Modular Coil Assembly Type-C

Final Design Review, Part III


June 30, 2005
Presentation Outline

- Specification of Type-C coil assembly – D. Williamson
- Lead blocks and winding sequence – P. Fogarty
- Drawing status and plans – D. Williamson
Charge Questions

• Is the design of the Type-C coil assembly complete?
• Are the specifications and drawings ready to be issued?
• Is the schedule for remaining documentation achievable and consistent with project need dates?
Earlier reviews focused on the models and drawings needed for procurement of cladding and lower lead blocks.

Chits addressed TRC experience, procurement strategy, managing the large number of parts needed for Type-C assembly.

Comments have been resolved and fabrication of first needed parts is underway.

### FDR Part I,II Results

<table>
<thead>
<tr>
<th>#</th>
<th>Chit/Audit Finding [Originator]</th>
<th>Review Board Recommendation</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Investigate ways of cleaning up drawing files. [Horner]</td>
<td>Concur</td>
<td>DXF/DWG output investigated, DXF appears best.</td>
</tr>
<tr>
<td>2</td>
<td>Consider process improvement for generating cladding/chill plate drawings for type A and type B. [Reiersen]</td>
<td>Concur</td>
<td>Process family table method studied and found to be best approach.</td>
</tr>
<tr>
<td>3</td>
<td>Expedite resolution of terminal block height issue. Determine how much TF structure can be relieved. Consider pre-bending prior to brazing replacing two 90° bends with one gentle bend. [Reiersen]</td>
<td>Concur</td>
<td>Terminal design has been improved, TF clearance increased to about 3/4-in.</td>
</tr>
<tr>
<td>4</td>
<td>Revised lead block design should be evaluated by Art Brooks for field errors. [Reiersen]</td>
<td>Concur</td>
<td>Calculation shows that field errors are acceptable.</td>
</tr>
<tr>
<td>5</td>
<td>Need to articulate procurement plan and incorporate into DMB for chill plates and cladding. Issues need resolution. [Reiersen]</td>
<td>Concur</td>
<td>Fab first set of cladding and chill plates at PPPL, procure remainder.</td>
</tr>
<tr>
<td>6</td>
<td>Fabricate the first set of each cladding and chill plates at PPPL. The remaining plates would be ordered with outside vendor. Various options should be evaluated. [Chranawski]</td>
<td>Concur</td>
<td>See above.</td>
</tr>
<tr>
<td>7</td>
<td>Check cladding/chill plate design by jacking just lot at PPPL before sending out for procurement. [Reiersen]</td>
<td>Concur</td>
<td>See above.</td>
</tr>
<tr>
<td>8</td>
<td>Identify side A and side B on the winding form when it comes through the door. [Nelson]</td>
<td>Concur</td>
<td>Included in MCWF Prep procedure, D-NCSX-MCF-001.</td>
</tr>
<tr>
<td>9</td>
<td>Add a number to the parts that correspond to the web hole numbering scheme. [Nelson]</td>
<td>Concur</td>
<td>Asm drawing correlates part and hole numbers.</td>
</tr>
</tbody>
</table>
This Review: Balance of Coil Asm

Type-C Asm se140-103

- Winding Form se141-103
  - MCWF se141-116
  - Pol Break se141-078
  - WF Prep se141-123
- Terminals se142c-050
  - Jumpers se142c-051
  - Lugs/Cable se142c-055
- Coil Asm-A se142c-251
  - Cladding se142c-382
  - Lead Blocks se142c-134
  - Chill Plates se142c-386
- Coil Asm-B se142c-241
  - Cladding se142c-482
  - Lead Blocks se142c-135
  - Chill Plates se142c-486
- Leads Encl se142c-270
- VPI Asm se140-103
- Clamp Asm se1405-275p
  - Clamp Bar se1405-276
  - Swivel Pads se1405-272

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FDR, Type-C Coil Assembly
Coil Assembly

Ref: se140-103

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FDR, Type-C Coil Assembly
Clamp Subassembly

