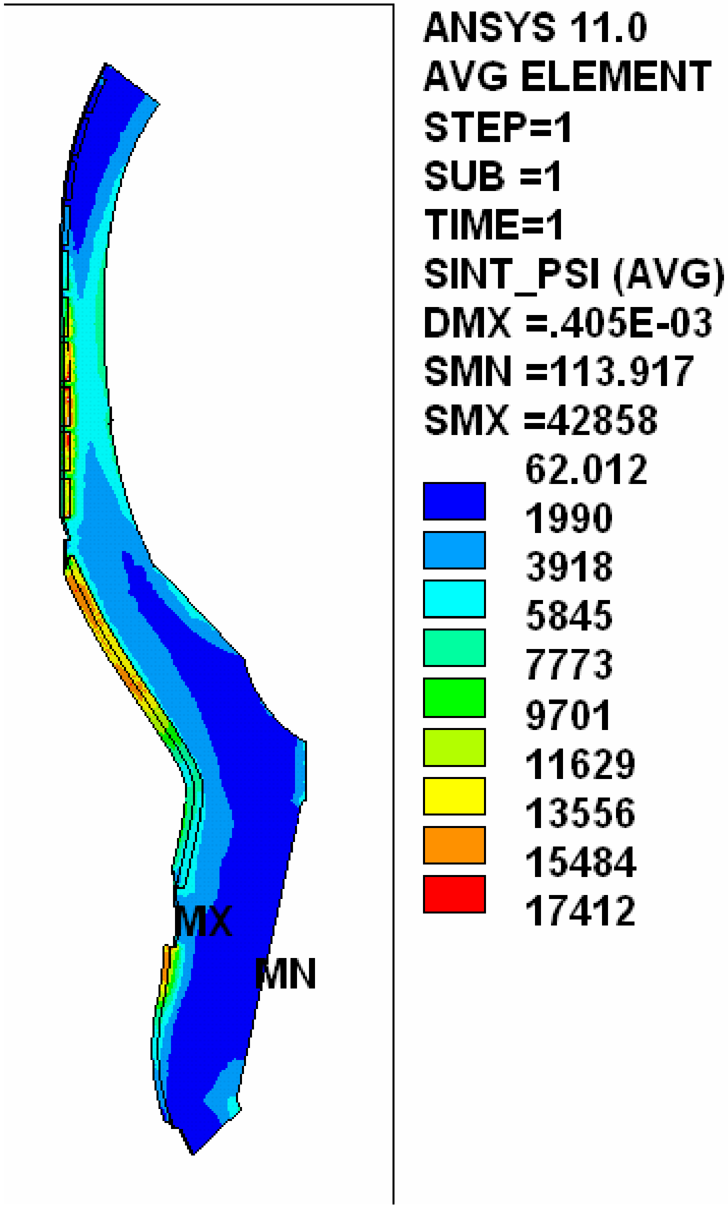
Peaky max stress occurs at corner of entrance to zone 3 (flanges removed)

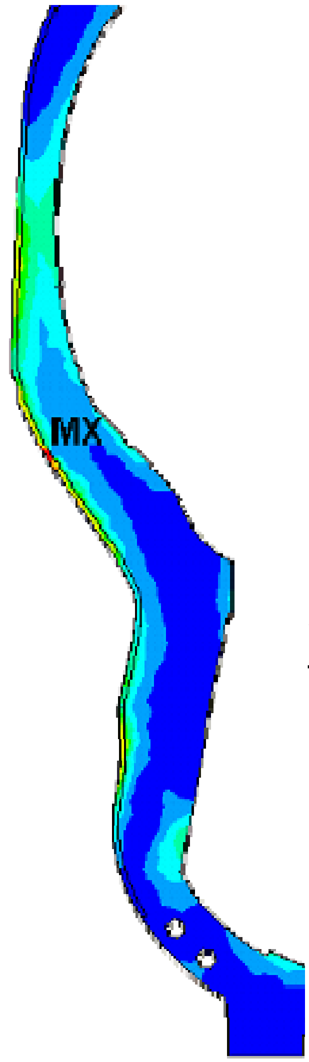
Same type of peaky stress that BC sees.



Peaky stress on end of weld

Same Scale as Global Model



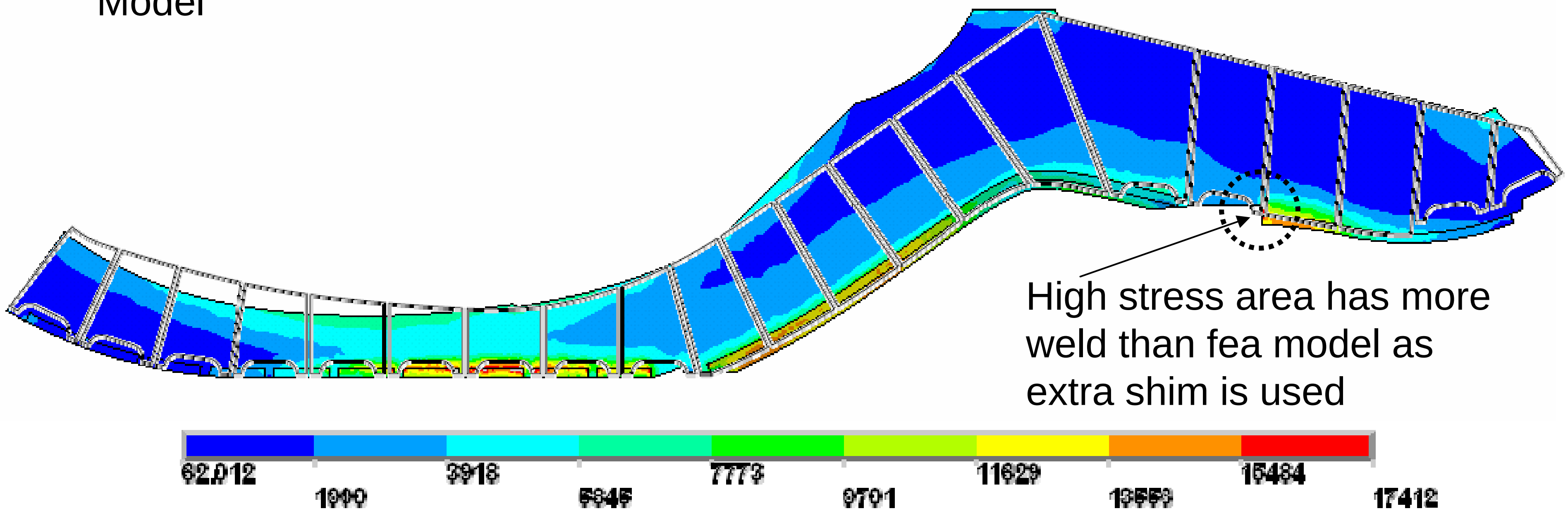


Global Model inboard leg

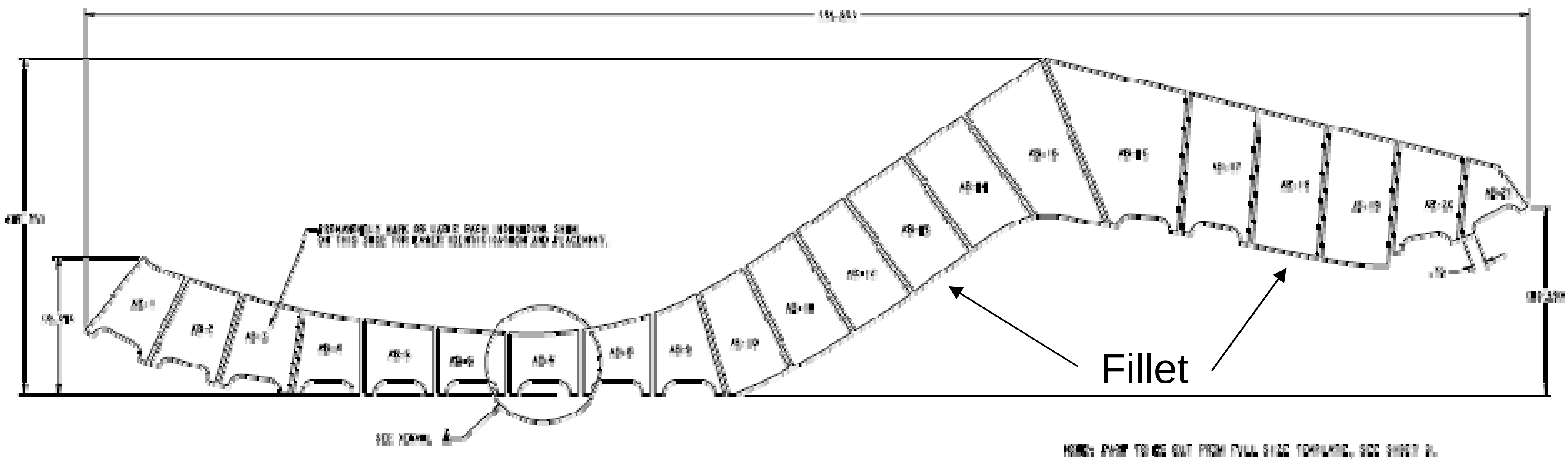
Stresses have definitely increased (approx 2X on average) going to the fillet welds and segmented welds but we are still under our allowable of 31.5 ksi and this compares well to the BC submodel.

How Does this fit with the actual design

Real Shims superimposed on Fea Model

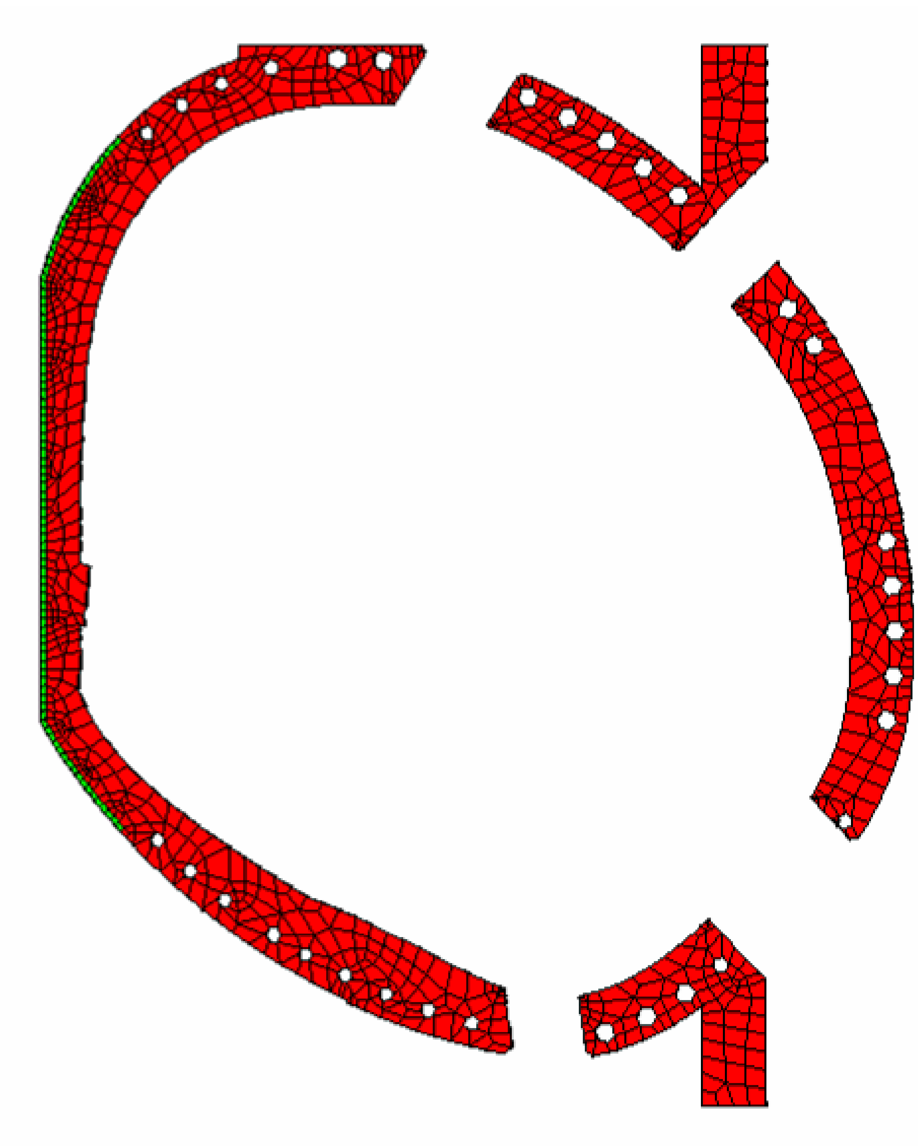


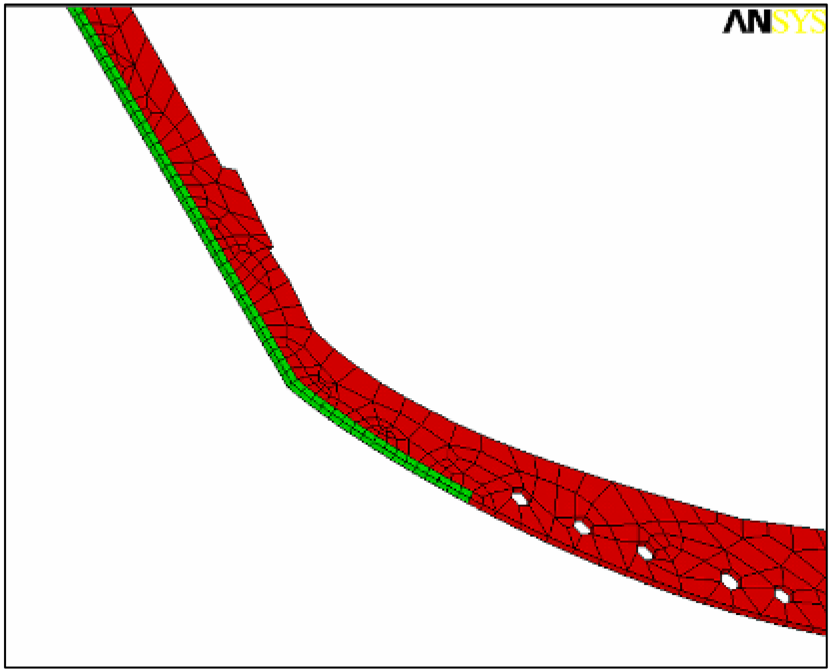
High stress area has more weld than fea model as extra shim is used



