OAK RIDGE National Laboratory

Moderator Reflector Assembly R&D

Jim Janney
MRA Lead Engineer

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U.S. DEPARTMENT OF ENERGY

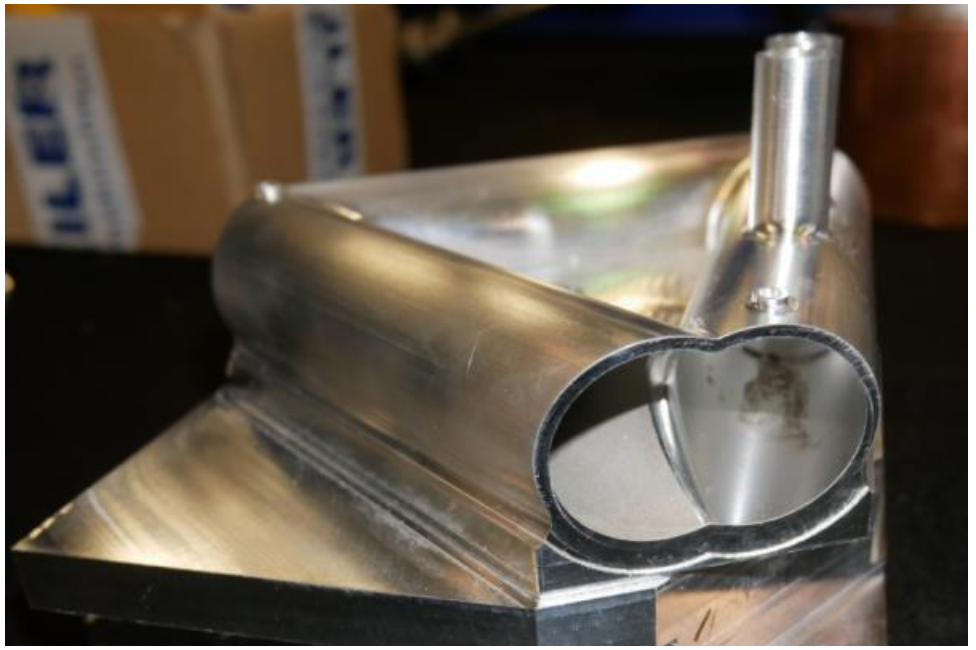
MRA Prototyping Purpose

- Prove manufacturing process
- Improve design for manufacturing
- Learn from moderator fabrication experts (Julich)
- Learn from trying manage building a moderator ourselves using domestic suppliers
- Determine if predicted tolerances are achievable

Tube moderator photos provided by Yannick Bessler of Julich

Moderator Machining

- Tested strategy to push for difficult machining to reduce number and difficulty of welds
- Machining operations were largely successful – machining aluminum is quick and relatively easy compared to welding it



