

Modular Coil Winding Form Procurement Status



Type C CAD Model



Photo of C1

P Heitzenroeder for the NCSX Project

The First Year of Production Has Been Good

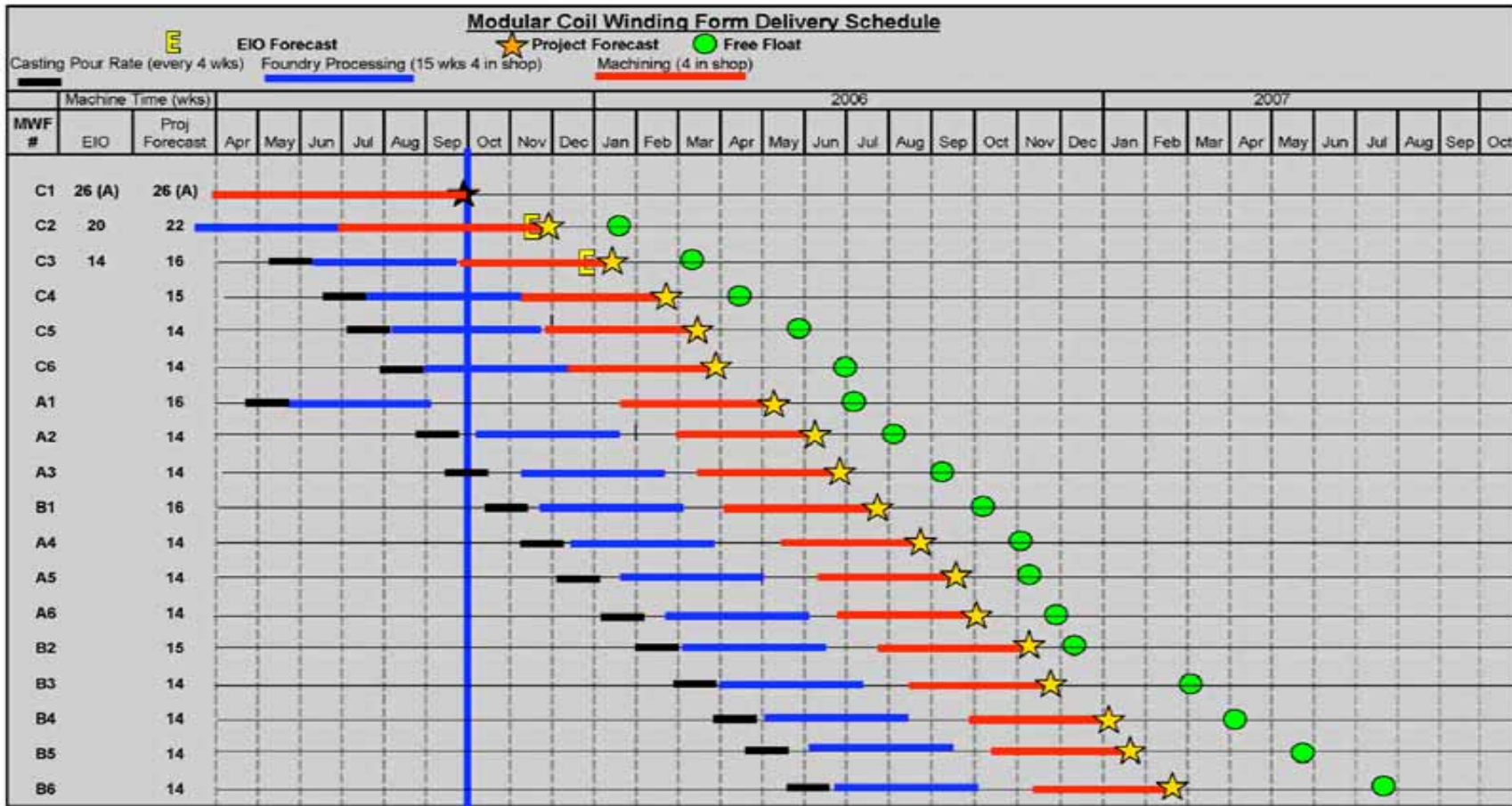


- Most importantly, acceptable quality and performance requirements are being achieved for these key complex parts.
- Issues from the last review were, for the most part, resolved:
 - The team has successfully overcome a number of “start up” challenges:
 - Volatile metal pricing
 - Technical challenges (complex patterns; unexpected solidification & machining simulation results; challenges in meeting requirements, developing cutters, CAM programs, etc.)
 - There has been a lot of progress.