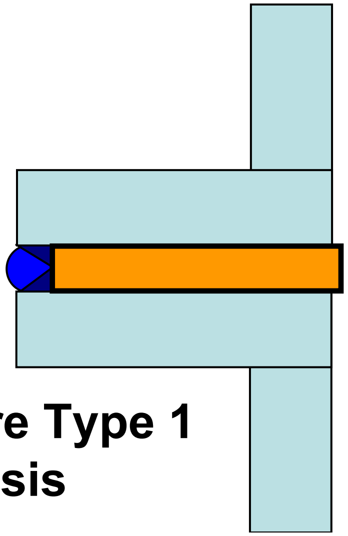
BC Weld Analysis

BC Flange (coarse global model)





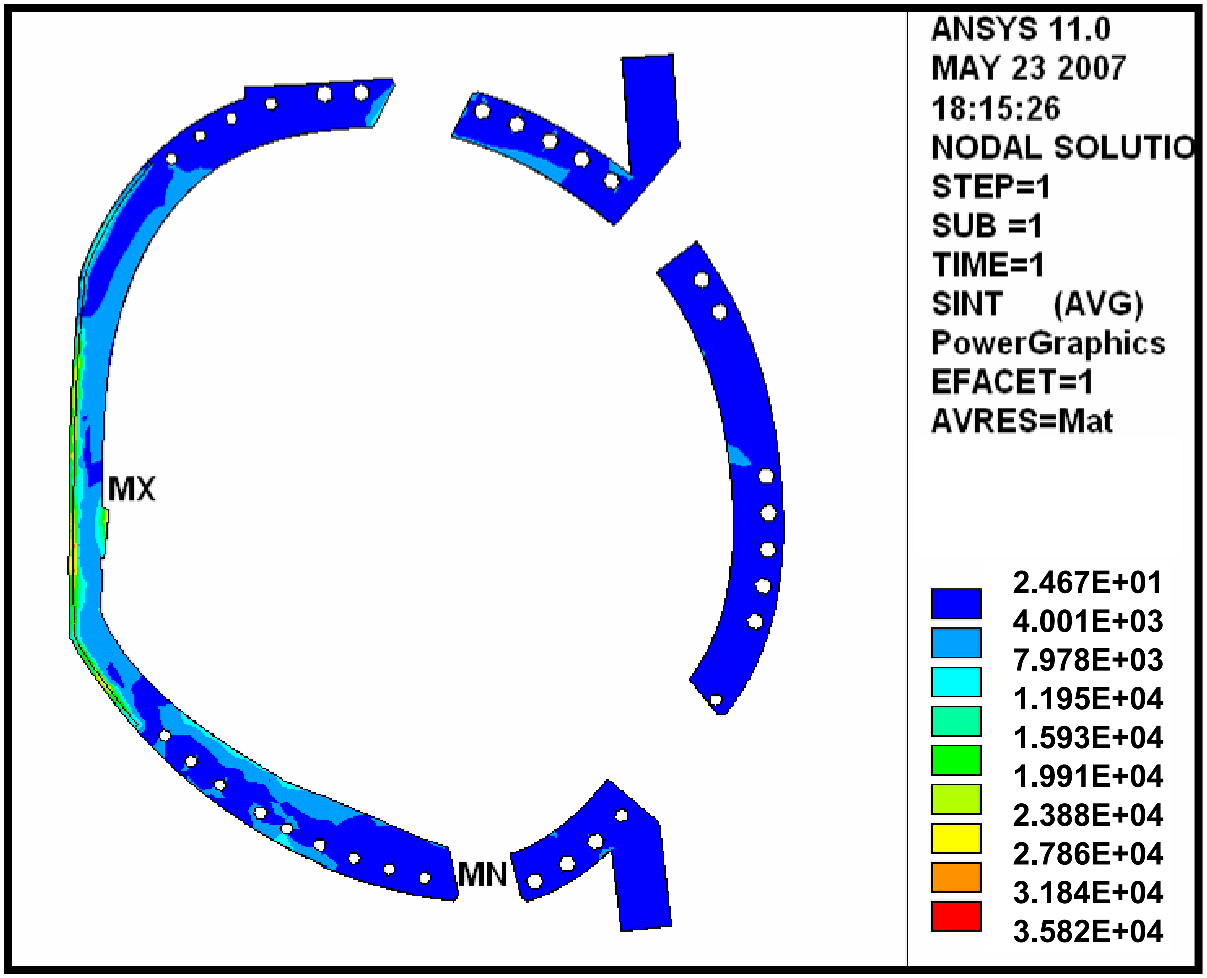
Weld is green elements are 20 node bricks.

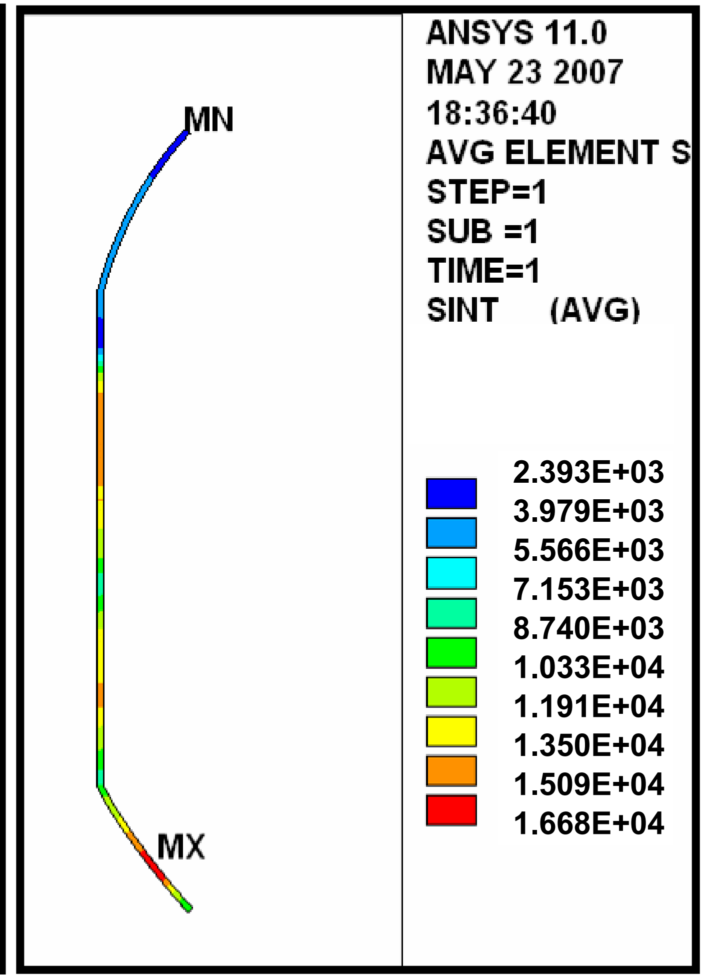


All welds are Type 1 in the analysis

Stress intensity BC (units are psi)

NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT

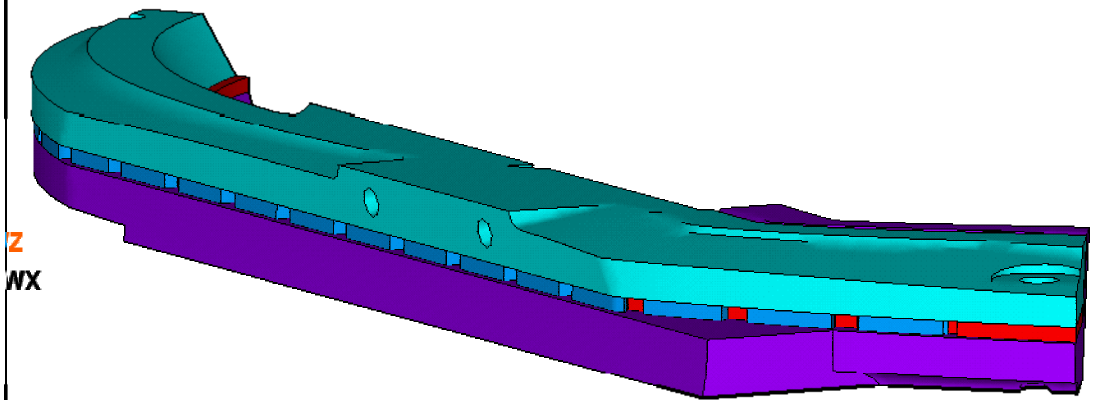


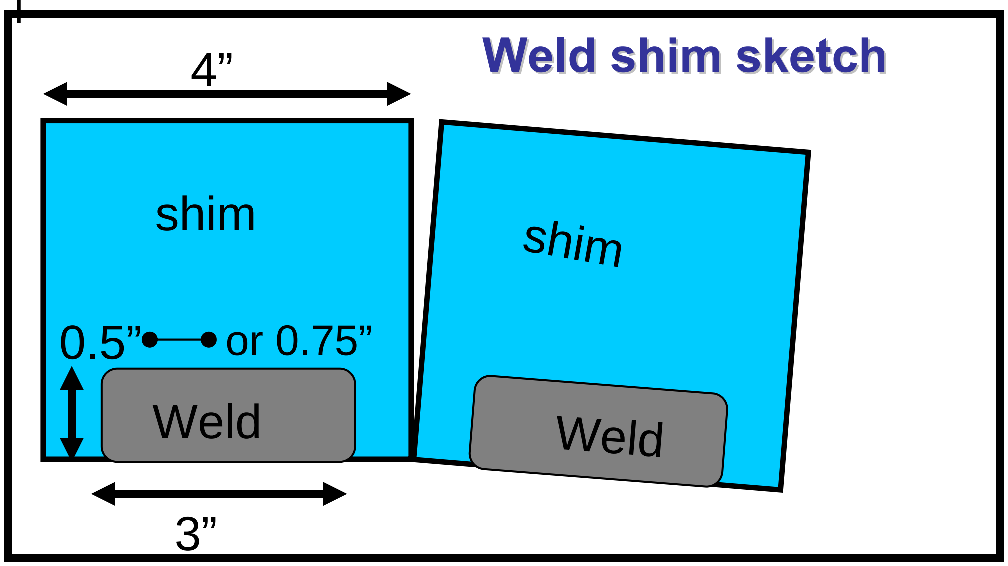


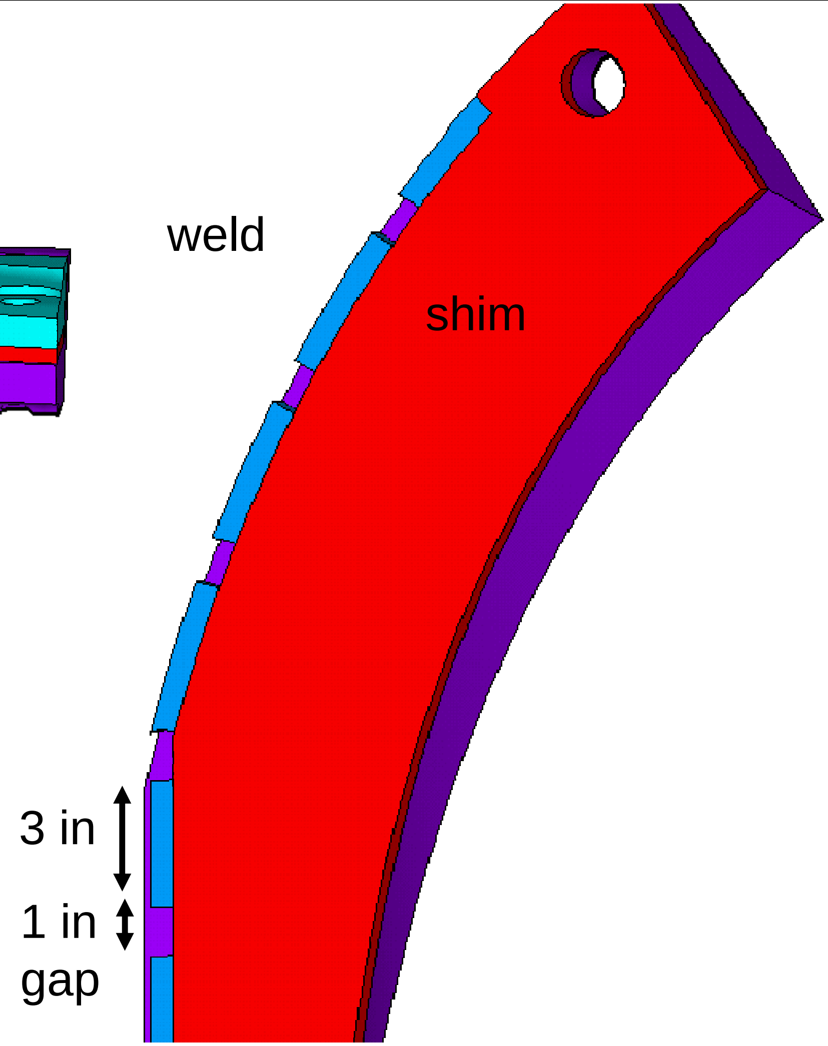
Global Model stresses are only used as a reference since segmentation and filet welds are not included.