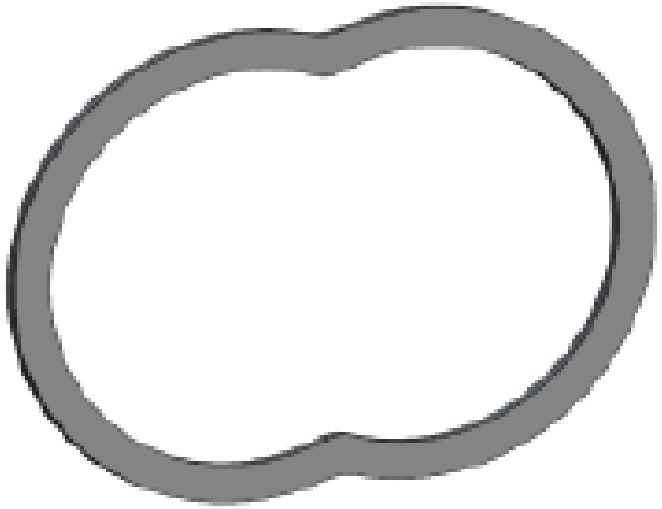
Moderator Welding Overview

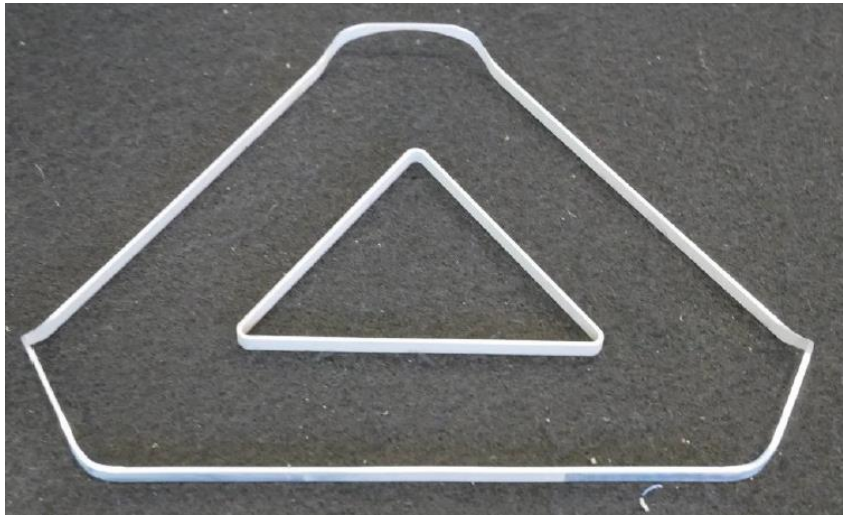
- Electron beam welding for reduced deformation and repeatability
- Moderator material is Al 6061-T6
  - Al 4047 shim stock used for filler
- Moderator parts and shims cut to close fit up tolerance
  - Gaps less than 0.1 mm
- All parts pickled and then nitrogen bagged to prepare for welding
- Bags opened immediately prior to welding

Photos provided by Yannick Bessler of Julich

Weld Filler Metal

- Julich preferred filler metal thickness of 1 mm vs. 0.25 mm at PTR
- Filler was cut with micro-waterjet for hydrogen vessel or milling for vacuum vessel (very difficult)
- Vacuum vessel filler was machined from 12.5 mm thick stock
  - Sourcing thick stock was challenging
- Vacuum vessel shim fit up was very challenging and the first shim was scrapped after it bent upon initial assembly attempt





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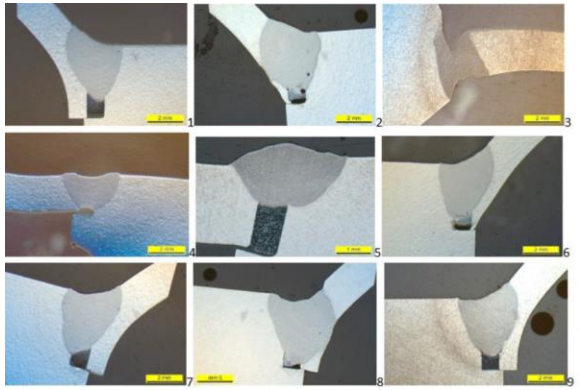
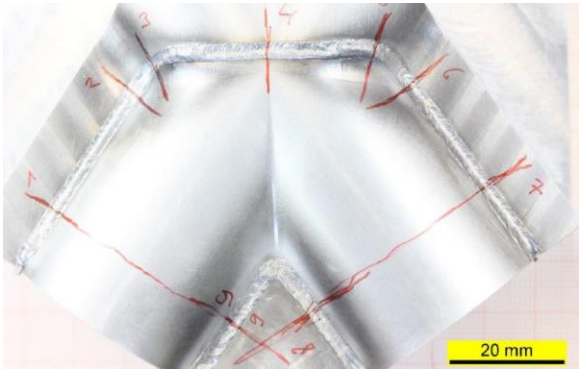
Weld Parameter Development

- Samples of progressing complexity and similarity to final geometry were welded
- Samples sectioned and polished to determine required changes
- Final weld programs based on lots of geometric samples!