 - **Patterns:** All three patterns have been completed.
 - **Foundry:** Nine castings have been produced to date.
 - **Machining:** Fixtures, tooling, and programming techniques applicable to all 3 casting types have been completed. One casting delivered, others will follow soon.
- A great deal of risk has been retired during this period.
- The most important remaining risk is schedule, but current projections indicate that this is manageable.

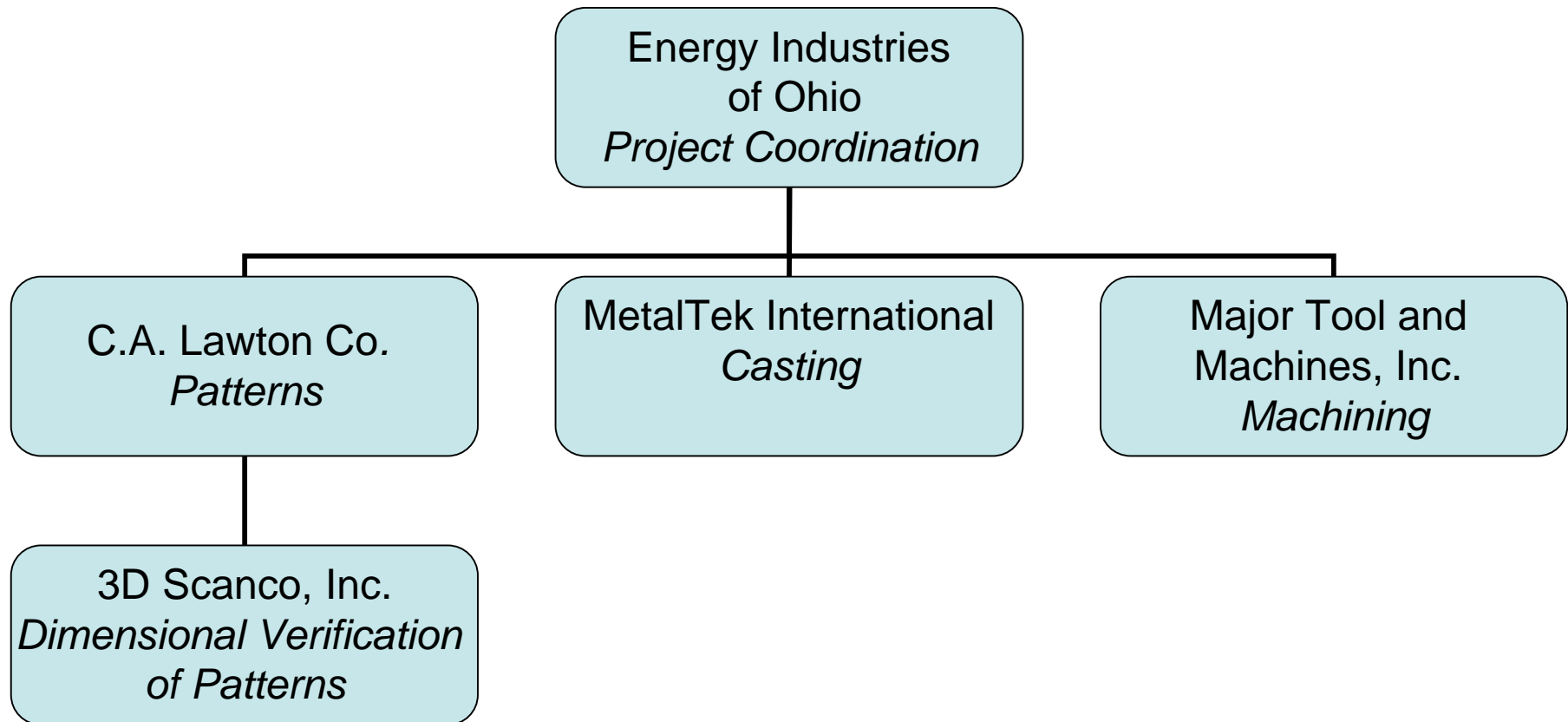
Our Projected Dates for Winding Form Deliveries Are Compatible with the Project Schedule



- Production durations are based on discussions with EIO, but are more conservative.