Peak Stress in global (un-segmented) model is approx 17 ksi. This needs further examination by sub-model.

Segmented Weld of BC



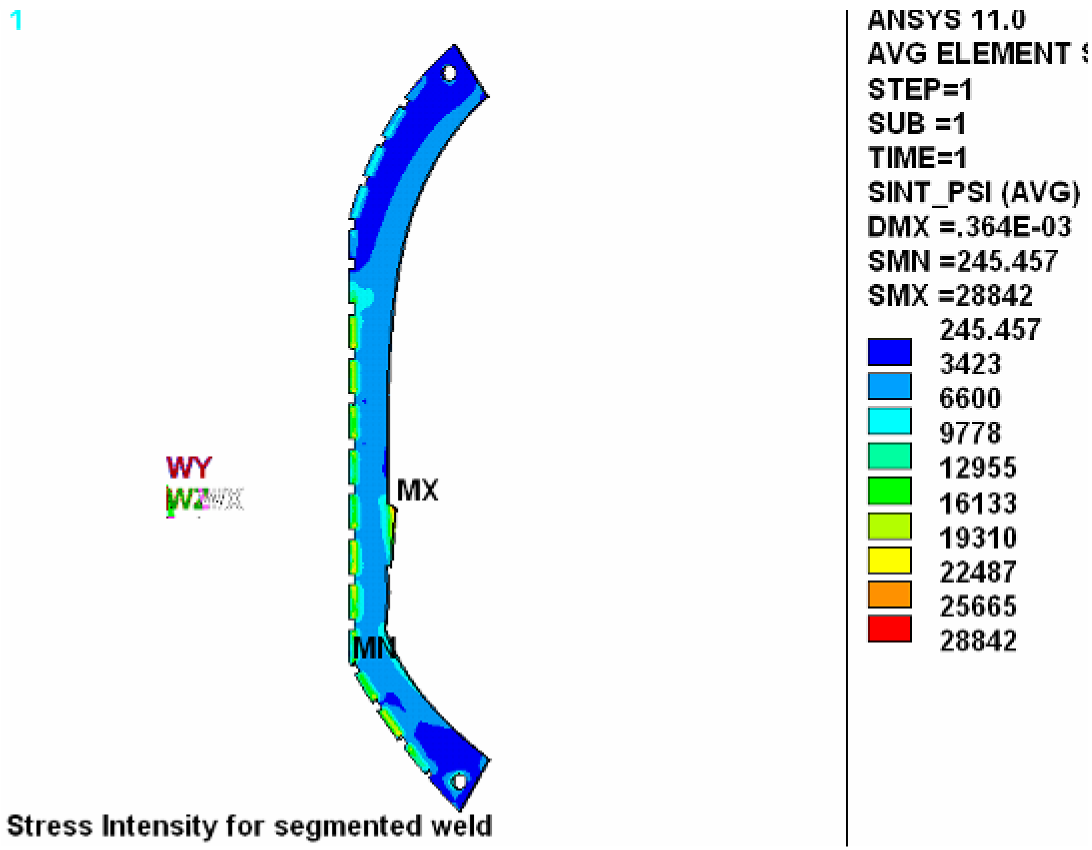


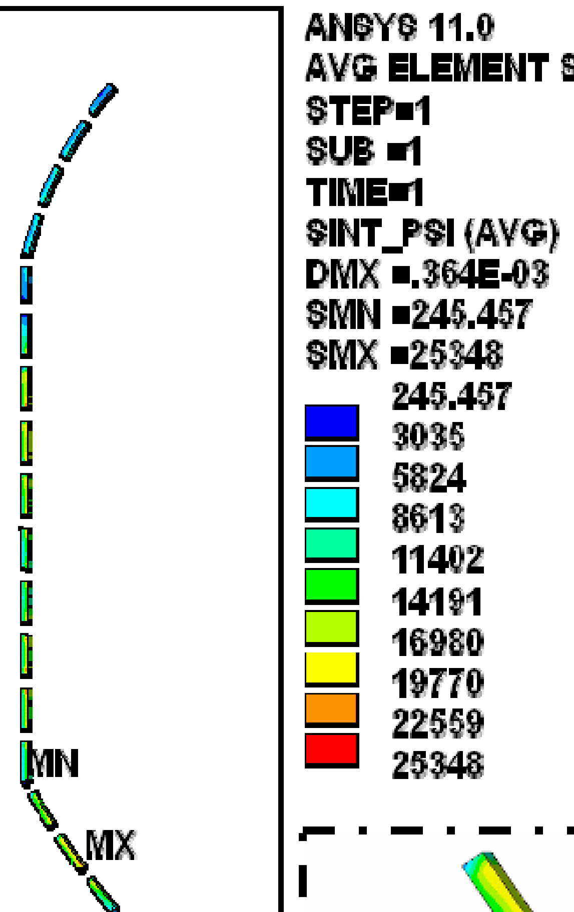


- **In the first attempt, Shim elements were removed between welds, this is non-conservative.**
- **No filet welds were added.**

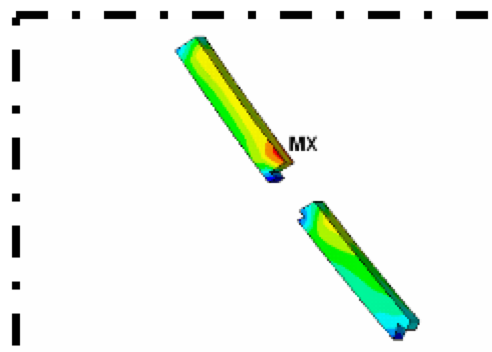
Stress Intensity with segmented weld

NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT





Segmented weld

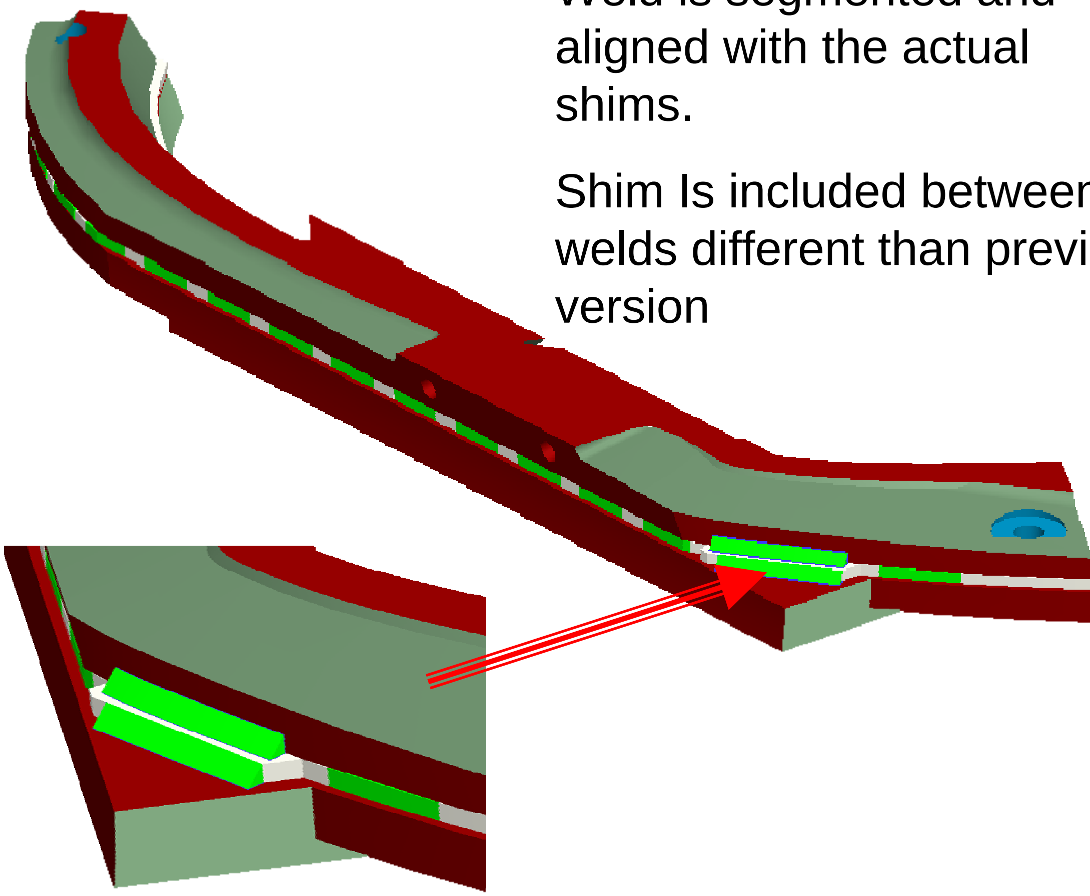


Stress Increases from 19.2 to 25.3 ksi with added segmentation, no filet welds, no shim between segments.

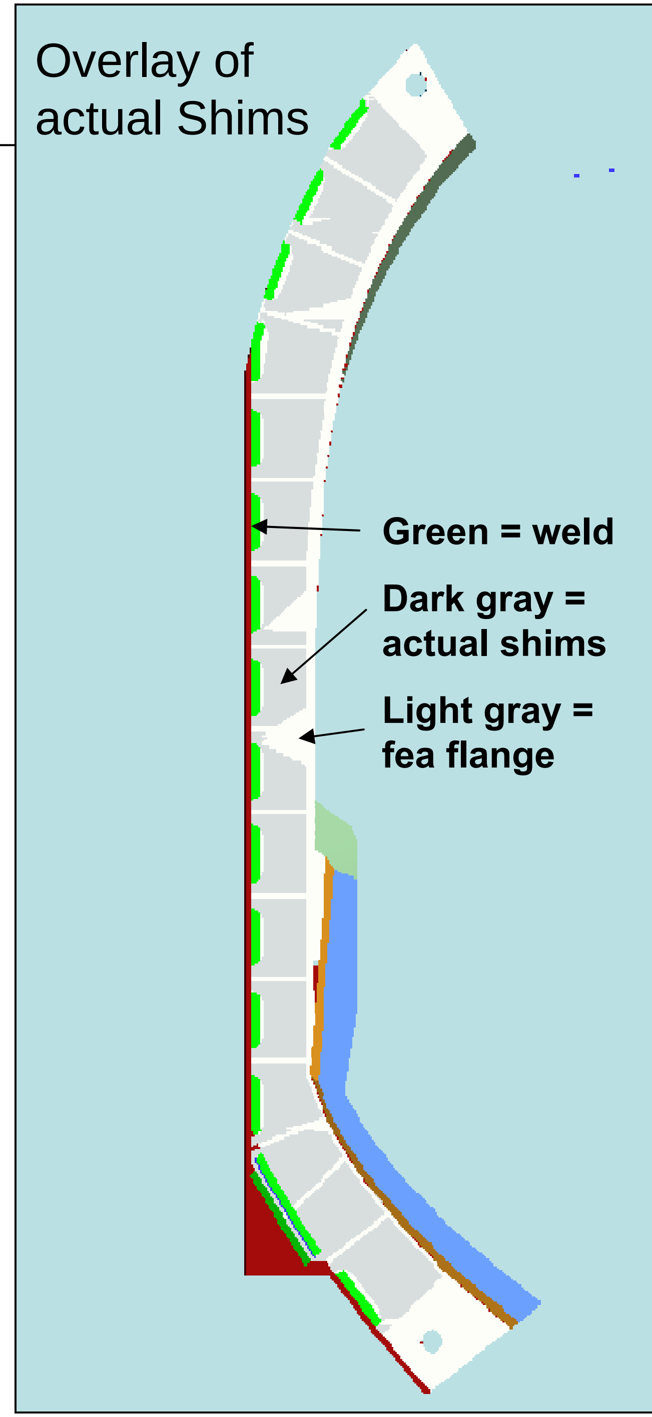
Model of BC

Weld is segmented and aligned with the actual shims.

