SMR Mfg. and Fabrication plus, Establishing Modular In-Chamber Electron Beam Welding Capability in the USA

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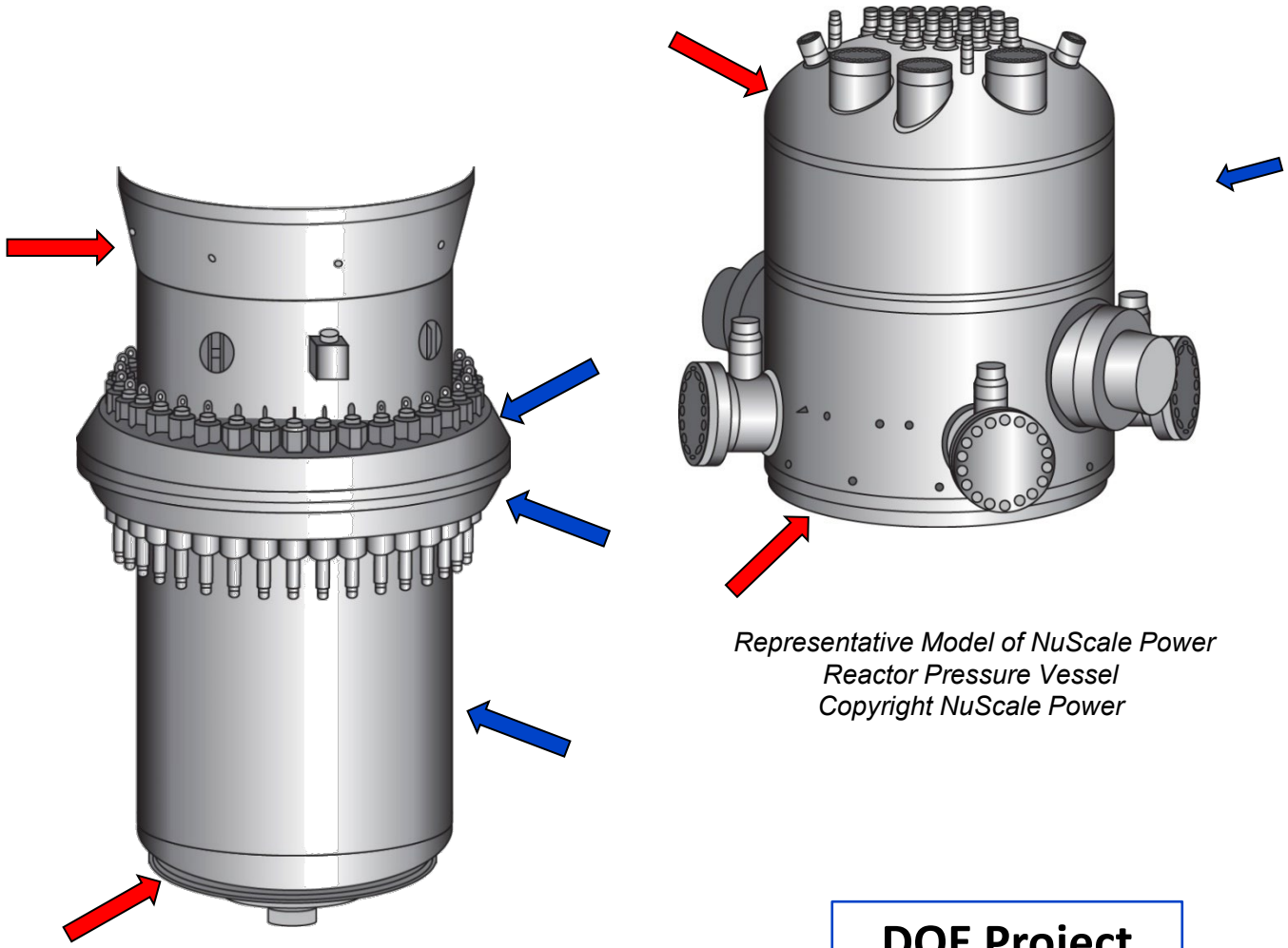
Objectives – SMR Advanced Manufacturing Project

- Rapidly accelerate the deployment of SMRs
- Develop/Demonstrate new methods for manufacture / fabrication of a RPV in **< 12 months**
- Eliminate 40% from the cost of an SMR RPV, while significantly reducing the schedule
- Primary Advanced Methods:
  - PM-HIP
  - Electron Beam Welding
  - Diode Laser Cladding



Representative Model of NuScale Power Reactor Pressure Vessel
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EPRI ELECTRIC POWER RESEARCH INSTITUTE