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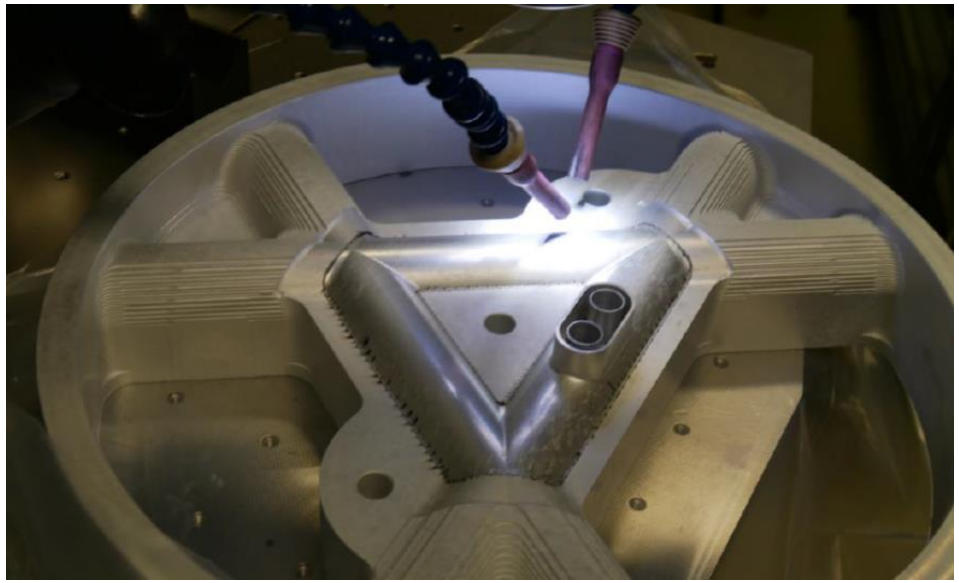
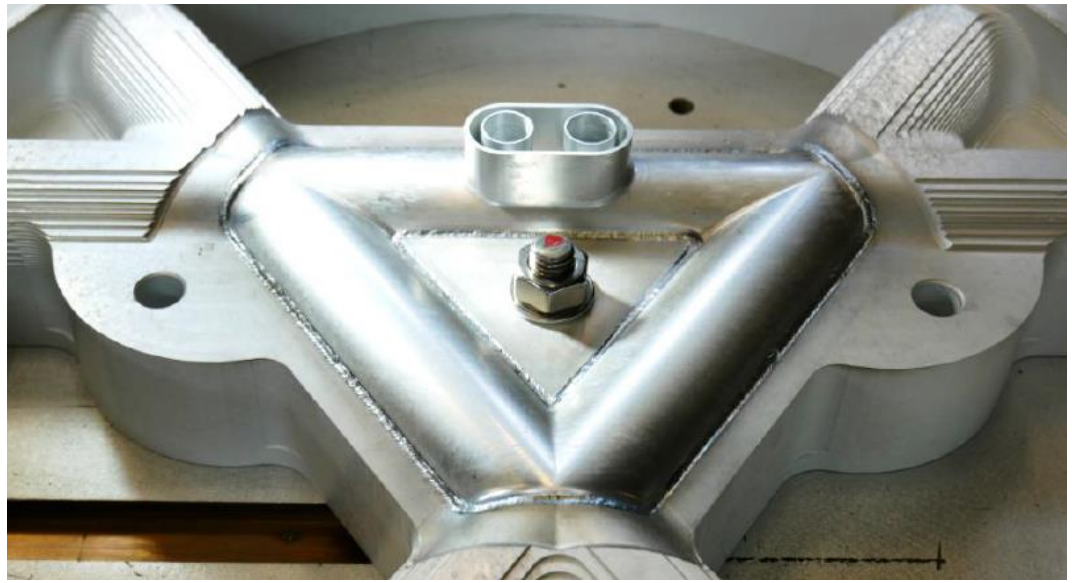
Final Welding

- Custom fixtures created for welding
- Parts removed from bags just before welding
- Laser tacking of parts
- Full power final pass