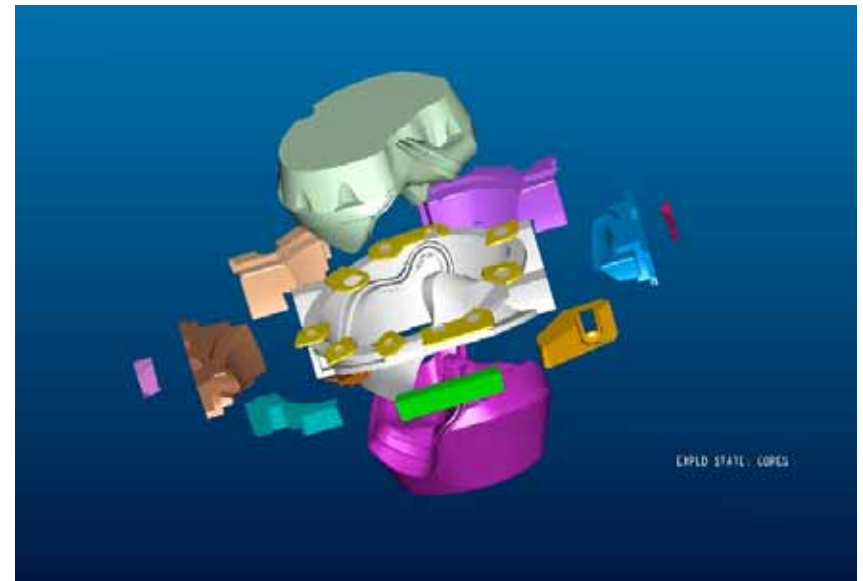
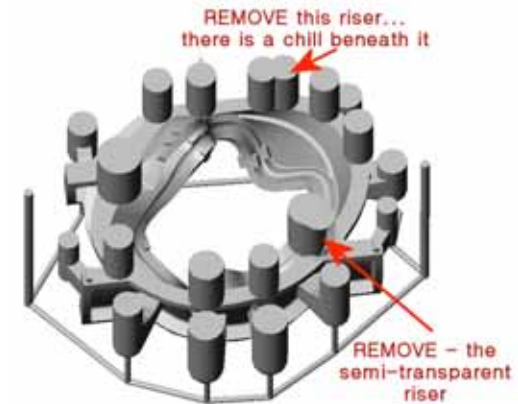
The Modular Coil Winding Form Production Team



Pattern Scope Nearing Completion



- All three patterns have been fabricated.
- Pattern designs were guided by advanced flow solidification analyses
- Design details coordinated with foundry.
- Contour milled from mahogany.
- Lawton's obligations will be complete (and risks in this area retired) as soon as the Type B pattern is verified later this month.



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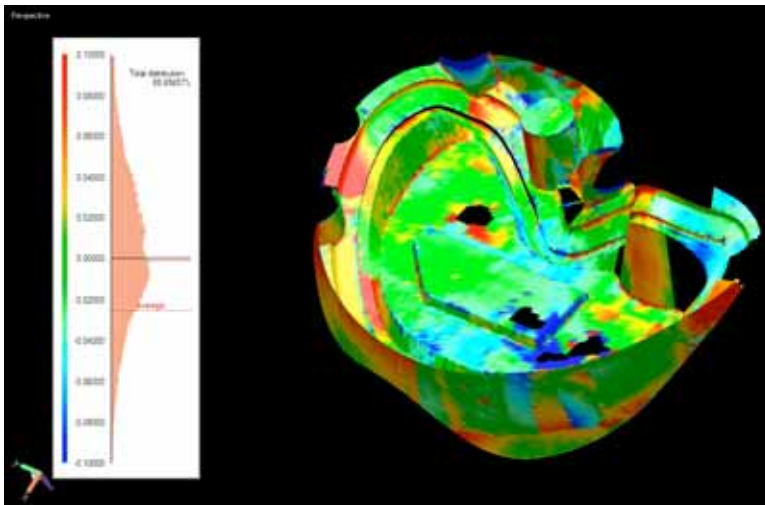
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5

The Risk of Pattern Errors is Mitigated by Dimensional Verifications



- 3-D Scanco uses a photogrammetry/ laser scanning process to verify the accuracy of the patterns and first casting.
- The digitized data is compared with the CAD model in a color contour plot.