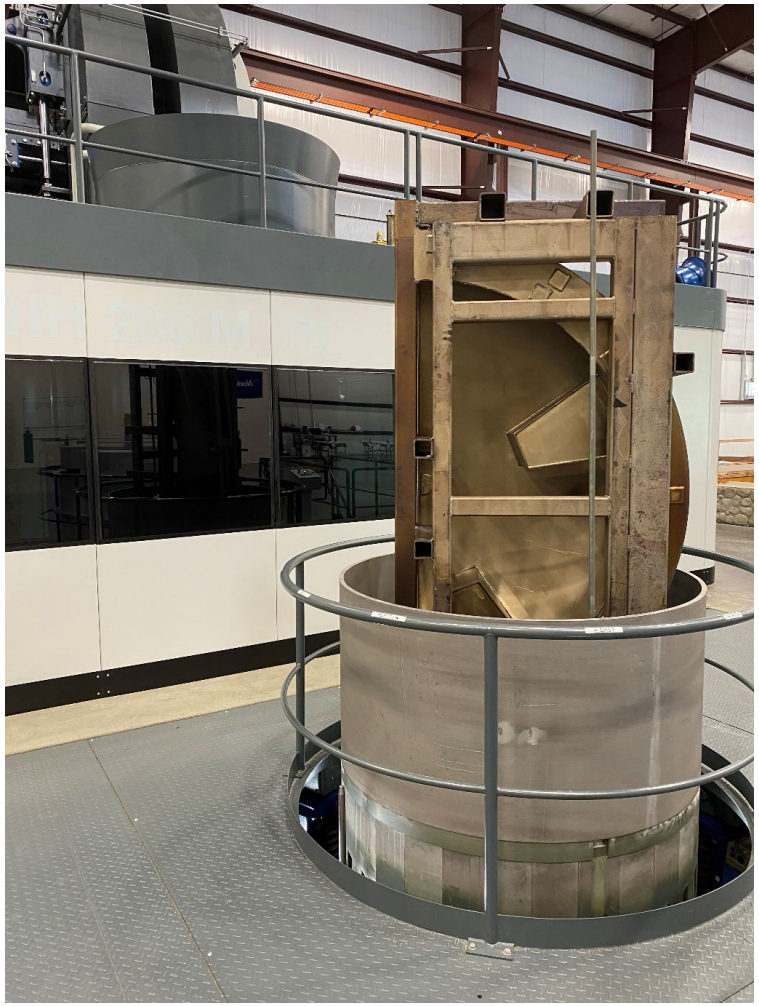
NUCLEAR AMRC

U.S. DEPARTMENT OF ENERGY

NUSCALE Power for all humankind

DOE Project DE-NE0008629

Scaling to Larger Components —Lower Head Halves

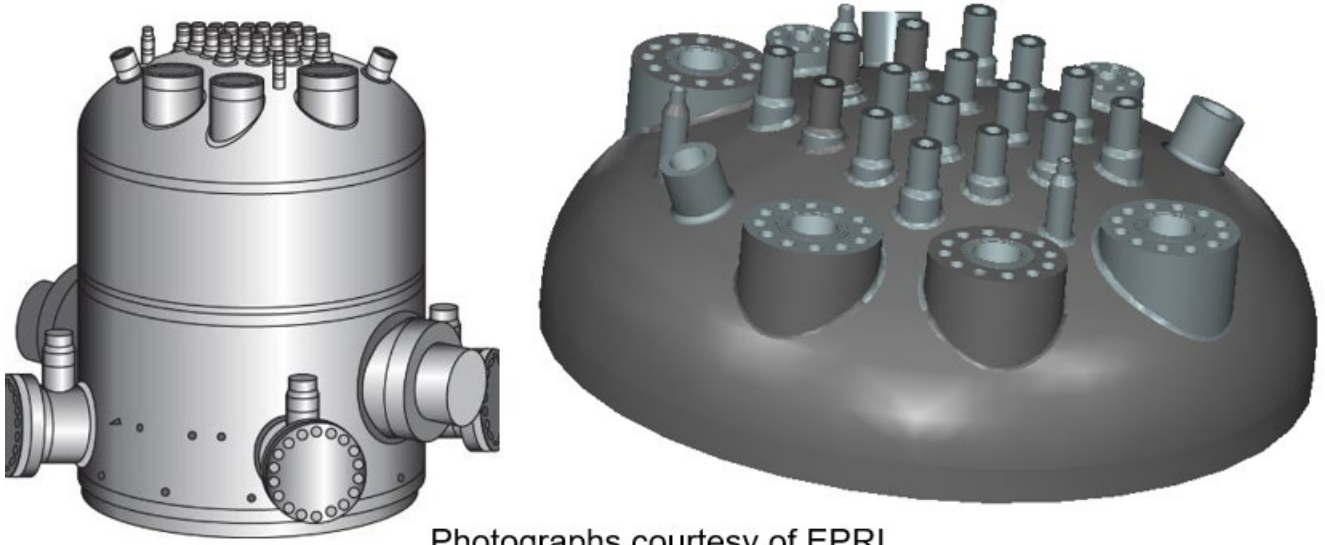


One-half lower head being inserted into HIP Vessel

Lower one-half head following HIP

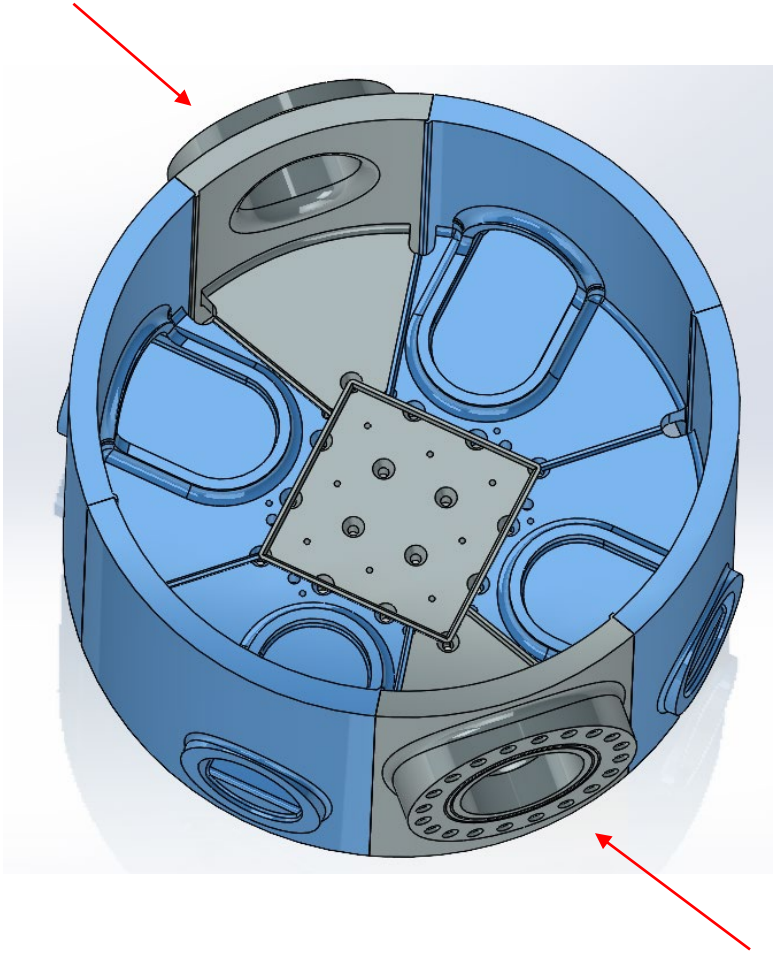
Lower one-half head after HIP and during final machining

SMR PM-HIP Components



Photographs courtesy of EPRI and NuScale Power

Steam Plenum—HIP'ed Segments



Steam Plenum is being produced/assembled in 6 segments

First Segment following HIP

Modular In-Chamber Electron Beam Welding --Project Update