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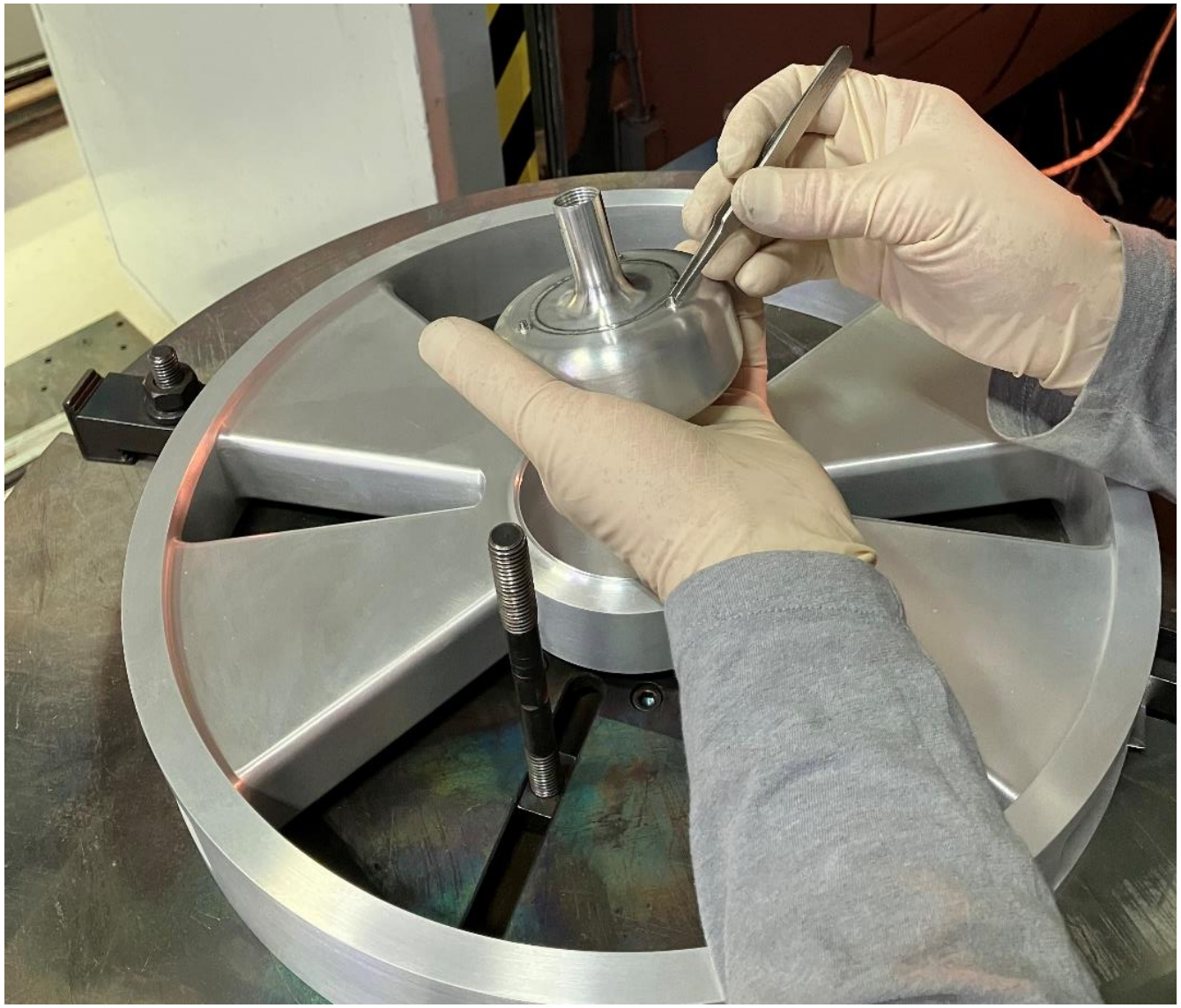
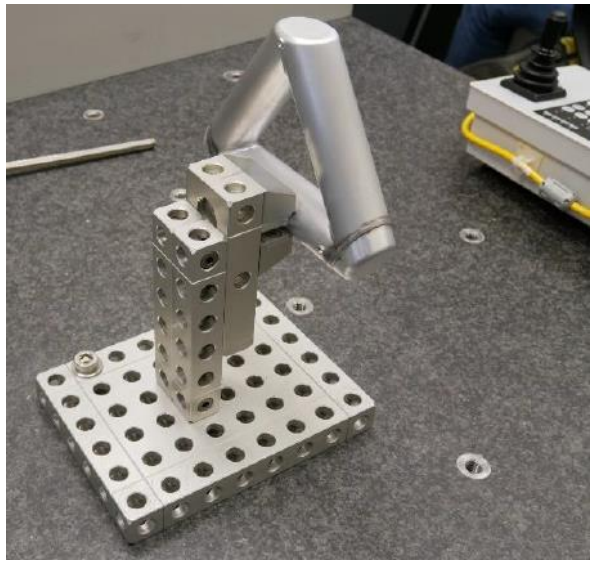
Tedious Vacuum Spacer Assembly