Shim Is included between welds different than previous version

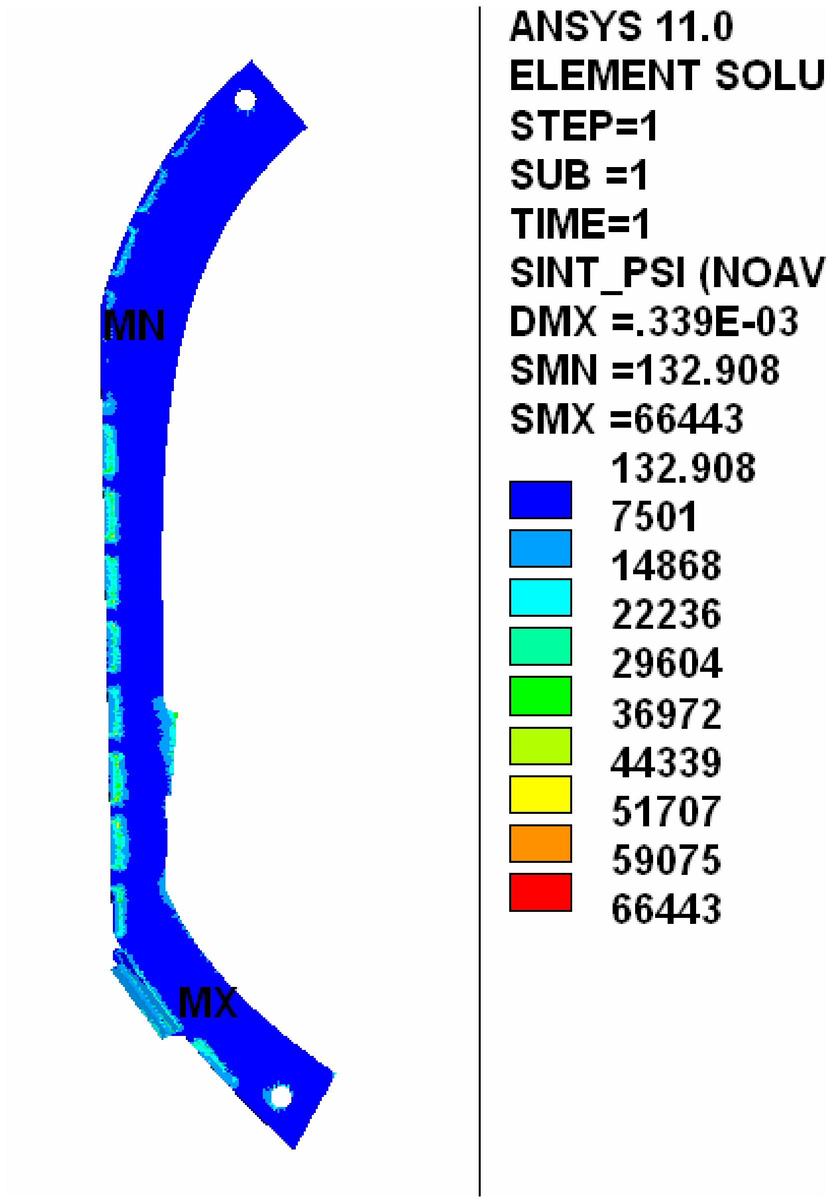


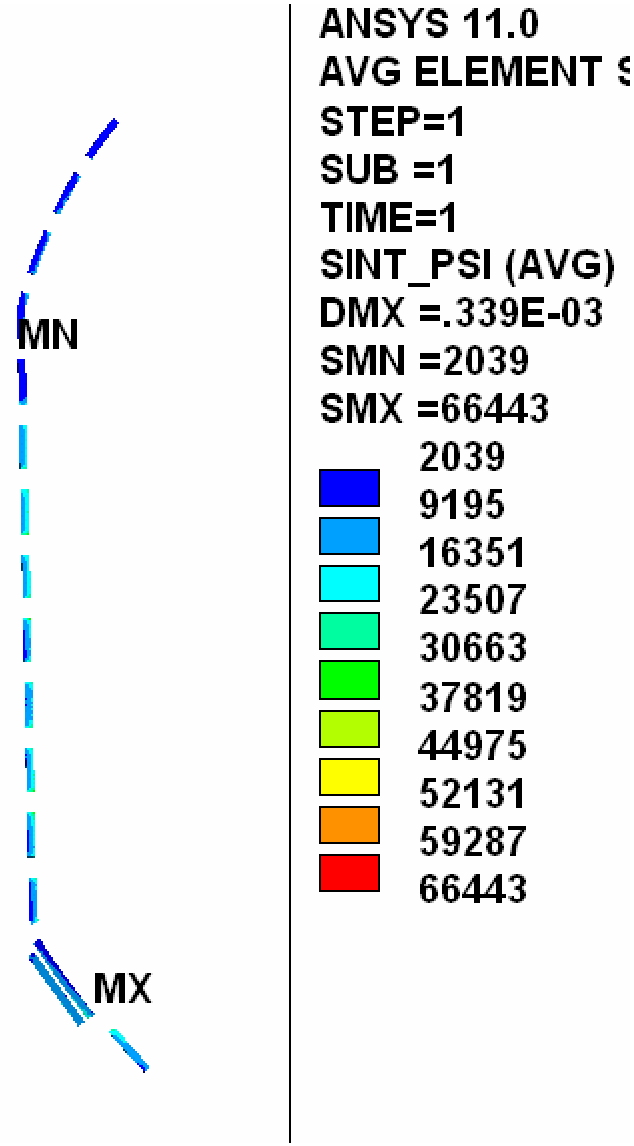
New Fillet welds are in place.



Stress Intensity

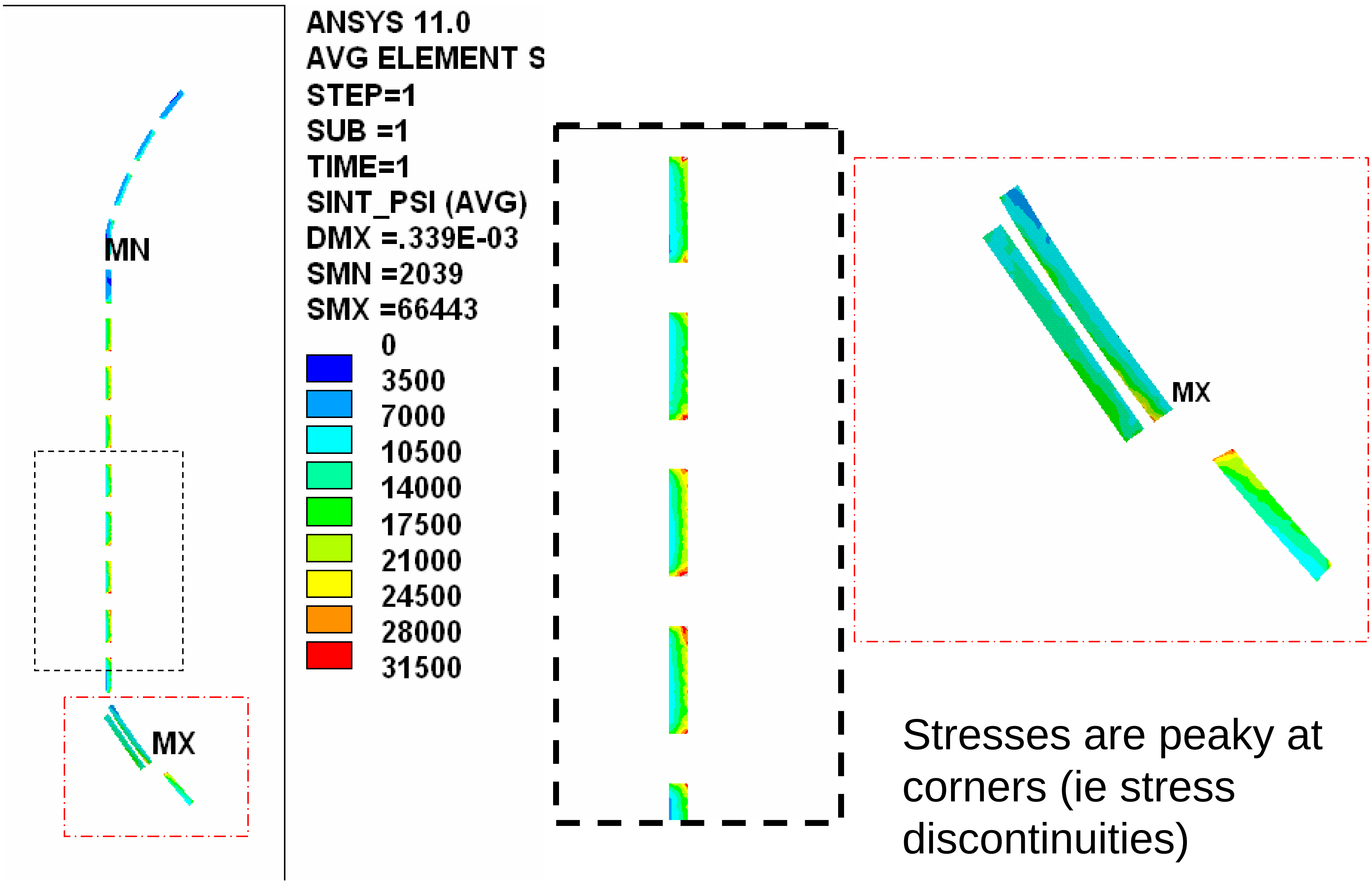
NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT





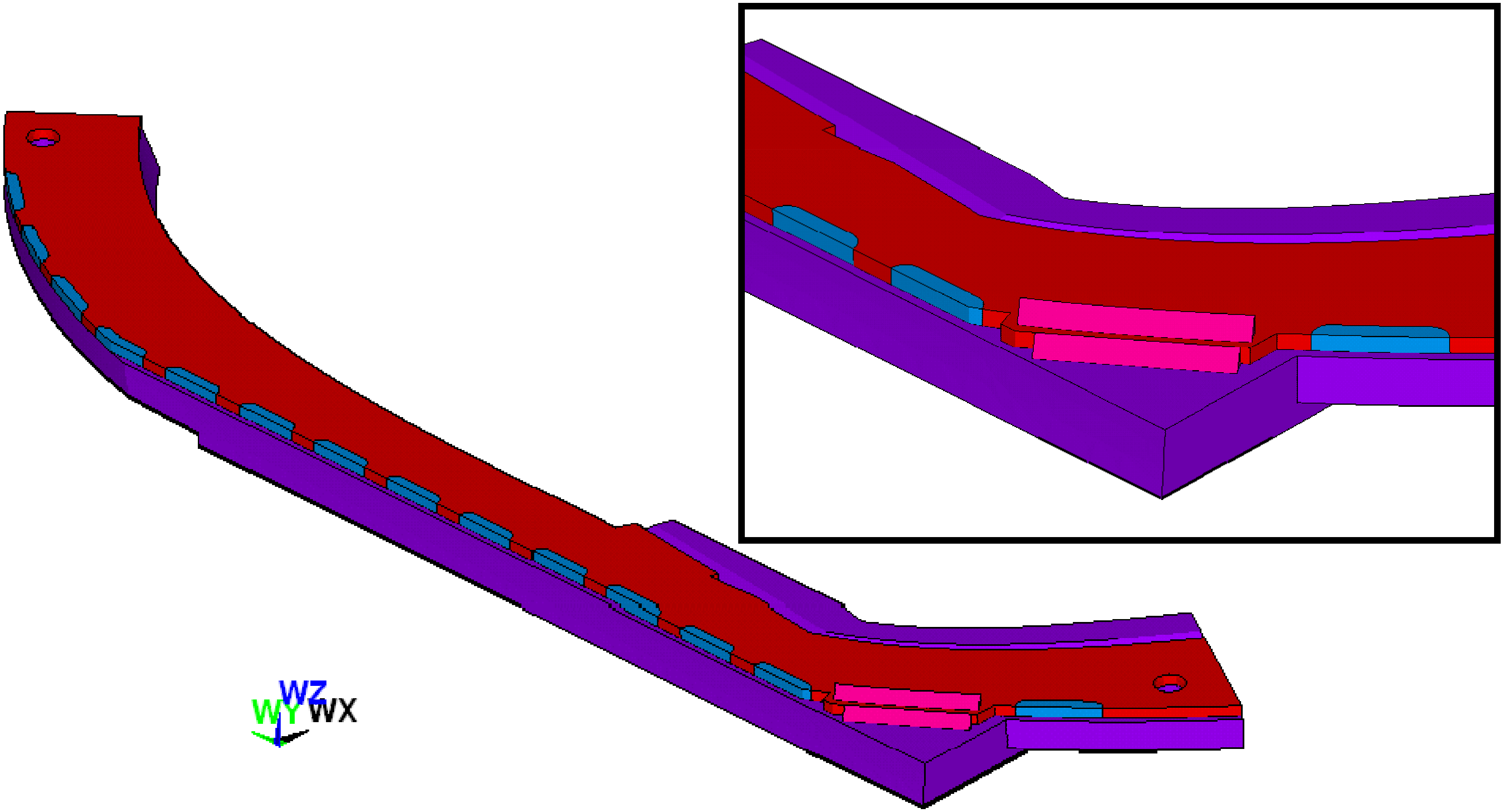
Stress Rescaled to max of 31.5 Ksi

NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT



Stresses are peaky at corners (ie stress discontinuities)