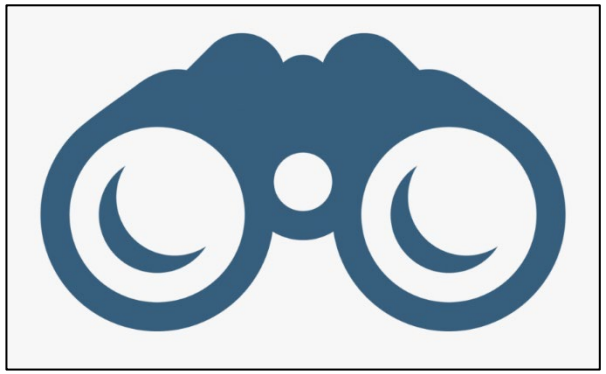
MIC-EBW Project Objectives

DOE Projects
DE-NE0008846
DE-NE0009039

- Develop and establish MIC-EBW capability at a major U.S. fabricator
- Reduce overall welding arc time by up to 90% compared to conventional welding technologies used for vessel production.
- Successfully demonstrate a 10-ft (3.05-m) diameter, 4.375-inch (110-mm) thick vessel EB weld in less than 90 minutes of welding time.
- Establish MIC-EBW capability to perform major RPV girth welds for the NuScale Power RPV.
- Develop manufacturing process plans based on the technology and required post-weld inspection/heat treatment.