- Function is to provide ~100-lb preload per pad to react thermal, EM loads
- Clamp bar dimensions = .75-in thk x 1.5-in depth, 5.22-in wide for TRC
- Type-C requires 44 clamp assemblies, ref: se1405-275p rev1 (TRC), rev2 pending
Clamp Asm Drawing

• 11 drawings, last issue 4/4/05
TRC Experience

- About 20 of 25 clamps fit ok, others were modified by chamfering edges or cutting off a leg to prevent interference with cooling tubes
- Stress analysis indicates max winding pack - tee gap = .006-in, max clamp stress = 10-ksi at bushing interface for altered clamp (Side-A pusher left off)
- Issues of coil lateral build, twist, and G11 pad thickness and fit suggest increasing width of Type-C clamp by .25-in
VPI Mold Assembly

- Function is to provide vacuum-pressure boundary over ~30-ft² surface area
- Composed of self-fusing silicone tape, chopped glass and Hysol resin/hardener
- Sealing groove is same as TRC, continuous on both sides for Type-C
- Bill of material callout on se140-103

Twisted Racetrack Bag Mold
Leads Enclosure

- G-11CR plates tie winding packs together in ~8 x 10 x 12-in enclosure
- Pre-fit features ensure proper alignment of starting lead blocks
- Top plate requires some contour machining
Leads Enclosure Top Plate
Leads Enclosure Side Plate

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FDR, Type-C Coil Assembly
Chill Plates Subassembly

- 384+ chill plate parts per winding pack, average dimensions 1.5 x 4 x 4-in
Chill Plate Drawings

- About 76 flat pattern drawings per winding pack, no format, DXF and PDF output
Chill Plates Asm Drawing

- Flat pattern layout drawing correlates part number with hole number
- Useful for QA check of parts before installation
Type-C chill plates incorporate TRC input:
- Increase part spacing to .125-in, tab gap = .060-in
- Reduce number of slits, make min tab width > .2-in
- Increase tab length, trim at assembly
- Number parts according to hole position
- Replace cladding with strips in tight bends (test)
- Reduce radius of clamp cutout
- Modify staking tools and procedure

New issues involve:
- Poloidal break
- Routing of cooling tubes
Leads Terminal Subassembly

- Revised design addresses issues of installation, clearance, and field errors
• 18 drawings, models checked
Flux Loop Termination Concept

- Flux loop locations
- Pomona-C Box (1.7x2.6x4.3-in)
- Mineral insulated wire w/ shrink tubing .044-dia
- Flux loops
- Section thru lead blocks
Winding Form Prep

- Winding form prep includes hole numbering, installation of winding clamp studs
- Drawing se141-123 ready after checking changes are made

Ref: se141-123
Winding Clamp Studs
Clamp Stud Adapter

- Adapter, 1.25-in dia x 2 lg required in cutaway region
- Approximates MCWF surface with flat cut
Go to Paul Fogarty’s slides
• Type-C drawing package includes 362+ drawings, of which 176 have been released for fabrication

• Status of remaining drawings:
  – Top level asm and layouts
    • Major cleanup in progress, schematics not started, issue all by Jul-27
  – Winding form assembly
    • Making checking changes to stud drawing, issue by Jul-11
  – Side-A winding pack assembly (incl lead blocks)
    • Approx 78 chill plate drawings in progress, check and issue by Jul-20
    • Issue upper lead block, misc G11 parts by Jul-13
  – Side-B winding pack assembly (incl lead blocks)
    • Approx 78 chill plate drawings in progress, check and issue by Jul-20
    • Issue upper lead block, misc G11 parts by Jul-13
  – Leads terminal assembly
    • Model check complete, drw check in progress, issue by Jul-15
    • If schedule problems, use STL mockup to start C1 winding
  – Lead blocks enclosure
    • Model check complete, drw check in progress, issue by Jul-13
    • If schedule problems, use STL mockup to do C1 pre-fit
  – Clamp assembly
    • Rev to clamp bar complete, check and issue by Jul-15
Conclusion

• Is the design of the Type-C coil assembly complete?
  – All components have been modeled, incorporating design requirements and TRC recommendations
  – Some work remains to complete lead area chill plates, cooling tube routing at poloidal break, and flux loop wire termination

• Are the specifications and drawings ready to be issued?
  – Assembly specification has been issued for comment
  – Remaining lead blocks have been detailed and checked, chill plates are being checked in parallel with drawing preparation
  – Clamp drawing revision is complete

• Is the schedule for remaining documentation achievable and consistent with project need dates?
  – First priority given to long lead outside procurement: lead blocks, terminal parts, clamps
  – Second priority to water-jet cutting: chill plates for C1, then shift to outside procurement
Backup Slides
Comparison of Twisted Racetrack analysis to Global NCSX Modular Coil analyses

Non-linear Modular Coil analyses [2T high Beta loading applied.]