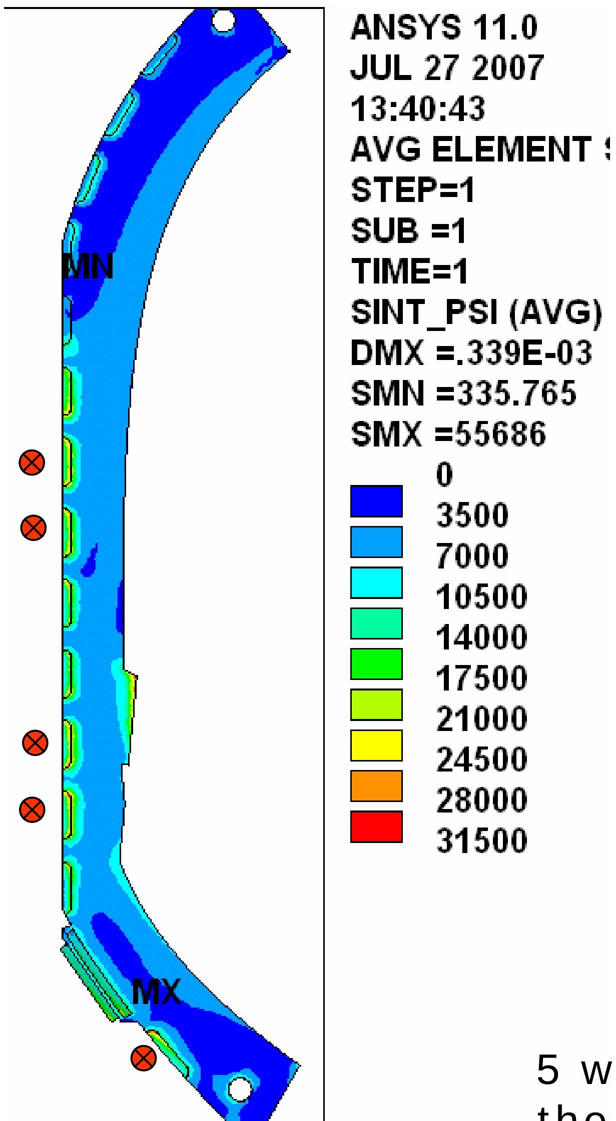
Latest Run of BC



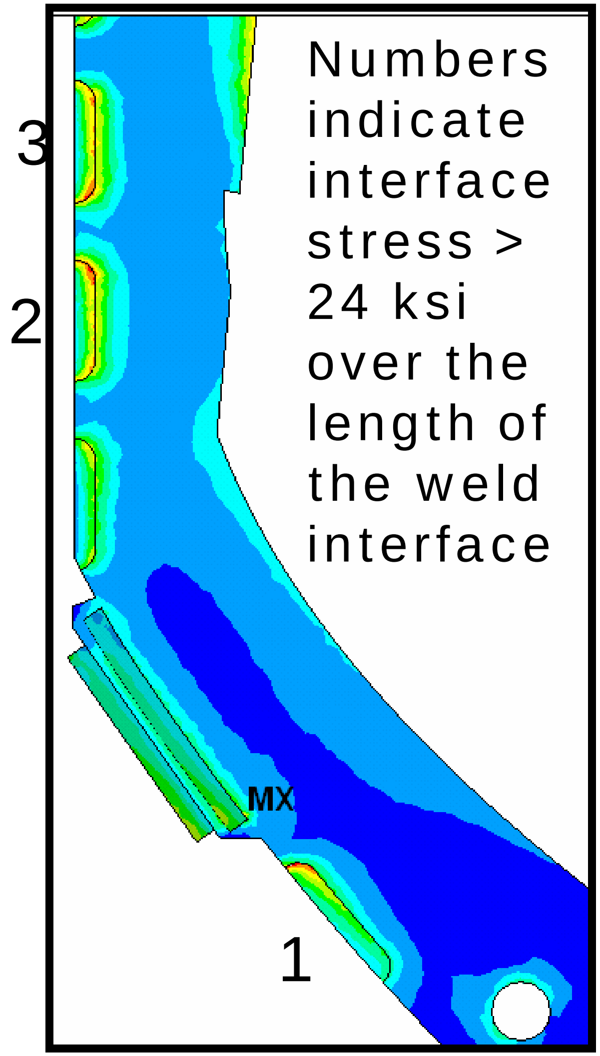
Rounded corners modeled in segmented weld region.

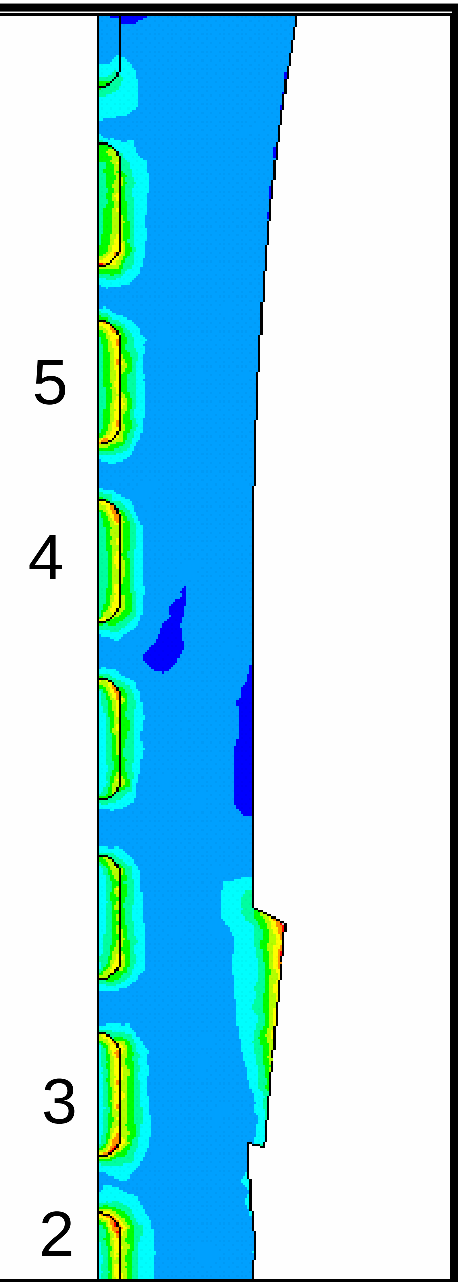
Fillet welds moved a bit to reduce corner/corner interactions

Which segmented welds to enlarge



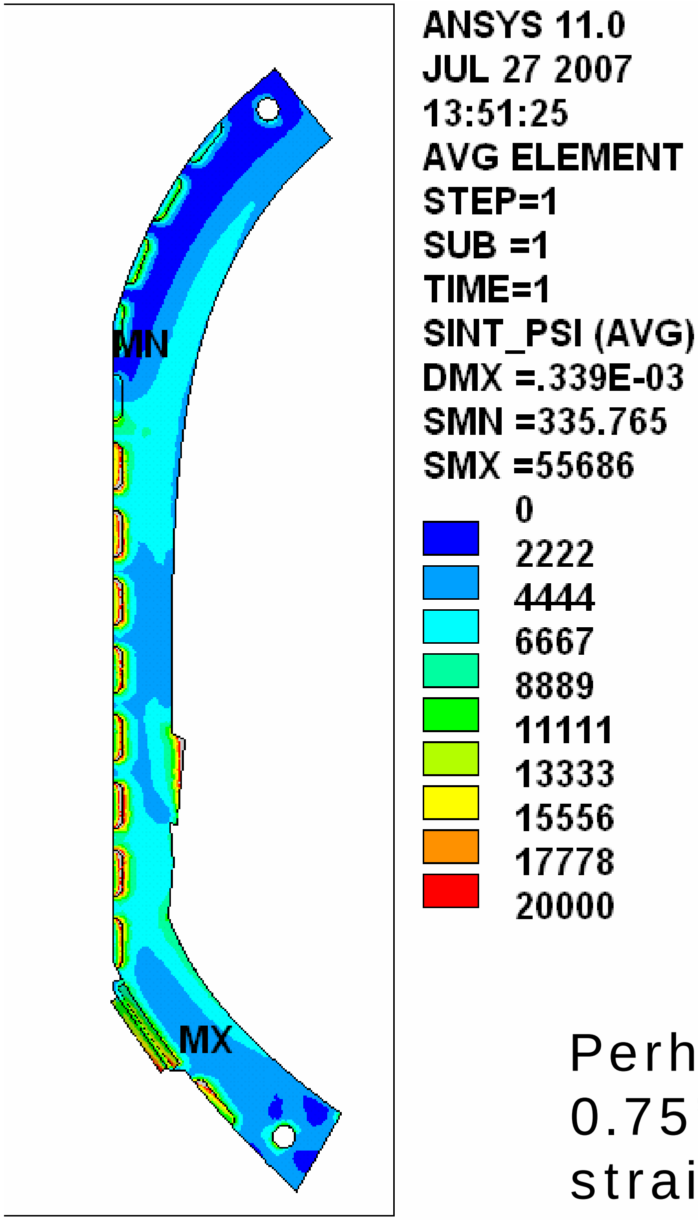
Stresses scales to
design limit of 31.5 Ksi

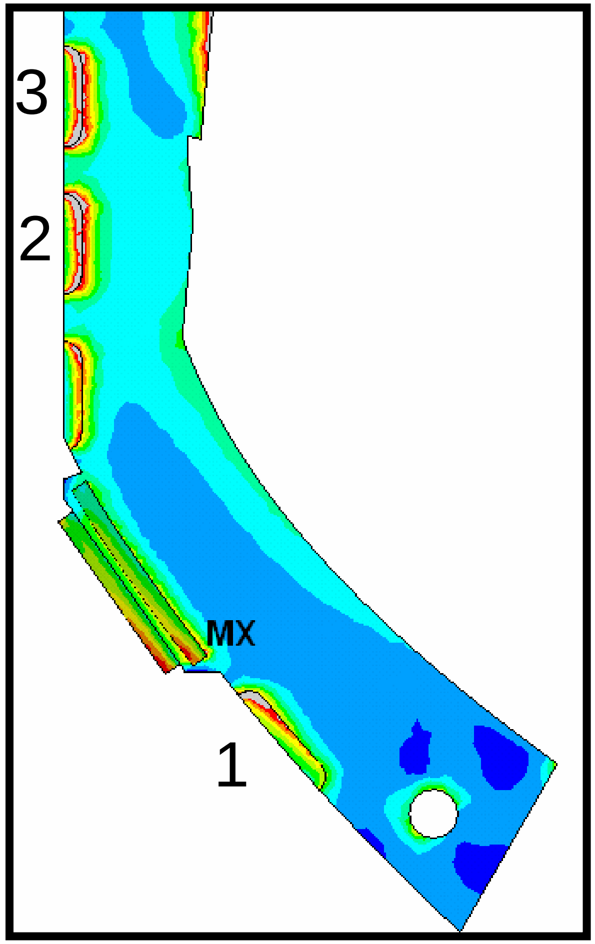


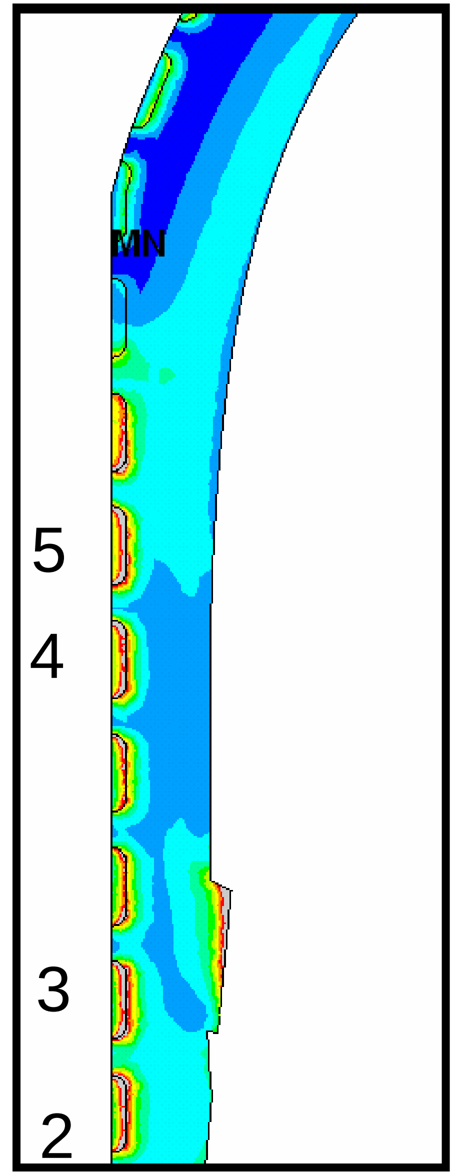


5 welds have stress Intensities on the edge interface near limit. Average Stresses in these welds appear ok.