Modular In-Chamber Electron Beam Welding (MIC-EBW)—Project Overview

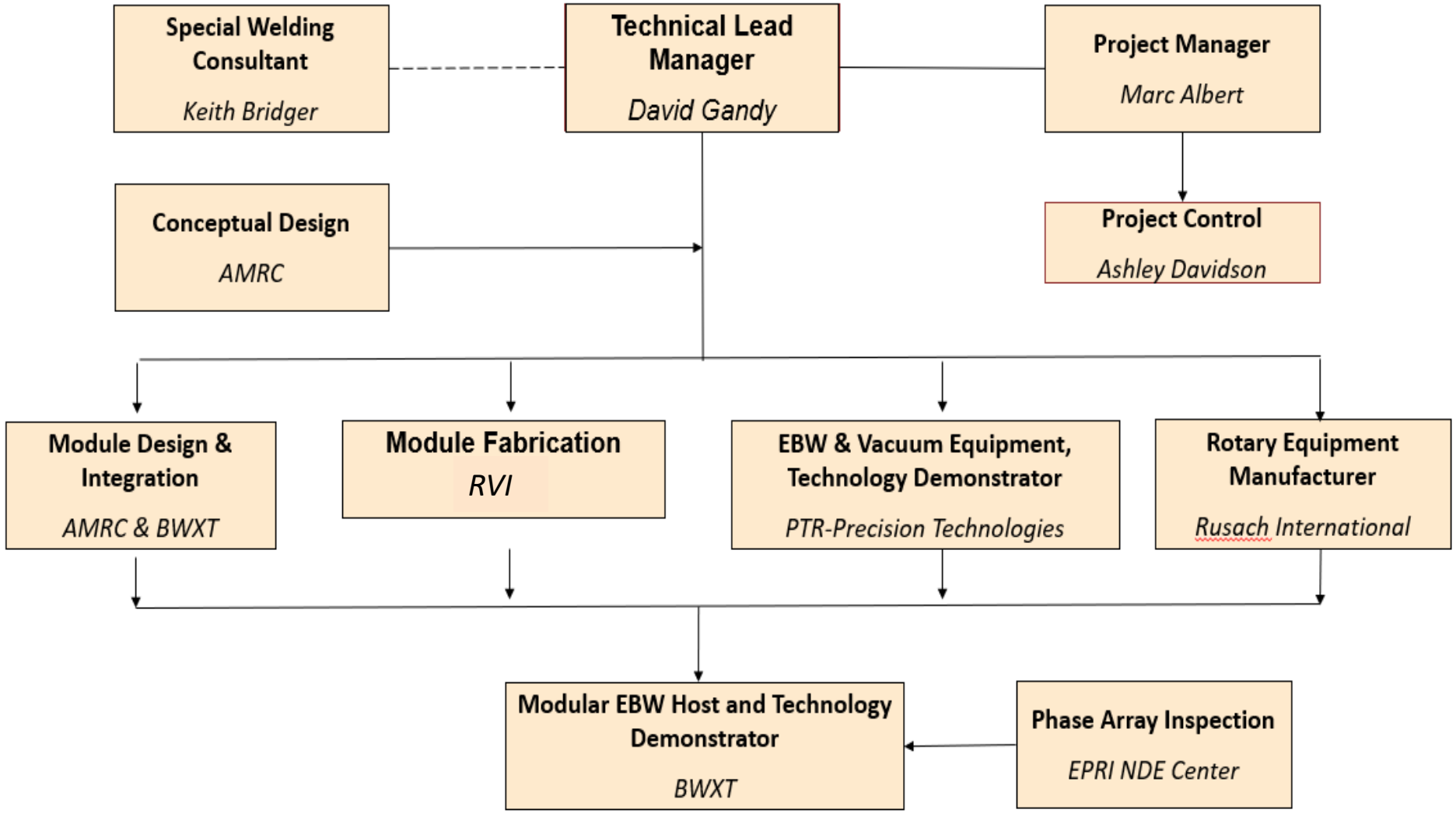
- Project initiated in Oct 2017 (Phase 1 – completed, **DE-NE 0008846**).
  - Assembled vacuum pumps and EB generator
  - Designed MIC-EBW system and generated all drawings
  - Performed some early-stage welds using EB generator