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MCWF Casting Process Is Well Established



- Pre-cast billets of argon oxygen decarburized (AOD) refined “Stellalloy” are melted in 5 induction furnaces.
- Real-time analyses are performed to verify chemistry; elemental adjustments are performed as required.
- Typically, 22,000 lbs. of “Stellalloy” is poured in 1 ½ minutes through three inlets in the mold.



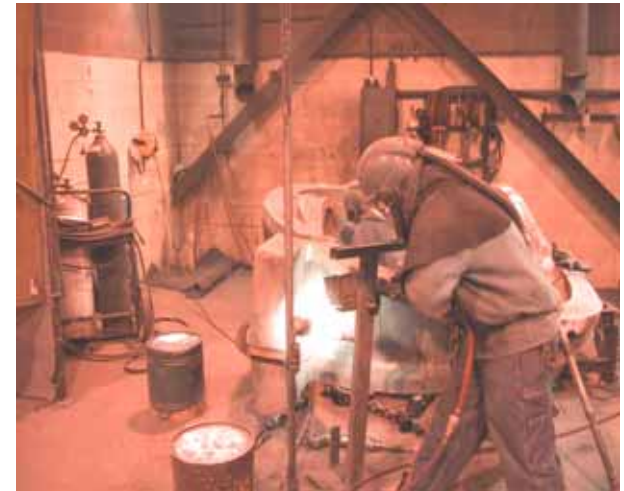
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Foundry Operations are Going Well – 9 of 18 Castings Have Been Poured



- 100% (6) of Type C poured.
- 50% (3) of Type A poured.
- The mold is being assembled for the first Type B.



- *All material has been procured to mitigate the risk of fluctuating prices and material availability.*