<table>
<thead>
<tr>
<th>Coil</th>
<th>Winding Stress (ksi)</th>
<th>Shell/Tee Stress (ksi)</th>
<th>Max Principal Strain (in/in)</th>
<th>Gap [Lateral] (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanica A</td>
<td>10.5</td>
<td>24.7</td>
<td>0.0011</td>
<td>0.0889</td>
</tr>
<tr>
<td>Mechanica B</td>
<td>11.5</td>
<td>39.0</td>
<td>0.00012</td>
<td>0.5842</td>
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<tr>
<td>Mechanica C</td>
<td>12.9</td>
<td>32.0</td>
<td>0.0015</td>
<td>0.8128</td>
</tr>
<tr>
<td>Ansys A</td>
<td>11.5</td>
<td>33.5</td>
<td>0.0013</td>
<td>0.2</td>
</tr>
<tr>
<td>Ansys B</td>
<td>9.6</td>
<td>36.1</td>
<td>0.001</td>
<td>0.5</td>
</tr>
<tr>
<td>Ansys C</td>
<td>11.0</td>
<td>32.9</td>
<td>0.0012</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Ranges for expected max stress/strain on the TRC tee and windings

<table>
<thead>
<tr>
<th>Twisted Racetrack Summary</th>
<th>Current (kAmps)</th>
<th>Estimated range for max stress in tee (ksi)</th>
<th>Estimated range for max stress in winding (ksi)</th>
<th>Estimated range for max strain in winding (in/in)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>42</td>
<td>43</td>
<td>18</td>
<td>3.0E-03</td>
</tr>
<tr>
<td>Linear</td>
<td>31.5</td>
<td>24</td>
<td>10</td>
<td>1.7E-03</td>
</tr>
<tr>
<td>non-linear</td>
<td>42</td>
<td>71</td>
<td>13</td>
<td>3.0E-03</td>
</tr>
<tr>
<td>non-linear</td>
<td>31.5</td>
<td>40</td>
<td>8</td>
<td>1.8E-03</td>
</tr>
</tbody>
</table>

Twisted Racetrack Non-linear Coil Analysis (magnetic pressure and thermal stress) [$E_{\text{Winding}} = 9 \text{ E6 psi}$ $E_{\text{Shell}} = 23 \text{ E6 psi}$]
Property Comparison on the Twisted Racetrack Analysis

The latest test data suggests that the assumed modulus values used in the analysis for the tee and winding were slightly higher than needed.

<table>
<thead>
<tr>
<th>Twisted Racetrack Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis Type</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>non-linear</td>
</tr>
<tr>
<td>non-linear</td>
</tr>
<tr>
<td>(new Mat. Props.)</td>
</tr>
</tbody>
</table>

The difference in property values has little effect on the Twisted Racetrack Analysis and thus the lower modulus is not expected to impact the Global NCSX Modular Coil Analysis.
Winding Pack Thermal Analysis

- Temperature dependent heat generation (see next slide)
- Crimp conductivity set to 100 W/m-K
- Groundwrap overlap is reduced from 2X to 1.3X.
- Copper thickness is 0.04 in.
- Pulse shot is still 2T, high beta, 10,390 Amps/cable.
- Cool down time is still 15 minutes.

K. Freudenberg
First Cycle

Immediately after pulse

T = 15 minutes (after cool down)
Ten Cycles

Temperature (K)

Time (sec)
Temperatures during the 10th shot

Temperature after the 10th shot

Temperature after the 10th cool down
After 10th cycle (winding and tee isolated)