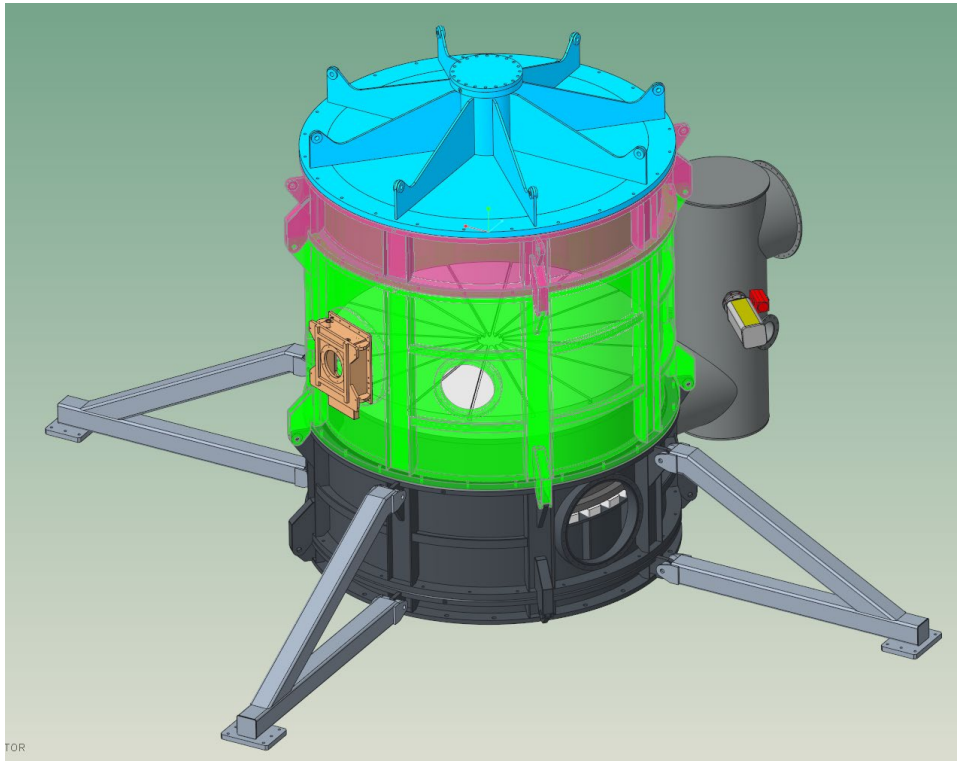
- Phase 2 – Initiated in August 2021 (**DE-NE 0009039**)
  - 24-month project – ending in August 2023
  - Anticipated new completion: Q2-2024