As-Cast Properties Exceed Specifications and Are Consistent

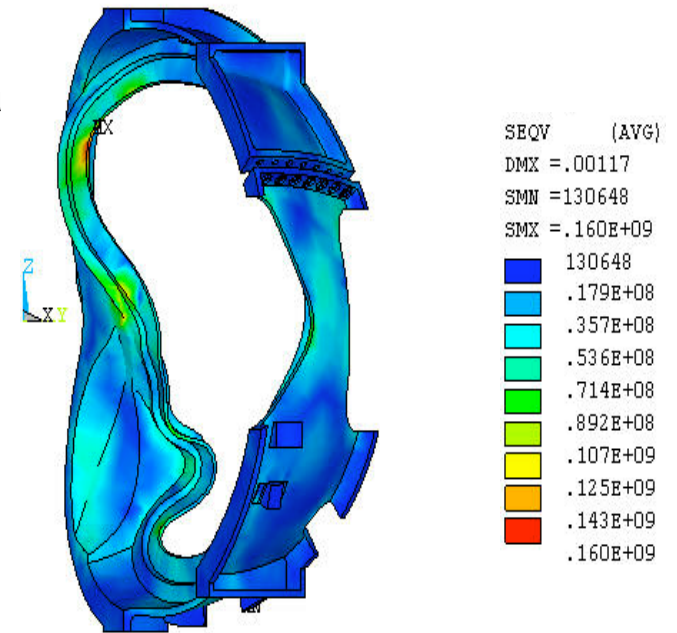
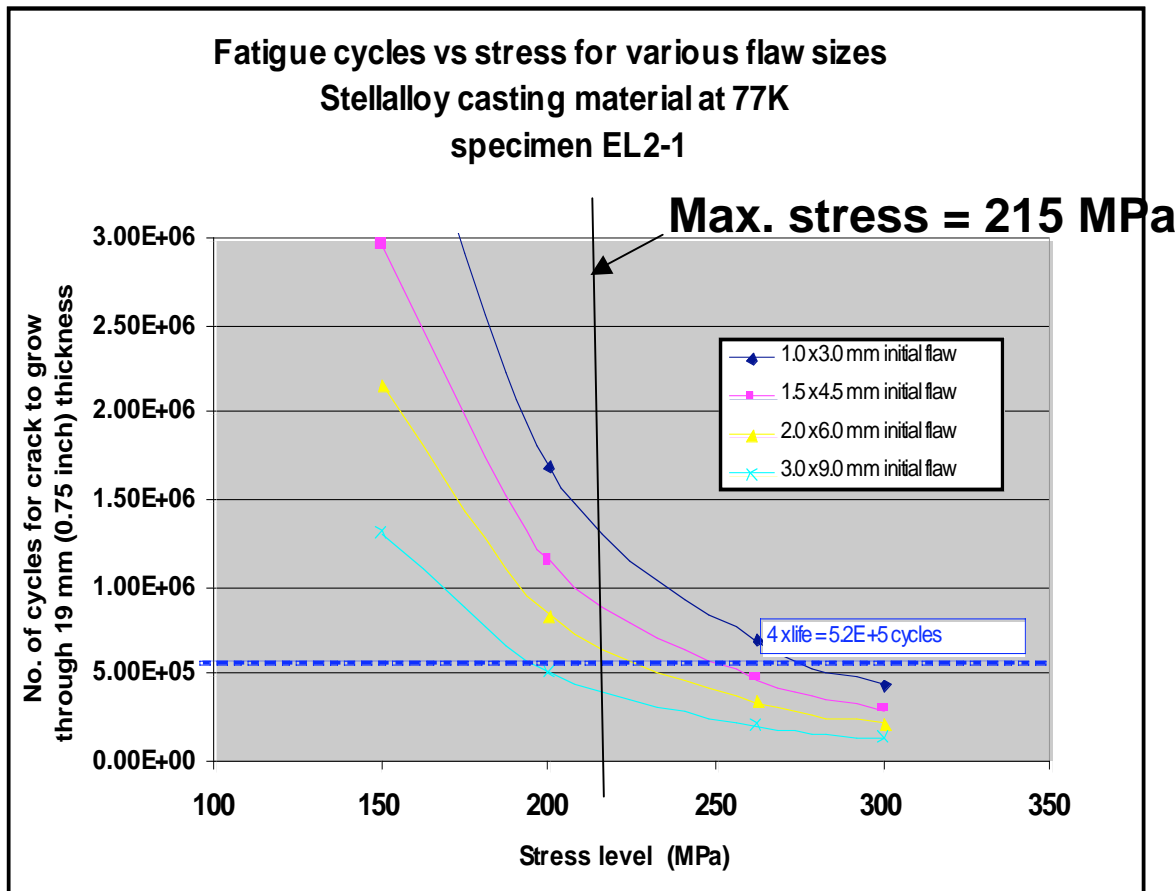


Winding Form Average Properties

At 77 K	Specification	C1	C2	C3	A-1
Elastic Modulus	144.8 Gpa	160.9	176.1	171.9	175.8
0.2% Yield Strength	496.4 Mpa	678.5	642.6	669.5	670.9
Tensile Strength	655 Mpa	1174.0	1129.6	1124.8	1146.6
Elongation	32.0%	55.7%	54.3%	55.7%	56.0%
Charpy V – notch Energy	47.4 J	104.9	113.9	134.6	106.2

At 293 K	Specification	C1	C2	C3	A1
Elastic Modulus	137.9 Gpa	159.5	156.3	148.9	149.4
0.2% Yield Strength	234.4 Mpa	241.9	252.1	263.8	252.6
Tensile Strength	537.8 Mpa	576.9	568.4	570.2	567.9
Elongation	36.0%	52.0%	53.5%	52.5%	53.2%
Charpy V – notch Energy	67.8 J	191.7	203.4	212.4	221.0

Fracture Properties Have Been Developed & Are Good!



Stress in the Type A Castings

Note that the regions where stress is >100 MPa is small.