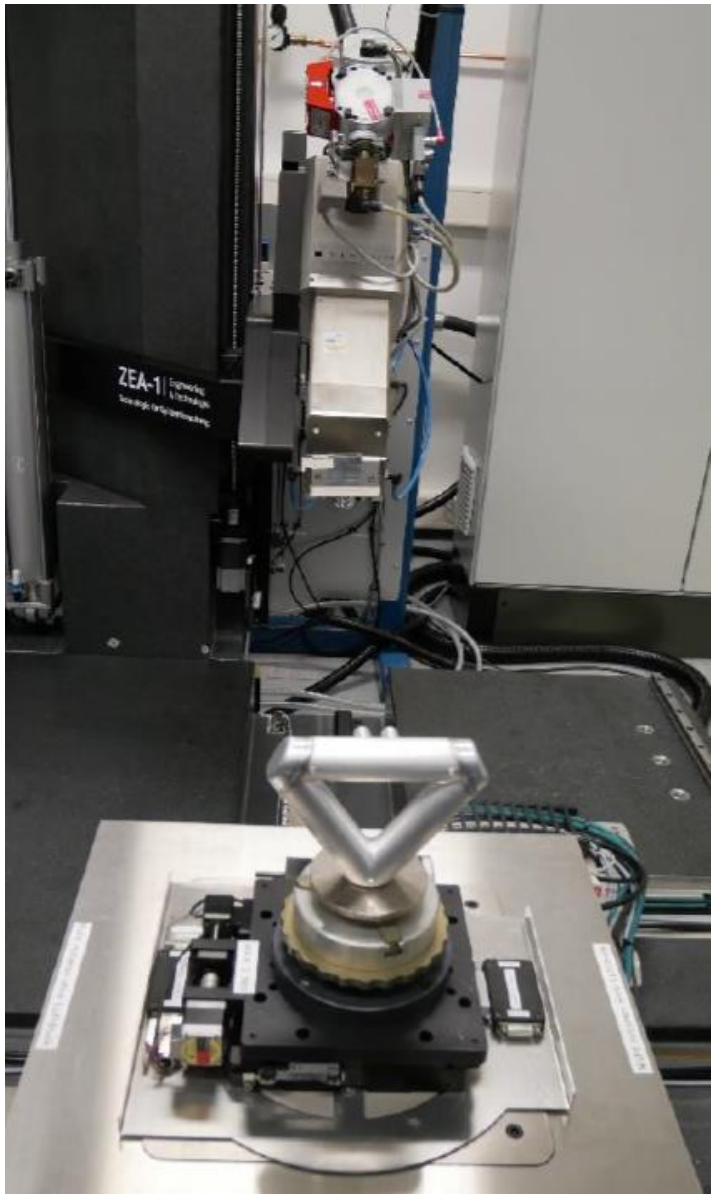


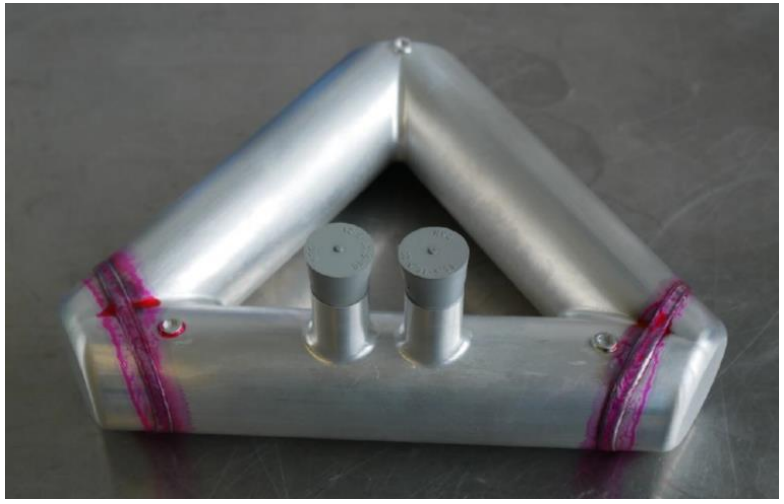
LN2 Cold Shocking to Mimic Cool Down Cycles

Post Weld Inspection

- CMM measurement to evaluate weld distortion
- PT for surface defects
- CT for internal defects
- Helium leak checking