Team Members and Responsibilities

DOE Project DE-NE0009039



Demonstrator and Full Height EBW System



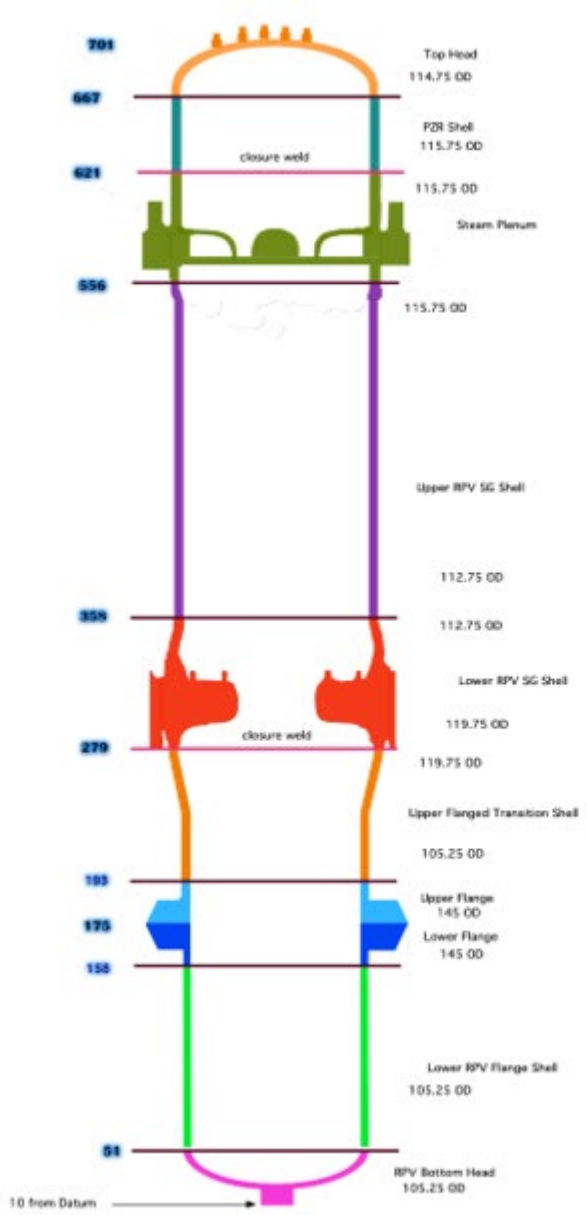
Demonstrator

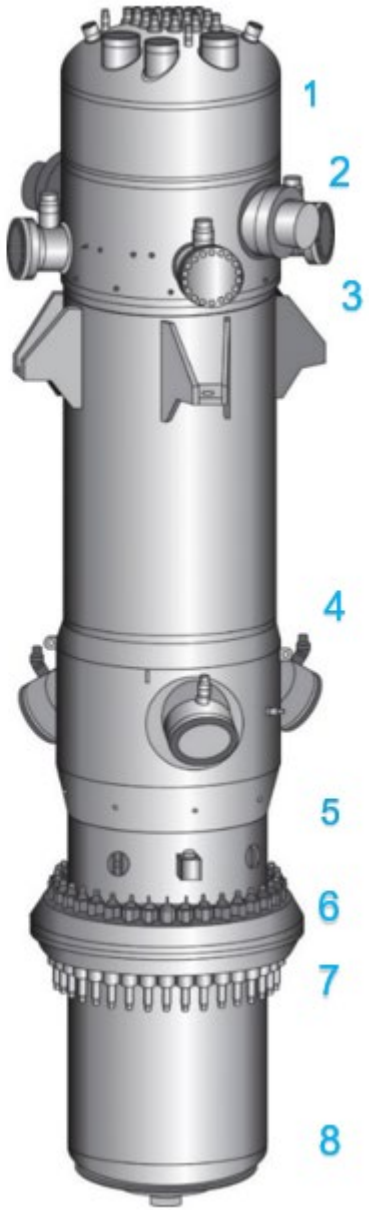
Drawings for MIC-EBW System

- 404371 -Base Module
- 404580 -Vessel Section Module—30-inch
- 404662 -Lid
- 406359 -Vessel Section Module—EB Gun
- 406456 -Base Arrangement – Outriggers
- 406460 -Pump Connection Section Module
- 406627 -Demonstrator Overview
- 40”, 48”, 60” modules (not produced in DOE Project)

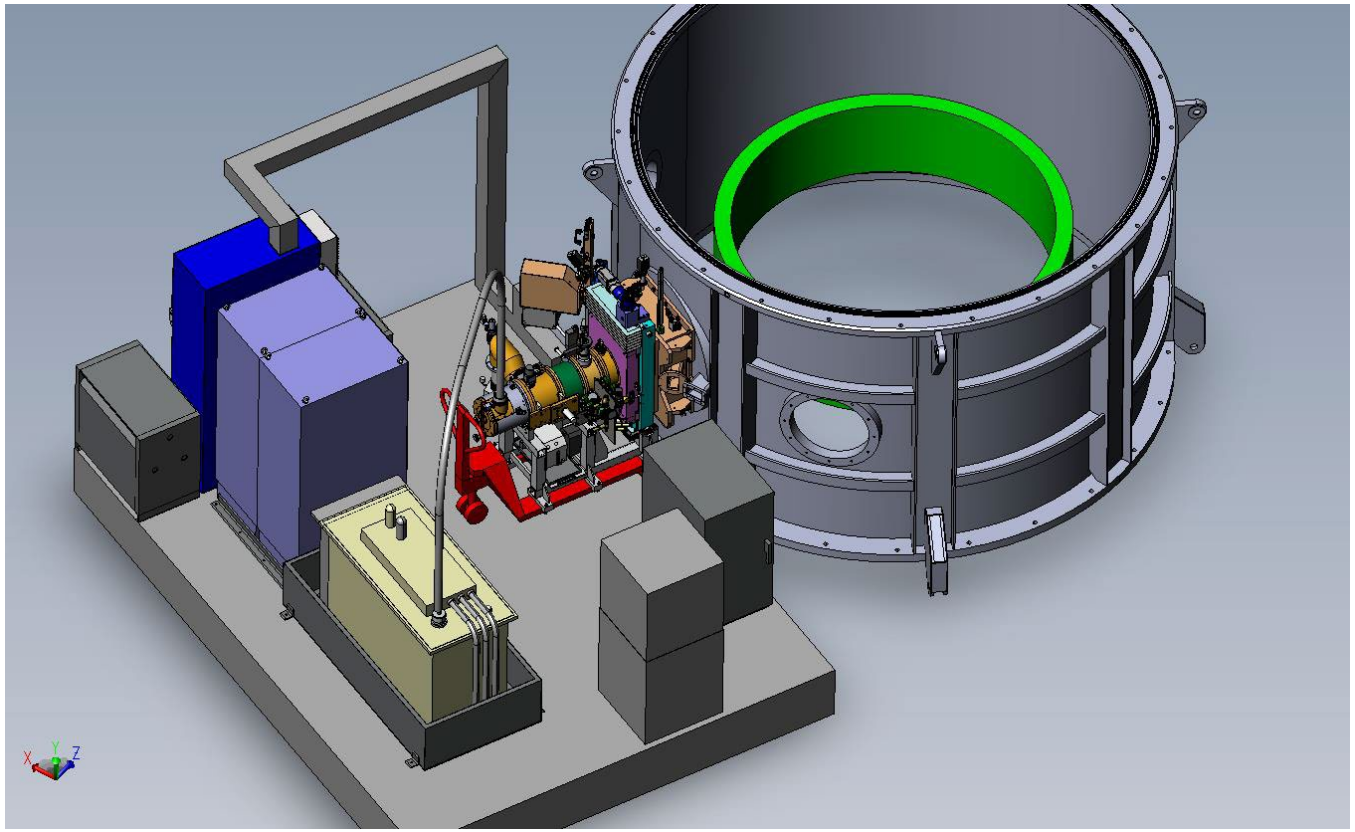
8 Major Girth Welds Required for NuScale Power Reactor