Which Welds to enlarge





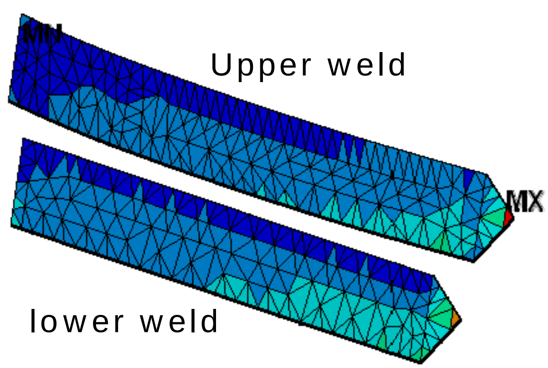


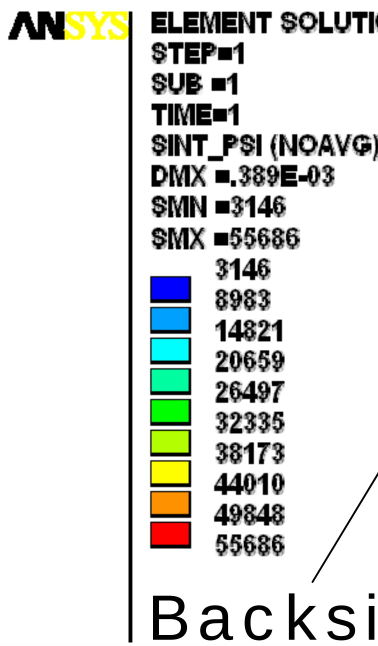
Perhaps, Increasing to 0.75” along the entire straight leg is warranted.

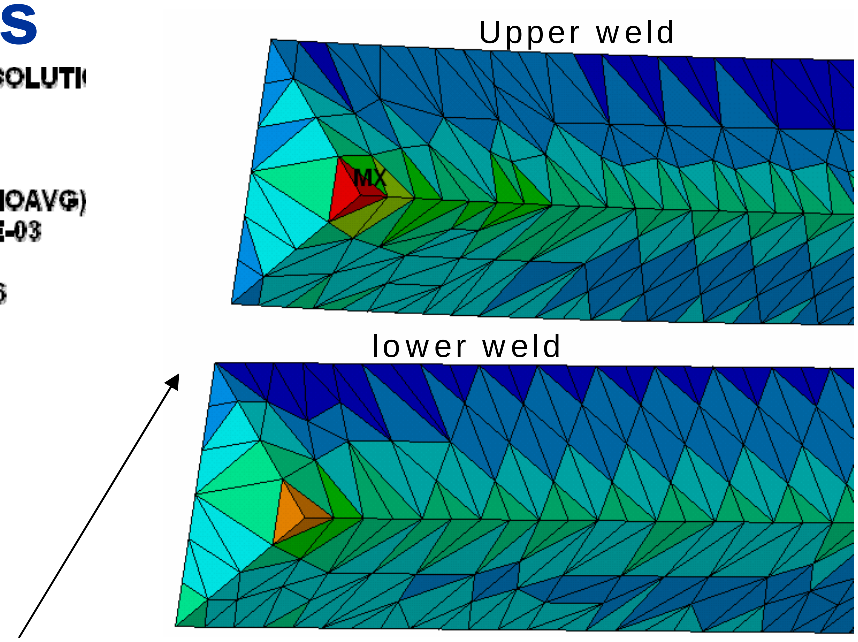
Stresses scales to 20 Ksi

Corner Nodes/Elements of fillet welds are peaky in Stress

NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT

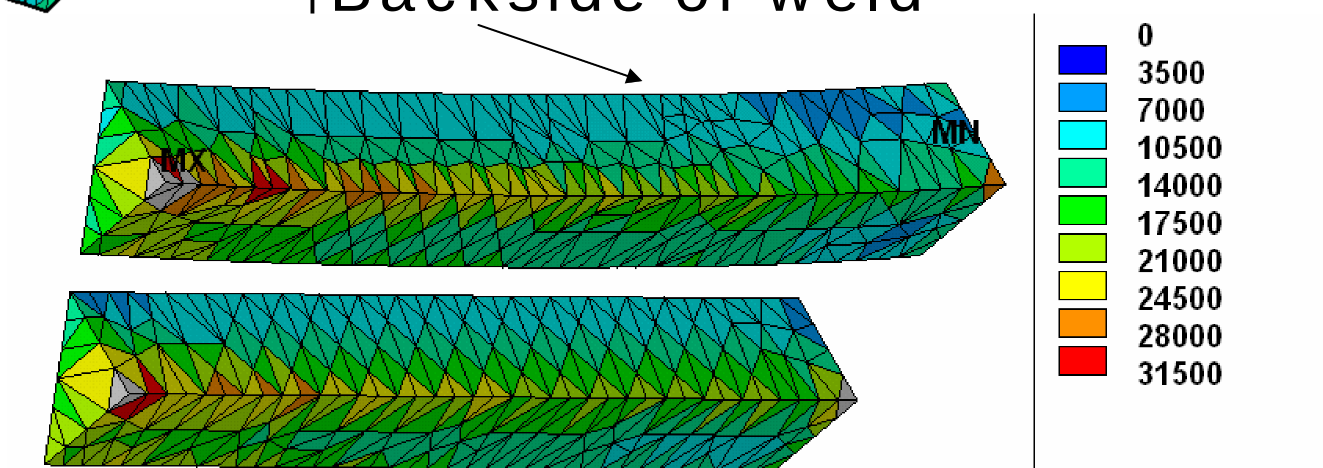






Backside of weld

Stress peaky near interface and espeically the corner but average stress is still low.



Rescaled to max of 31.5 ksi

BC Summary

NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT

Run/model #	Description	Weld type	Peak Stress (ksi)	Average Stress through weld (ksi)	Plug Weld interface stress (ksi)
0	Global Model, very course mesh	Continuous	16.8	≈ 16.8	N/A
1	Submodel, 3X3 mesh for weld	Continuous	19.2	≈ 13	N/A
2	Submodel, no shim between weld segments, no fillet welds	Segmented	25.4	≈ 15	N/A
3	Submodel, between weld segments and fillet welds. No rounds on welds	Segmented	66.4	≈ 20	31 (5)*
4	Submodel, between weld segments and fillet welds. With rounded	Segmented	55.6	≈ 19	28 (5)*

* Number of plug weld shims that see greater than 20 ksi along an edge.

The peaky stresses do not tell the story here, they are most likely geometric modeling limitations that show much greater stress at the fillet weld corners.

Of greater concern are the plug type welds which see interface stresses greater than 24 ksi.

Weld Analysis Summary

NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT

Flange	model type	Peak stress Intensity (ksi)	Average Stress Intensity (ksi)	Peak Horizontal Shear Stresses (max, min) (ksi)	Peak Vertical Shear Stresses (max, min) (ksi)
AA	Global Model, very course mesh	9.2	9.2	(-1.7, 1.7)	(-3.4, 3.4)
AB	Global Model, very course mesh	17.4	17.4	(-7.8, 6.5)	(-3.6, 3.6)
BC	Global Model, very course mesh	16.7	16.7	(-1.5, 2.3)	(-1.9, 4)
AB	Sub model with fillets, segmented plug welds	42.9	16.0	(-15, 16)	(-2.8, 9)
BC	Sub model with fillets, segmented plug welds	66.4	20.0	(-9, 9)	(-13, 8)

Note: BC segmented welds see somewhat high stress access their shim/weld interface (> 25 Ksi , < 31.5 Ksi)

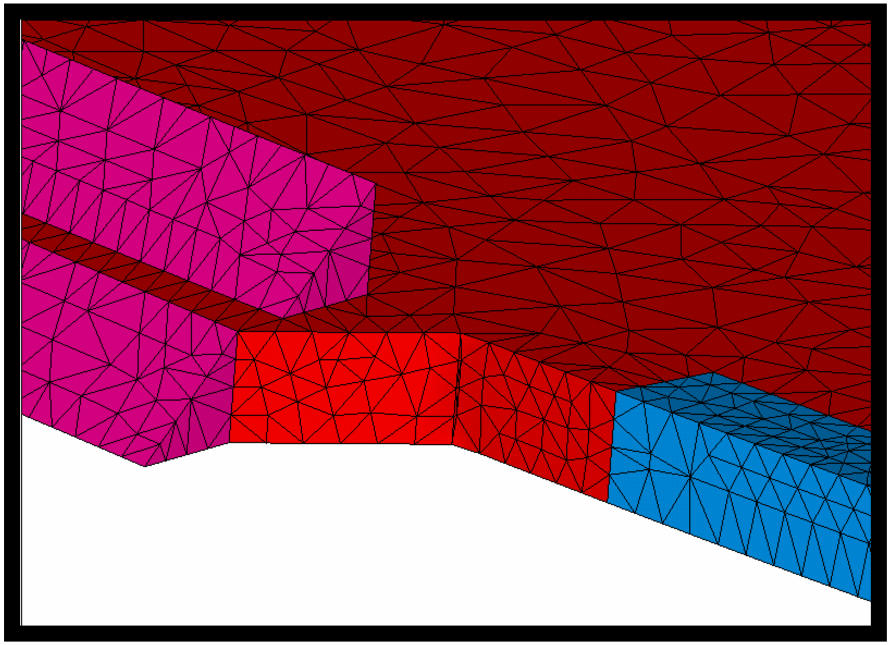
Note: The increase in shear stresses in sub-models occurs in the same areas as the peak stress intensities and are likely overestimates.

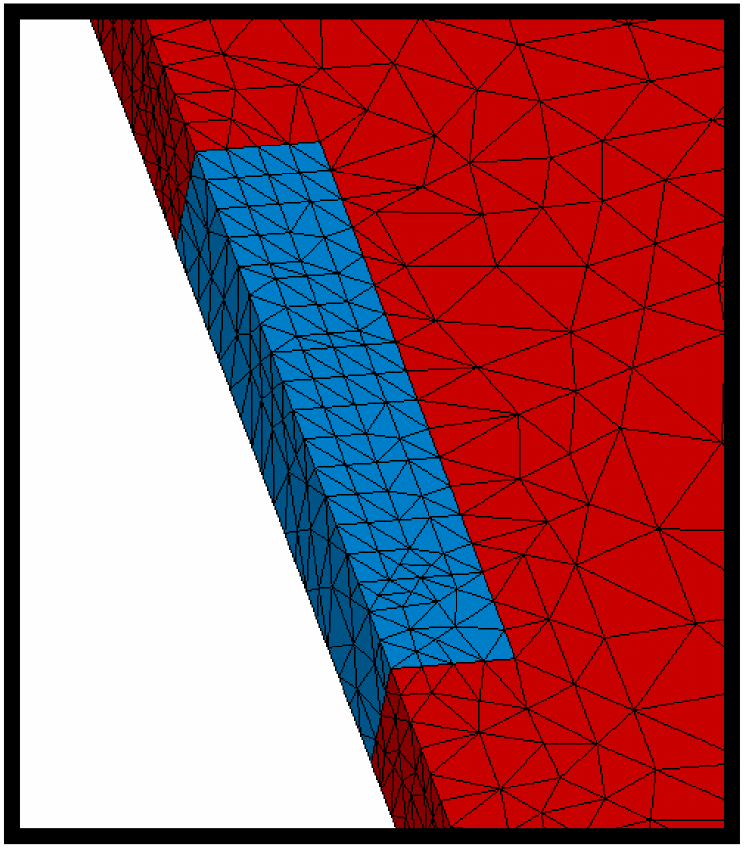
Comments

NCSX NATIONAL COMPACT STELLARATOR EXPERIMENT

- Peak stress of 43 ksi and 66.4 ksi on AB and BC sub models are anomalous as there will be additional weld material immediately near it. It is extremely peaky and likely due to sharp geometric cornering.
- Average stresses across weld when not considering those regions are approximately 20 ksi.
- Fea Model is conservative in that it leaves gaps between weld zones where in reality those gaps will have weld metal present.
- Model has shown that a 0.5” fillet weld (0.35” throat) in some areas and a segmented plug type weld (0.5”) in others **are adequate** to support the shear loads on the AB and AA flanges.
- The BC flange **may** need another analysis run with deeper pocket welds (0.75”) along the straight edge due to the high stress (>24 ksi) across the shim/weld interface.

Extra: BC Mesh





10 node tetrahedrals used with a minimum of three per width of weld.

Bonded to shim using common nodes.