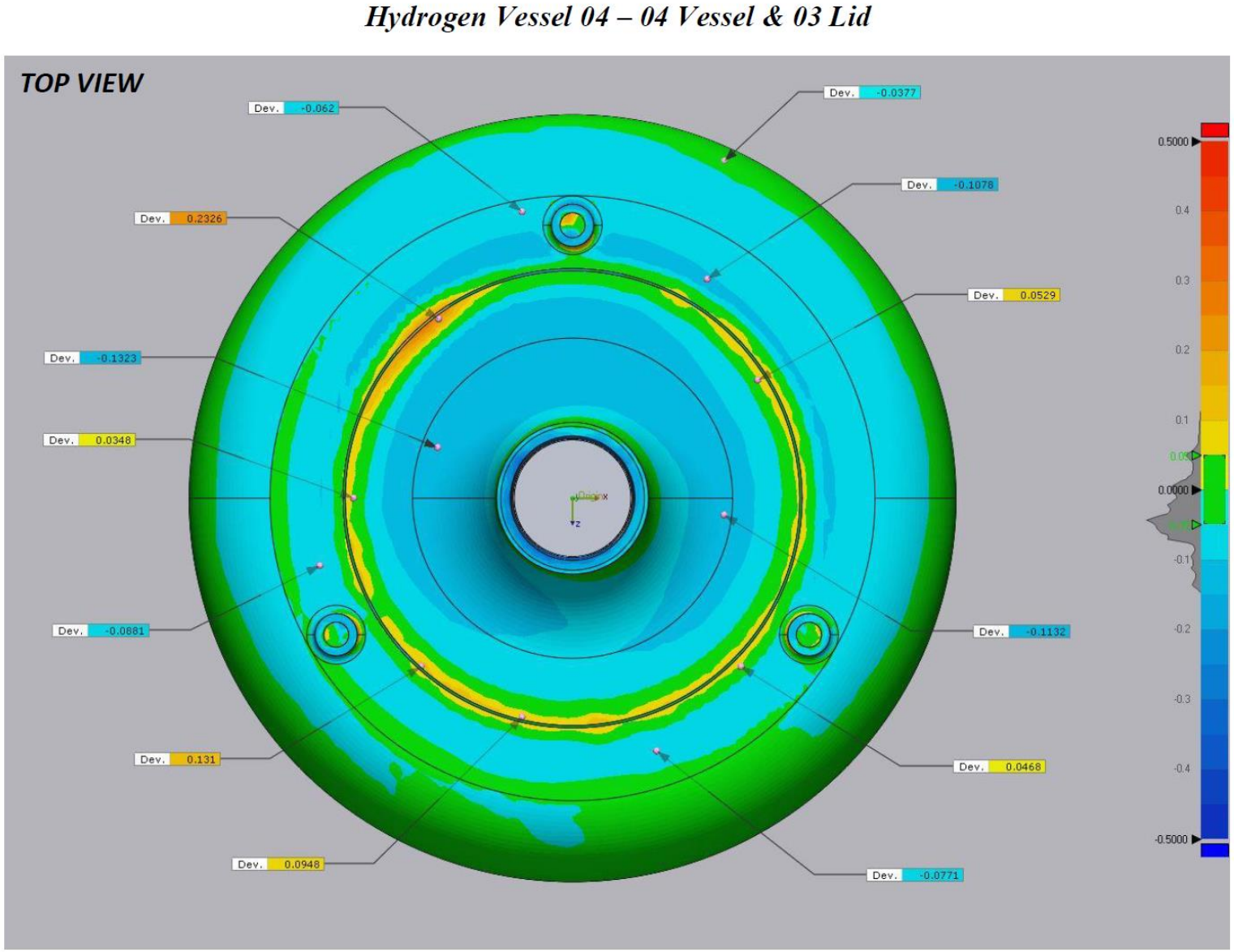






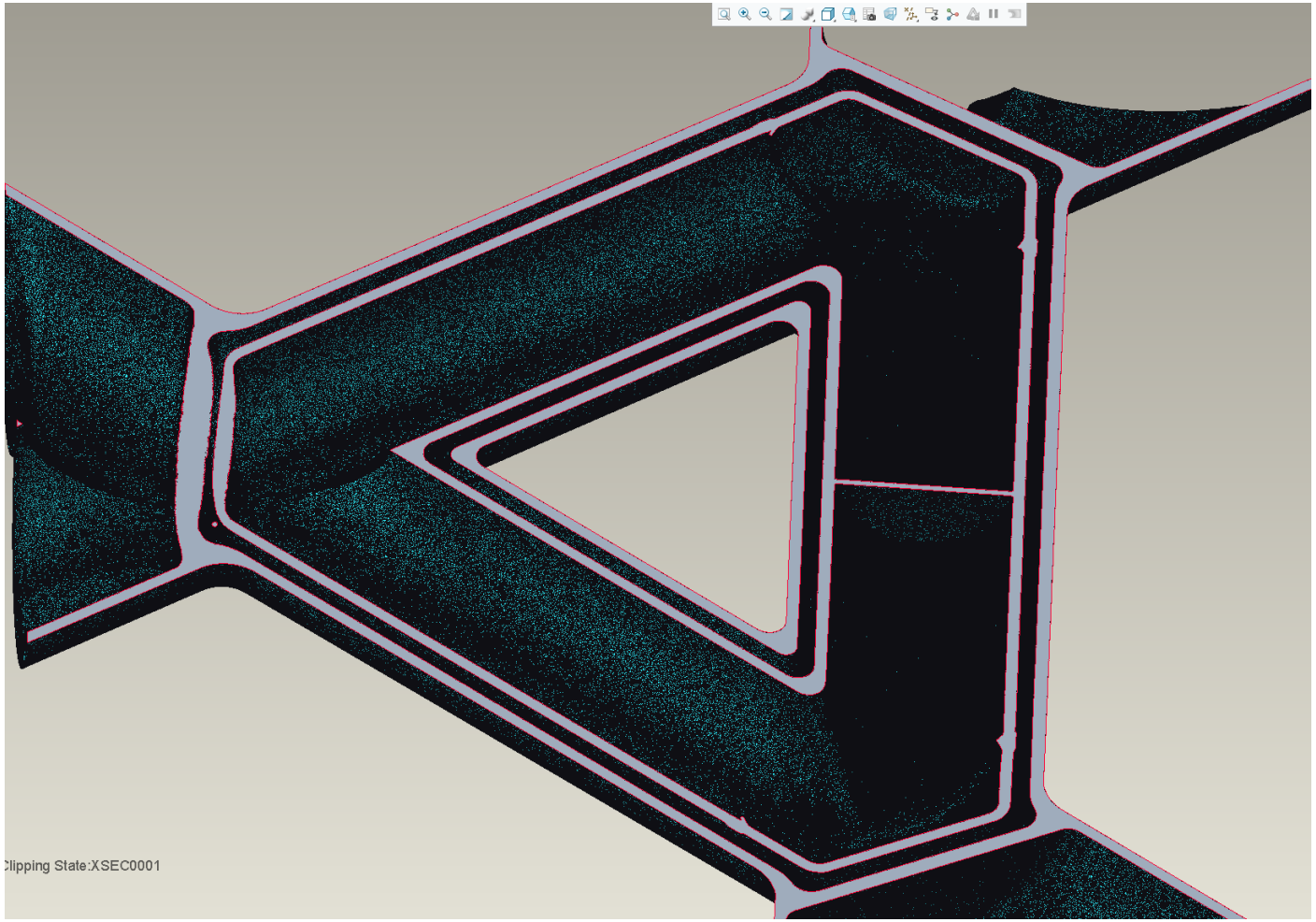
Tube Moderator photos provided by Yannick Bessler of Julich