~10 ft in diameter

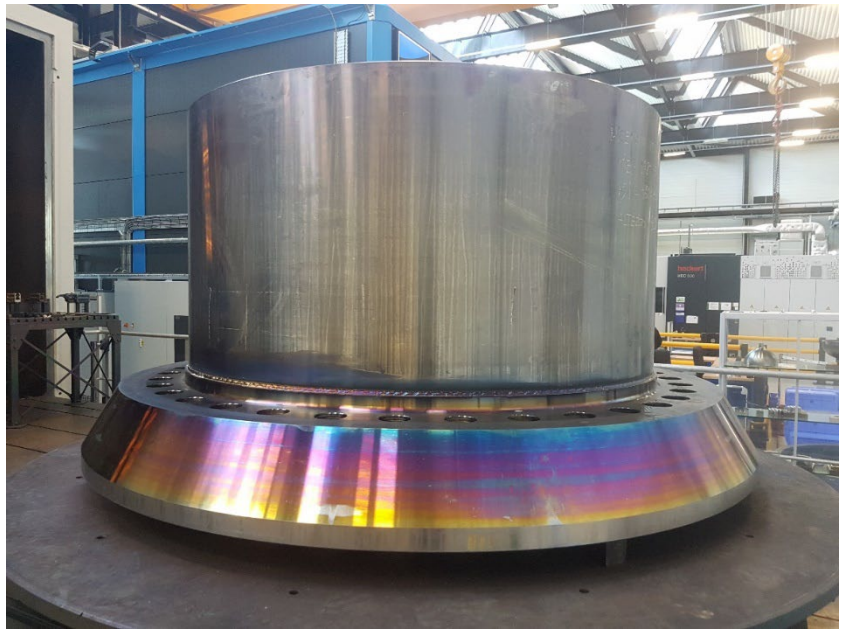




~65 ft (19.8m) in height



MIC-EBW Platform Equipment Overview



Lower Flange Shell Mockup EB Weld -- ~6 ft (1.82m) diameter (Note, mockup is upside down)