Chits Status

- Peer review of inboard welded shims conducted on May-18
- No chits submitted, but weld distortion identified as main risk
- Actions planned at that time:
  - Shim layout
  - Structural analysis of welds
  - Access for welding
  - Development of weld procedure
  - Material selection
  - Deformation control options

Plan to complete final design

Task	Description	Proposed	Sched
1421-3132	Inboard Interface AA/AB/BC PDR	2-Aug	1-Aug
INTRF-051	Release SE140-052, -053, -054 for procurement	6-Aug	31-Jul
PHIL-43	A6/B6 assembly and weld tests complete	22-Aug	22-Aug
INTRF-040	Issue inboard interface analysis report for checking	24-Aug	15-Aug
INTRF-055	Inboard Interface AA/AB/BC FDR	31-Aug	4-Sep
1429-3069X	Inboard shims AA/AB/BC ready for installation	19-Sep	19-Sep

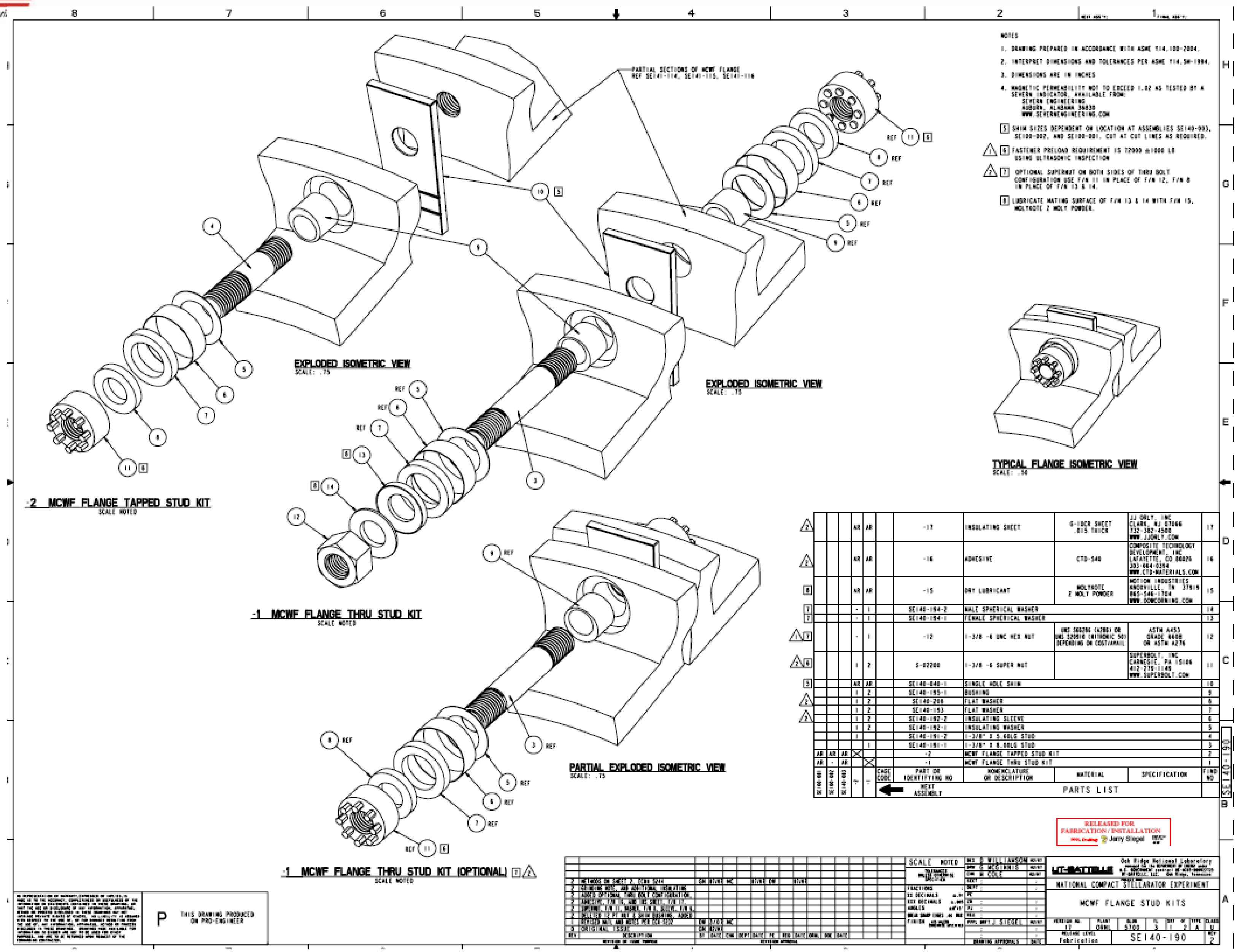
Conclusion

- Are the requirements defined? What is the proposed design?
  Shim layout complete, individual drawings ready to release
- What is the status of welding trials?
  A6/B6 asm and welding trial underway, complete by 8/22
- Is the analysis consistent with proposed design?
  Analysis updated- AA, AB welds adequate, BC to be checked
- Have prior design review chits been addressed?
  Peer review identified development activities- underway
- Have all technical, cost, schedule, and safety risks been addressed?

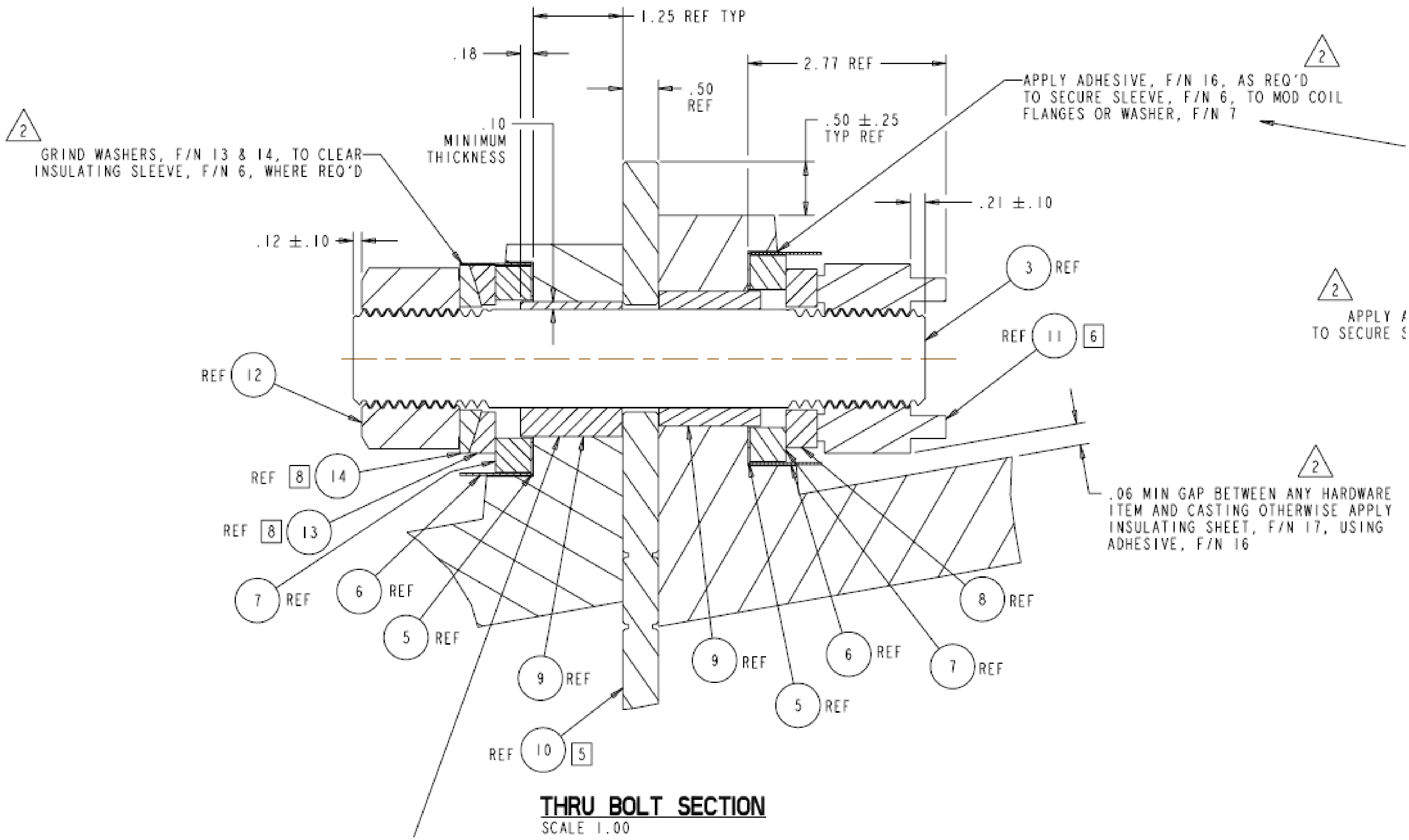
National Compact Stellarator Experiment

Backup Slides

Bolted Joint Asm (SE140-190-R2)

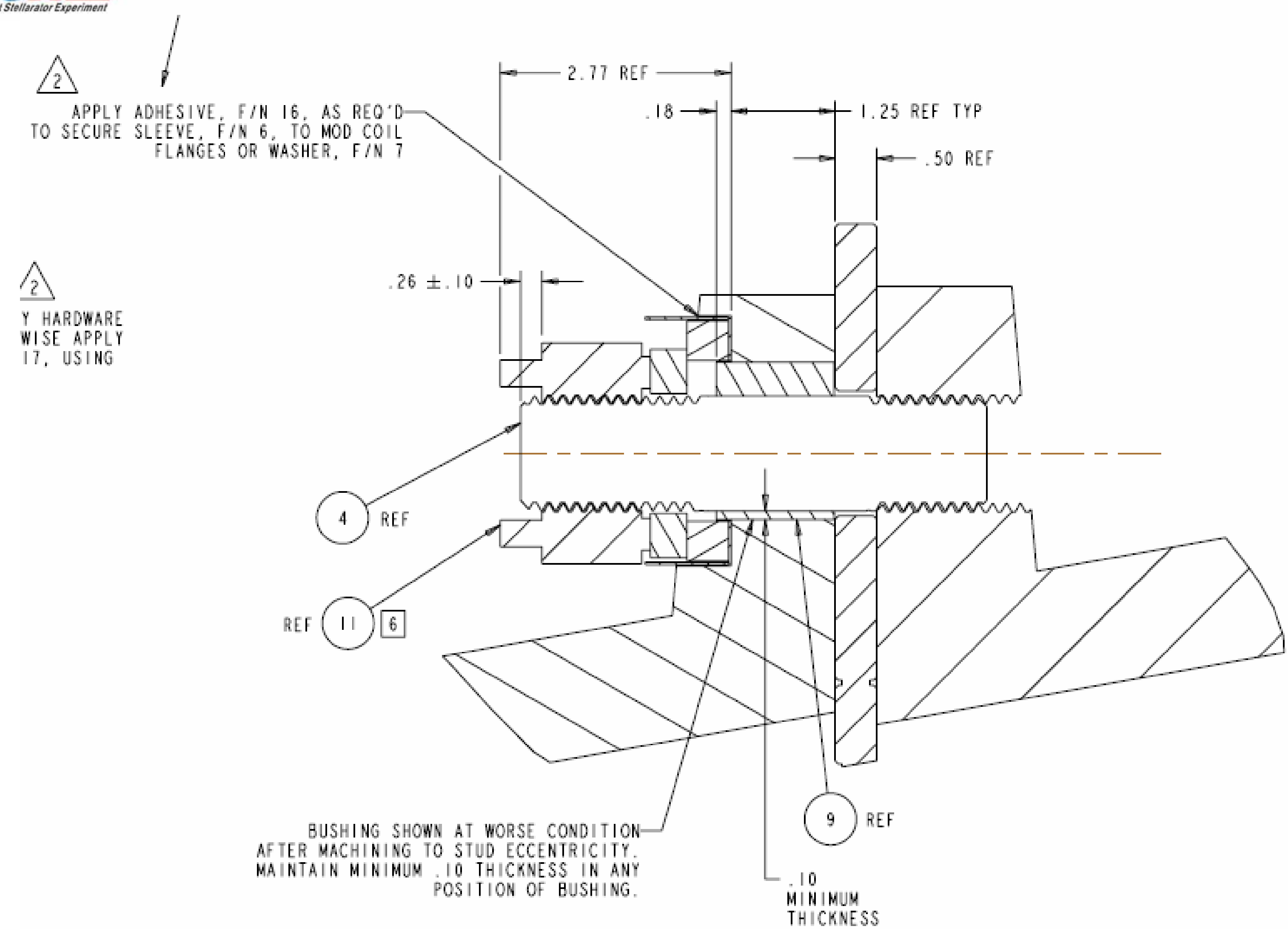


Bolted Joint Asm (SE140-190-R2)



THRU BOLT SECTION
SCALE 1.00

Bolted Joint Asm (SE140-190-R2)



TAPPED BOLT SECTION

SCALE 1.00

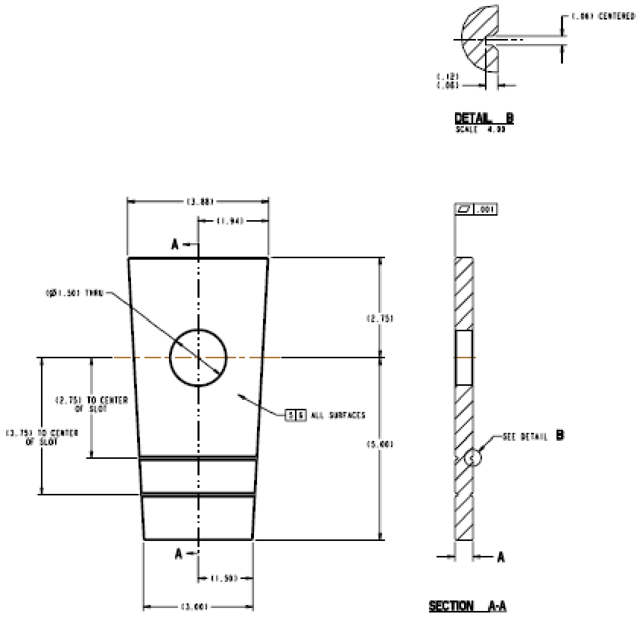
Shim (SE140-040-R0)

NCSX
National Compact Stellarator Experiment

NOTES

1. DRAWING PREPARED IN ACCORDANCE WITH ASME Y14.100-2004.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. DIMENSIONS ARE IN INCHES
4. MAGNETIC PERMEABILITY NOT TO EXCEED 1.02 AS TESTED BY A SEVERN INDICATOR. AVAILABLE FROM:
   SEVERN ENGINEERING
   AUBURN, ALABAMA 36830
   WWW.SEVERNENGINEERING.COM

   IF PERMEABILITY SPEC IS NOT ACHIEVED THEN SOLUTION ANNEAL PART PRIOR TO COATING.
5. ALUMINA COATING PER SPECIFICATION NCSX-CSPEC-142-06-00.
6. SURFACE FINISH AFTER COATING 150-500. SURFACE FINISH ON NON-COATED PART 125 OR LESS UNLESS OTHERWISE SPECIFIED BY COATING SUPPLIER.