Shipments of Castings from MetalTek to Major Tools Are Proceeding Well



- C1, C2, C3, and A1 have already been shipped to Major Tool.
- C4, C5, and C6 are all in various stages of upgrading; at least two are expected to be delivered to Major Tool in November.
- A2 (and possibly A3) will be shipped to Major Tool by year's end.
- The remaining castings are expected to be shipped at an average rate of one every 3-4 weeks.

Winding Forms Are Arriving at PPPL



- The first **machined winding form (C1)** was received at PPPL on October 3.
- Others will follow shortly.
 - C2 is ~80% machined and is expected at PPPL by 11/14.
 - C3 is ~20% machined and is expected at PPPL by the end of the year.



The machining tooling is 100% complete.



Three angle fixtures permit simultaneous machining of three castings.

Special machining cutters have been developed for Stellite and the casting geometry.



CAM Programming Methods & Machining Procedures Applicable To All Developed



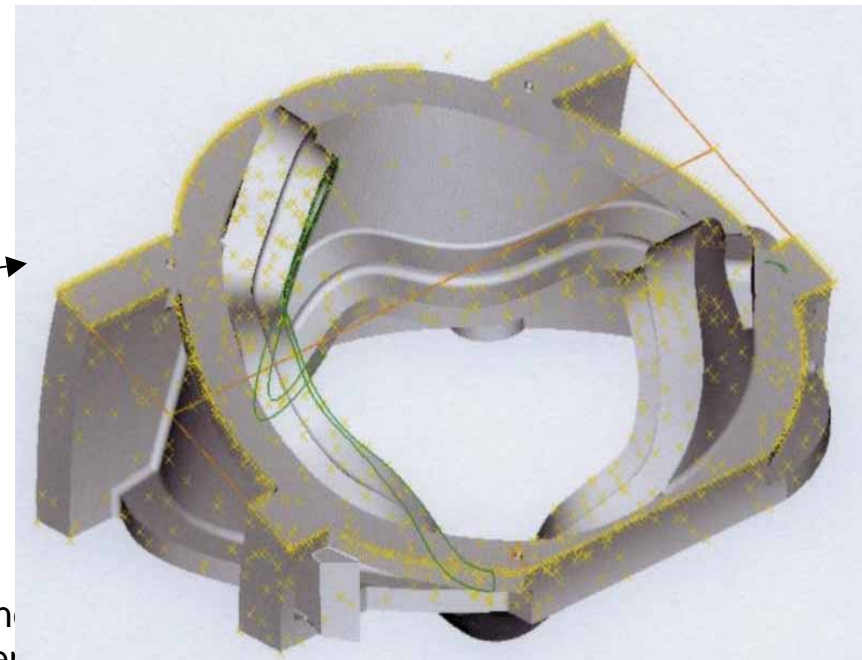
- Initial machining operations performed on 3 axis milling machines.
- The complex geometry of the winding surfaces are finish machined on a 5 axis milling machine.
- Following the 5 axis milling, the poloidal break is completed and machined surfaces are polished as required.



Final Dimensional Inspection Techniques Have Been Established



- **Coordinate Measuring Machine (CMM) data used to create “point cloud” scaled 3D representation of data.**
 - 4" x 4" grid pattern on cast surfaces;
 - 2" x 2" grid on machined surfaces.
- **Point cloud data is overlaid on NCSX's model and analyzed**