Hydrogen Vessel Profile Tolerance Confirmation



Confirmation of Assembly Tolerances

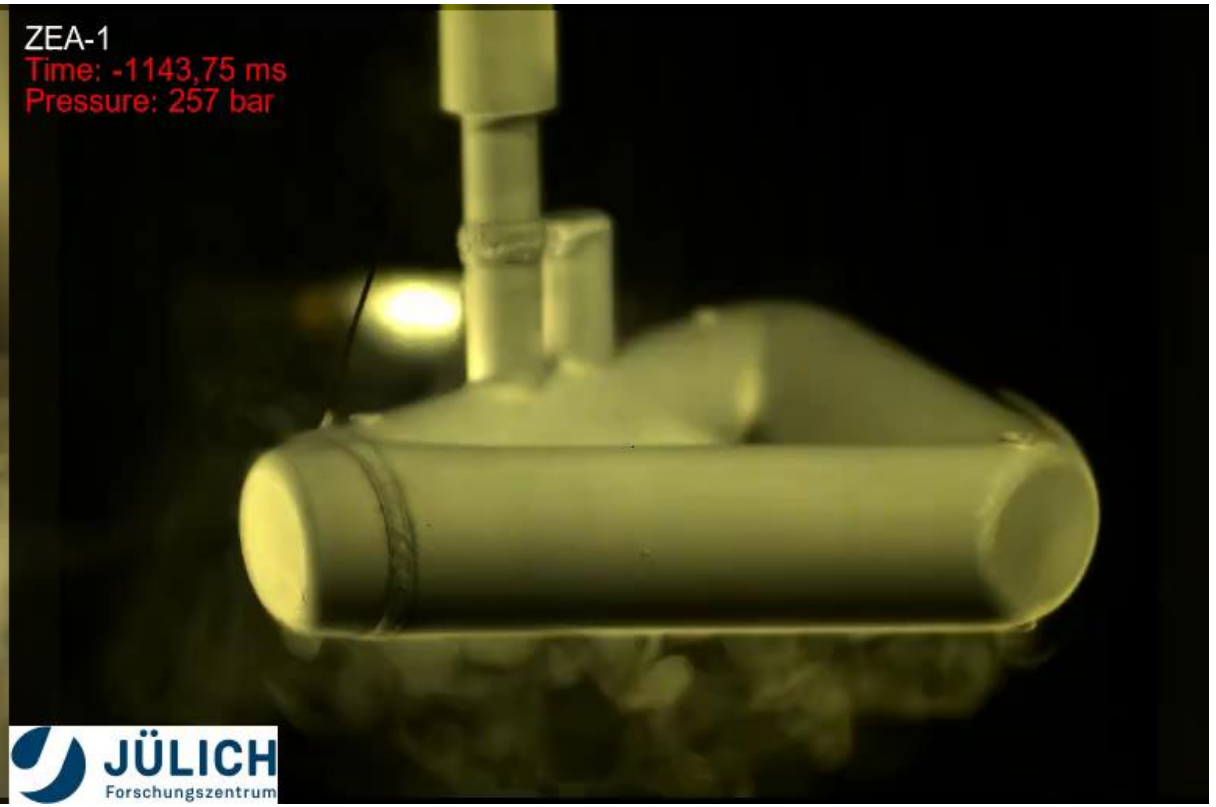
- CT Scan taken of tube moderator prototype
- Used cylinder fitting to combat significant noise in the data
- Worst case deviation between hydrogen boundary and outer vacuum vessel boundary was +0.29 mm, which should allow meeting +/-.5 mm assembly tolerance