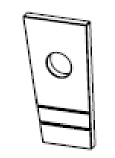


-1 SHINGLE HOLE SHIM
SCALE 1.00

NOTE: DIMENSIONS SHOWN ON THIS SHEET APPLY AFTER COATING
SEE SHEET 2 FOR NON-COATED PART

TOTAL 214

QTY REQ'D	DIM A FINISHED SIZE ALUMINA COATED THICKNESS PER SIDE .025 +.003 / -.002	FINISHED SIZE MIN	FINISHED SIZE MAX	THICKNESS OF SS ± .001	PART NO
1	.540	.535	.547	.490	-36
1	.538	.533	.545	.488	-35
1	.536	.531	.543	.486	-34
1	.534	.529	.541	.484	-33
2	.532	.527	.539	.482	-32
2	.530	.525	.537	.480	-31
3	.528	.523	.535	.478	-30
4	.526	.521	.533	.476	-29
5	.524	.519	.531	.474	-28
6	.522	.517	.529	.472	-27
7	.520	.515	.527	.470	-26
8	.518	.513	.525	.468	-25
9	.516	.511	.523	.466	-24
10	.514	.509	.521	.464	-23
10	.512	.507	.519	.462	-22
11	.510	.505	.517	.460	-21
12	.508	.503	.515	.458	-20
12	.506	.501	.513	.456	-19
12	.504	.499	.511	.454	-18
12	.502	.497	.509	.452	-17
11	.500	.495	.507	.450	-16
11	.498	.493	.505	.448	-15
10	.496	.491	.503	.446	-14
9	.494	.489	.501	.444	-13
8	.492	.487	.499	.442	-12
7	.490	.485	.497	.440	-11
6	.488	.483	.495	.438	-10
5	.486	.481	.493	.436	-9
4	.484	.479	.491	.434	-8
4	.482	.477	.489	.432	-7
3	.480	.475	.487	.430	-6
2	.478	.473	.485	.428	-5
2	.476	.471	.483	.426	-4
1	.474	.469	.481	.424	-3
1	.472	.467	.479	.422	-2
1	.470	.465	.477	.420	-1



ISOMETRIC VIEW
SCALE .50

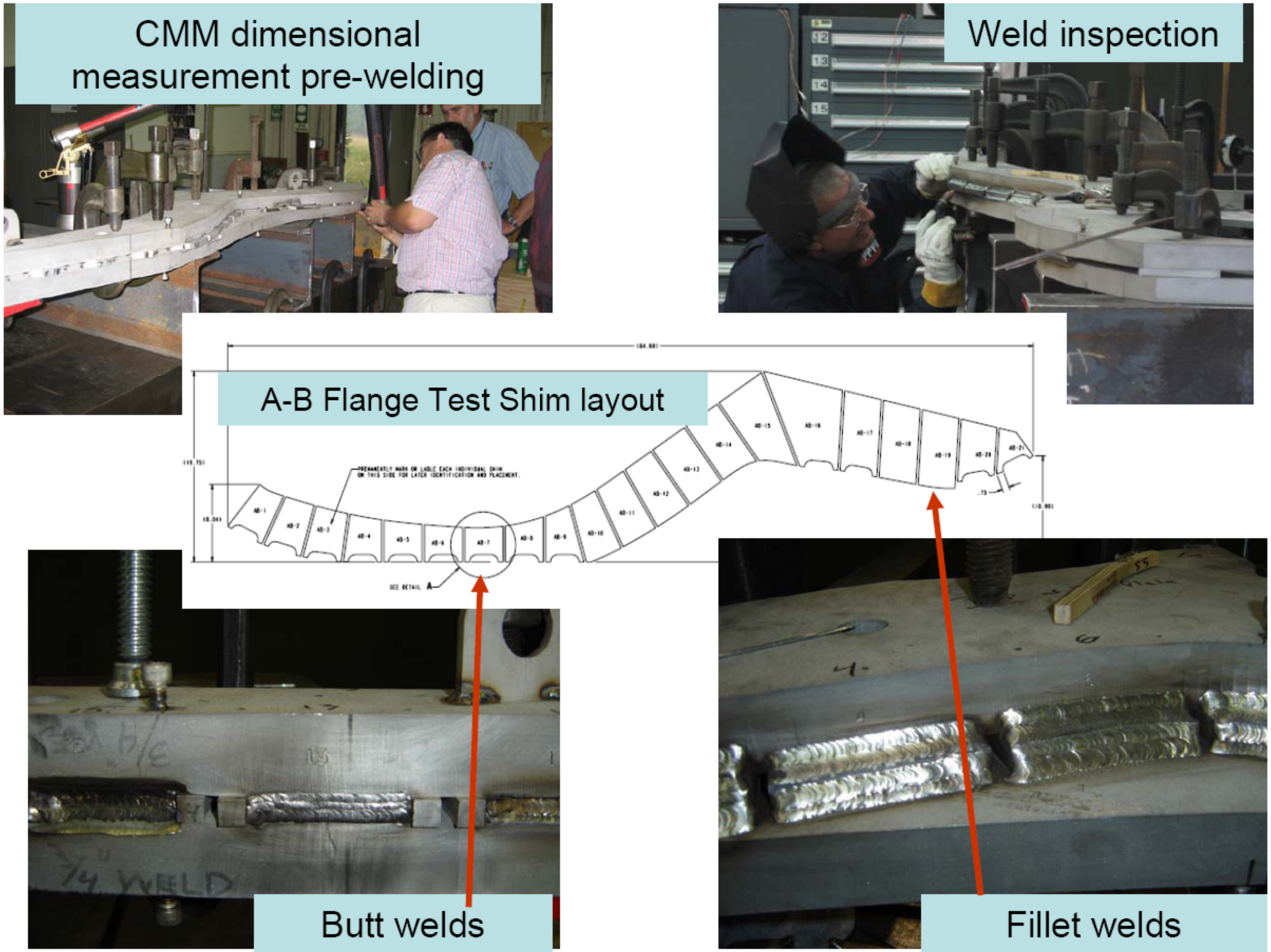
PART OR IDENTIFYING NO	SEE CHART	
NOMENCLATURE OR DESCRIPTION	SINGLE HOLE SHIM	
MATERIAL	316 SST 4 PLASMA ALUMINA COATED 5	
SPECIFICATION	ASTM A240	
FIND NO	1	

PARTS LIST

RELEASED FOR FABRICATION / INSTALLATION
Jerry Siegel

P THIS DRAWING PRODUCED ON PRO-ENGINEER

UT-BATTELLE
Oak Ridge National Laboratory
NATIONAL COMPACT STELLARATOR EXPERIMENT
SINGLE HOLE SHIM PLATE
SE140-040
0 ORIGINAL ISSUE


CMM dimensional measurement pre-welding
Weld inspection
A-B Flange Test Shim layout
Butt welds
Fillet welds

Weld Experience

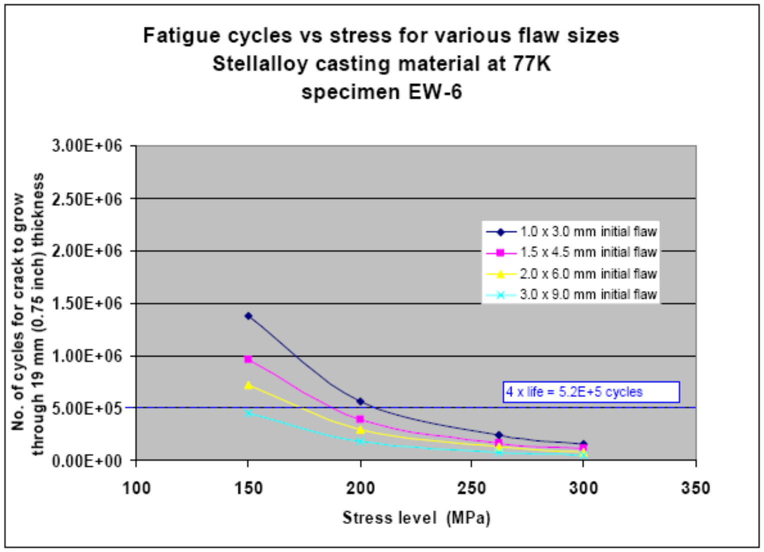
- Shims: re-configured 4 of them to get ½" legs on the welds.
  - Shim update is underway at ORNL.
  - Basically, no concerns – welding was straightforward.
  - Casting welds will all be horizontal except the A-A, which will be vertical.
  - Metal flow was good; like welding standard 308 or 316.
  - Should make a water jet cut aluminum template to simplify shim layout.
  - Chamfer grinding worked out well – will do it the same way in the future.

Weld Permeability Is Controlled

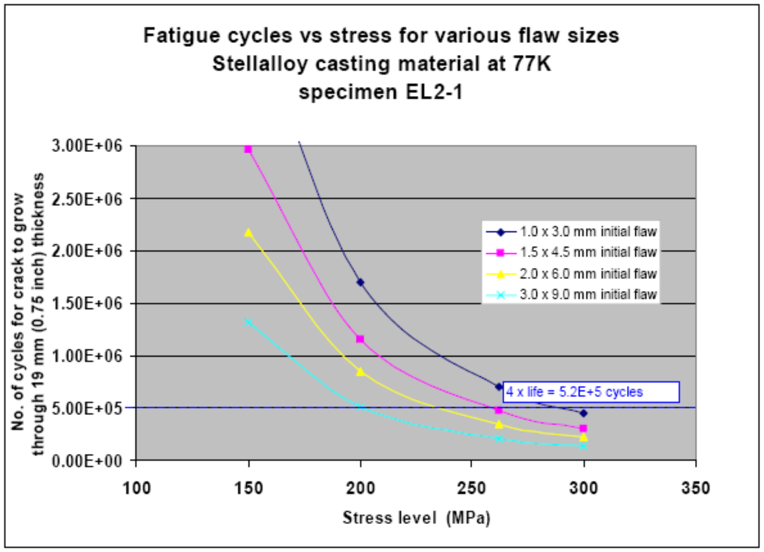
- Shims are made from 316 SS which, after all machining and grinding is completed, are solution annealed at 1150 C followed by rapid air cool to reduce magnetic permeability.

- Specified mu is 1.02; localized areas slightly higher can be accepted.
- Results from the weld tests are excellent:
  - 1.5" plate before welding: all below 1.02 Mu.
  - 1.5" plate after welding:all below 1.02 Mu.
  - 1/2" shims before welding: average of >1.02 Mu but <1.03 Mu with isolated readings of >1.03 Mu but <1.04 Mu.
  - 1/2" shims after welding: shims 2 & 3 rose slightly from >1.02 but <1.03 Mu to >1.03 but <1.04 Mu, shims 11 & 20 rose slightly from isolated spots of >1.03 but <1.04 Mu to isolated spots of >1.04 but <1.05 Mu, shim 18 rose from isolated spots of >1.03 but <1.04 to an isolated spot of >1.06 but <1.08 Mu.
  - Weld metal: all below 1.02 Mu.

Weld fatigue is satisfactory



Fatigue data for welds in Stellalloy



Fatigue data for Stelalloy

- As can be seen in the curve above, crack growth is faster in the welds (but OK!).
- Welds are being sized for 20 ksi, max. (138.4 MPa).
- Calculations indicate that an initial flaw size of 5 mm can be tolerated for 4 x life (520 K cycles) at this stress level.
- We expect to be able to avoid flaws of this size in these welds by using qualified welders and procedures.
  - We will determine the reasonableness of of expectation through NDT and macro photographs of welds from the flange mock-up weld tests.

Deflection monitoring during test

- Criteria: deformation should be <0.010" anywhere on winding surfaces.
- Deformations will be most pronounced on wing areas, so the "inboard" area wings will be monitored during the test. How:
  - Dial indicators for real time.
    - Will capture as many directions as possible. (Bob Parsells, lead)
    - Will get digital type so welders can see them.
    - Welders will "skip" around based on indications.
  - IF POSSIBLE monitor with laser tracker in survey mode, real time.
  - Initial: full CMM characterization of 1 side of the T on both castings.
  - Septum tooling ball measurements along inner legs, ~ 9 locations on each casting using laser tracker.
    - ~ 1-2 hrs. for a set of measurements.
    - Perform each morning before welding begins.
    - Will decide to peen or not based on distortion results. (we're hopeful it will not be necessary).
- No formal interpass weld inspection.
- Visual inspection at the end.
- Welder and procedure qualifications have been made for Stellalloy-316-Stellalloy.