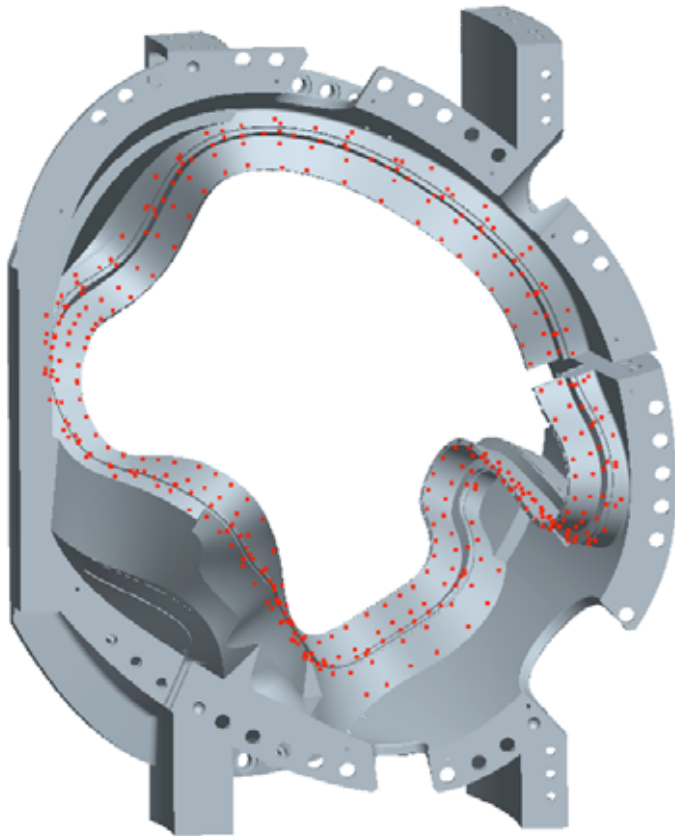
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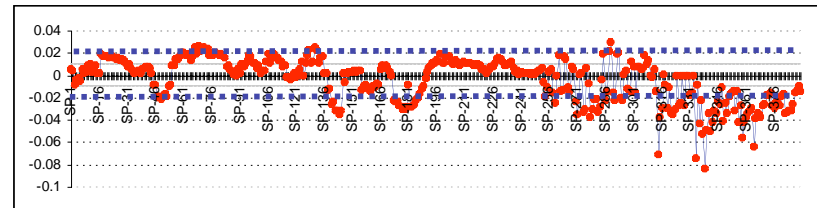
Dimensional Accuracy of C1 is Acceptable



D-SIDE T-RIB CONTOUR



0.02" Profile Tolerance



Points out of tolerance will be compensated for during winding.

We Are Minimizing Contract Changes



- Original contract price \$8,013,502.
- NCSX-initiated changes has been kept to a minimum (projected cost change ~2-3%):
 - Stress relieving added at NCSX's request (to assure dimensional stability and to assure more uniform properties) + \$33,363.00
 - Some winding form details (number & size of coolant holes; poloidal break hardware; tolerances in some areas) were revised based on analysis of C1. Cost estimate underway by EIO.
 - Changes will reduce winding form prep time at PPPL and avoid assembly problems.
- Remaining cost increase risks:
 - Type A and B not yet through incoming inspection / analysis, and may require some revisions similar to Type C.

Bottom Line: We expect to stay within a few % of the original contract price.



- MCWF subcontract managed by PPPL's most experienced subcontract administrator, Larry Sutton.
- Correspondence (both from PPPL and from EIO) is through Larry Sutton.
- He participates in virtually all conference calls and many field visits.
- EIO provides weekly e-mail project reports and monthly Projected Delivery Schedule reports.

Quality Assurance



- QA for the MCWF subcontract are coordinated by PPPL Quality Engineer Frank Malinowski who has much QA experience from the Nuclear industry.
- Manufacturing / Inspection / QA (MIT/QA) Plans are the key interface between PPPL and the EIO team members.
- Field inspections are performed mostly by DCMA field inspectors supplemented by periodic inspections by NCSX personnel.
- Weld and materials consultants provide expertise in these areas.
- Weekly Quality conference calls are held to discuss and clarify current QA issues.
 - Notes are issued prior to the call and action items assigned as a result of the call.
- Documentation packages for each winding form are reviewed as they are developed.

Conclusion: There have been delays with the early winding forms, but otherwise this contract is proceeding very well!



- A good working relationship has been established between EIO and NCSX.
- Much risk has been retired:
 - As soon as the Type B pattern is verified, all risks associated with the patterns will be behind us.
 - Since the alloy has been purchased, cost and availability risks associated with it have been retired.
 - The foundry processes have all been well established.
 - The machining fixtures and cutting tools are complete. CAM programming for Type C complete; techniques are transferrable to Type B and A.
 - Dimensional verification methods have been established.
- Schedule is the most significant remaining risk, and good progress has been made.
 - Our schedule projections indicate that it is consistent with the Project schedule.