Tube Moderator Burst Test Successful

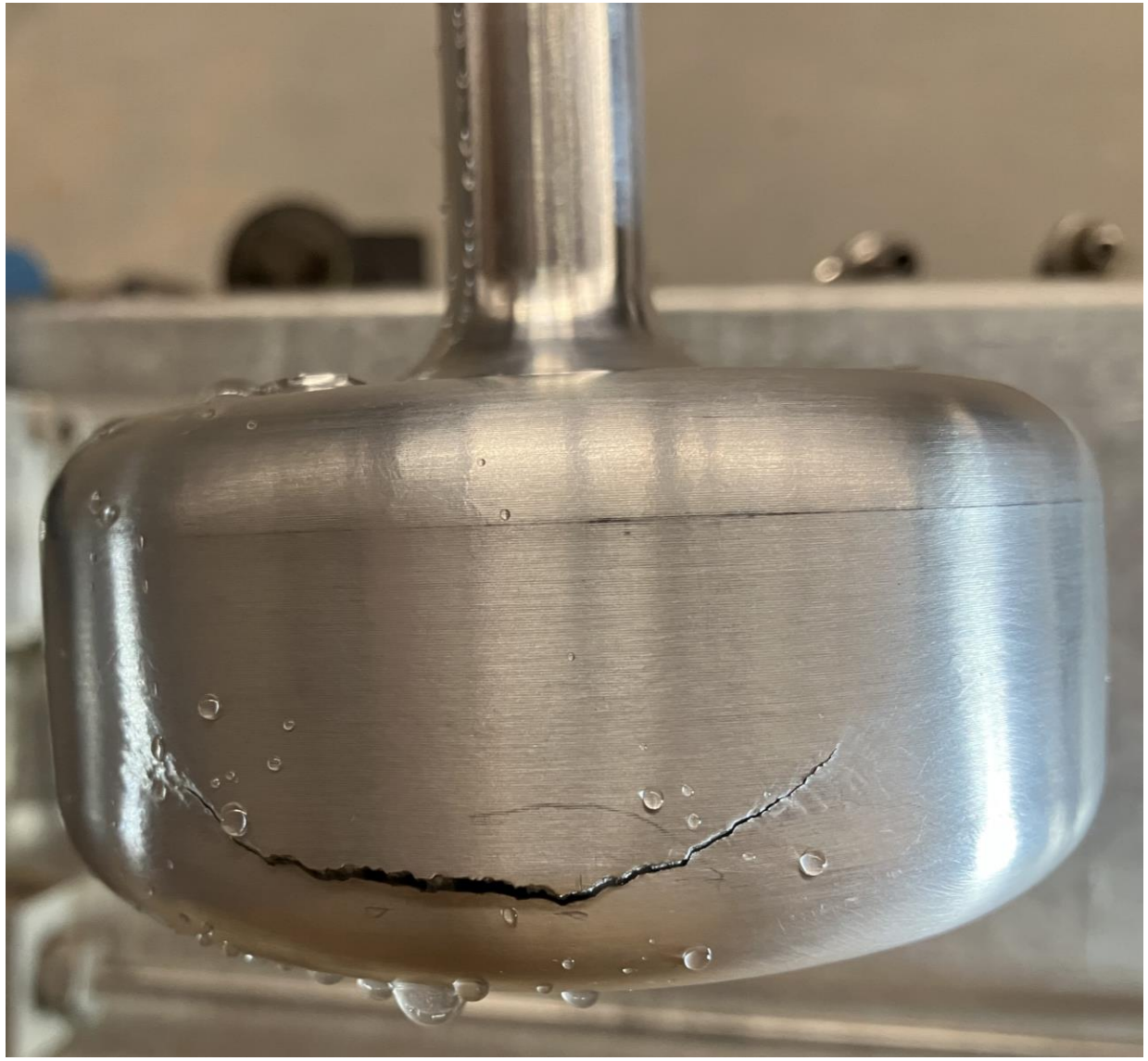
- Tube Hydrogen Vessel was filled with liquid nitrogen, valved off, and removed from the nitrogen bath
- Burst pressure was 264 bar after the temperature rose to ~92K
- Factor of safety of 13.9 compared to planned maximum allowable working pressure of 19 bar

Tube Moderator Burst Test Video



Cylinder Moderator Burst Test Successful

- Cylinder Hydrogen Vessel hydrostatically tested to failure
- Burst pressure was 129 bar
- Factor of safety of 6.8 compared to planned maximum allowable working pressure of 19 bar



Conclusions

- Strategy to increase machining complexity to reduce number and complexity of welds successful
- Tube moderator is more difficult than cylinder moderator, but still manufacturable
- Careful attention must be paid to weld shrinkage and post weld machining strategies to achieve tolerance requirements
- Domestic supply chain is capable of building moderators