Completed in 47 minutes

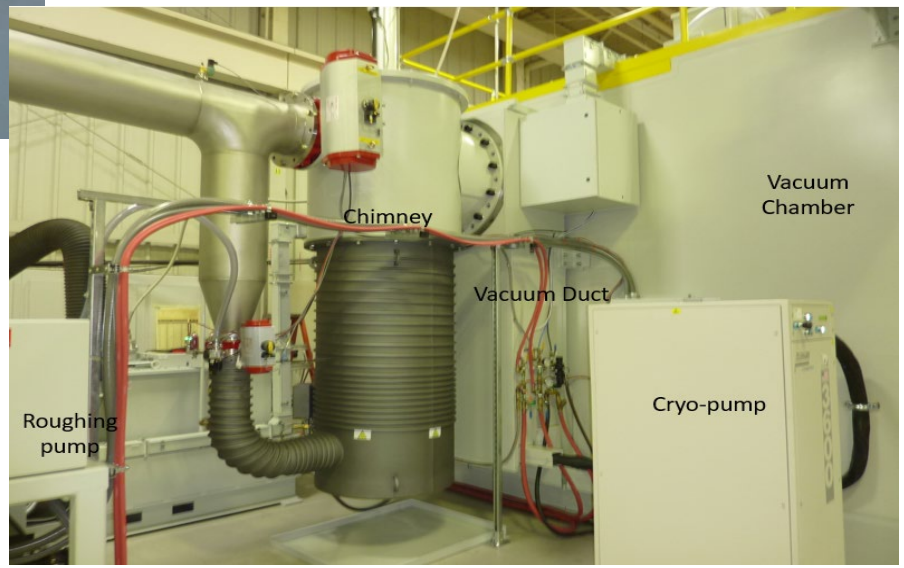
Phase 1 – Highlights
Includes: Equipment & Design Completion

Design/Manufacture Vacuum Pumping Stages of EBW System (PTR lead)

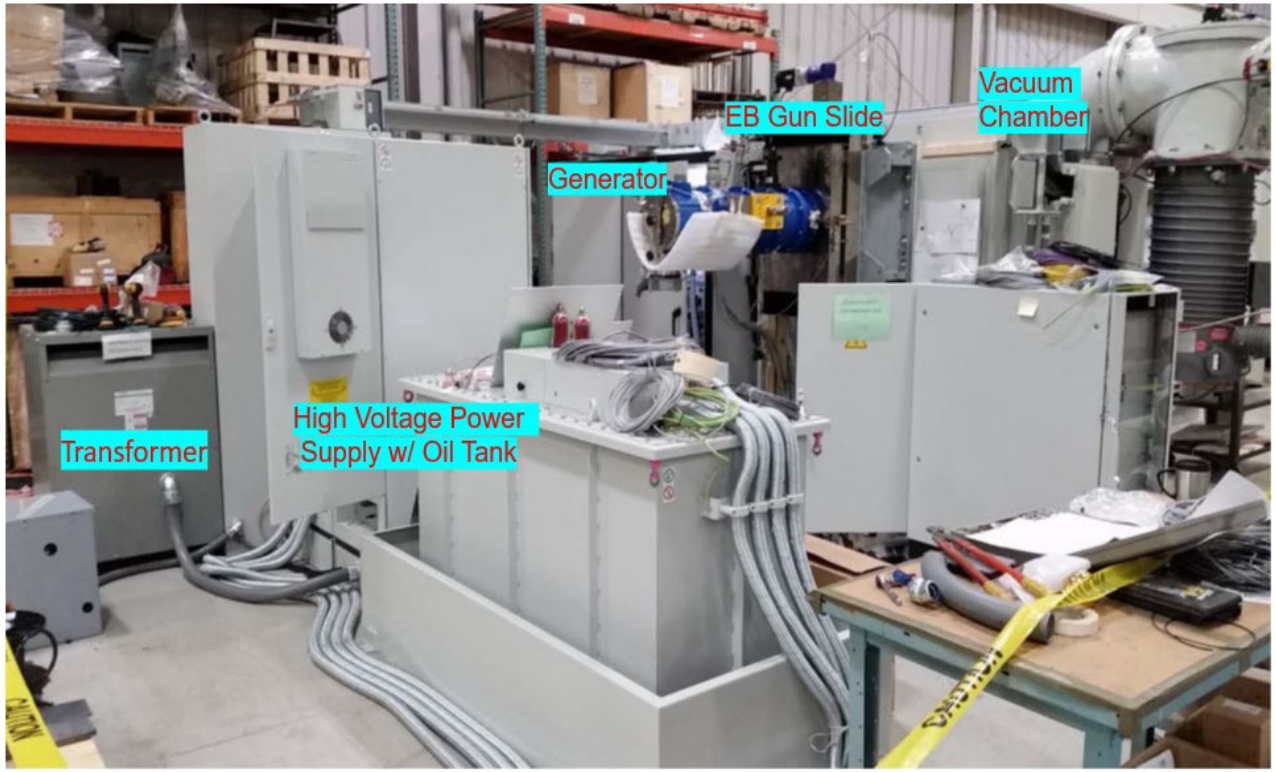
Vacuum Pumping System

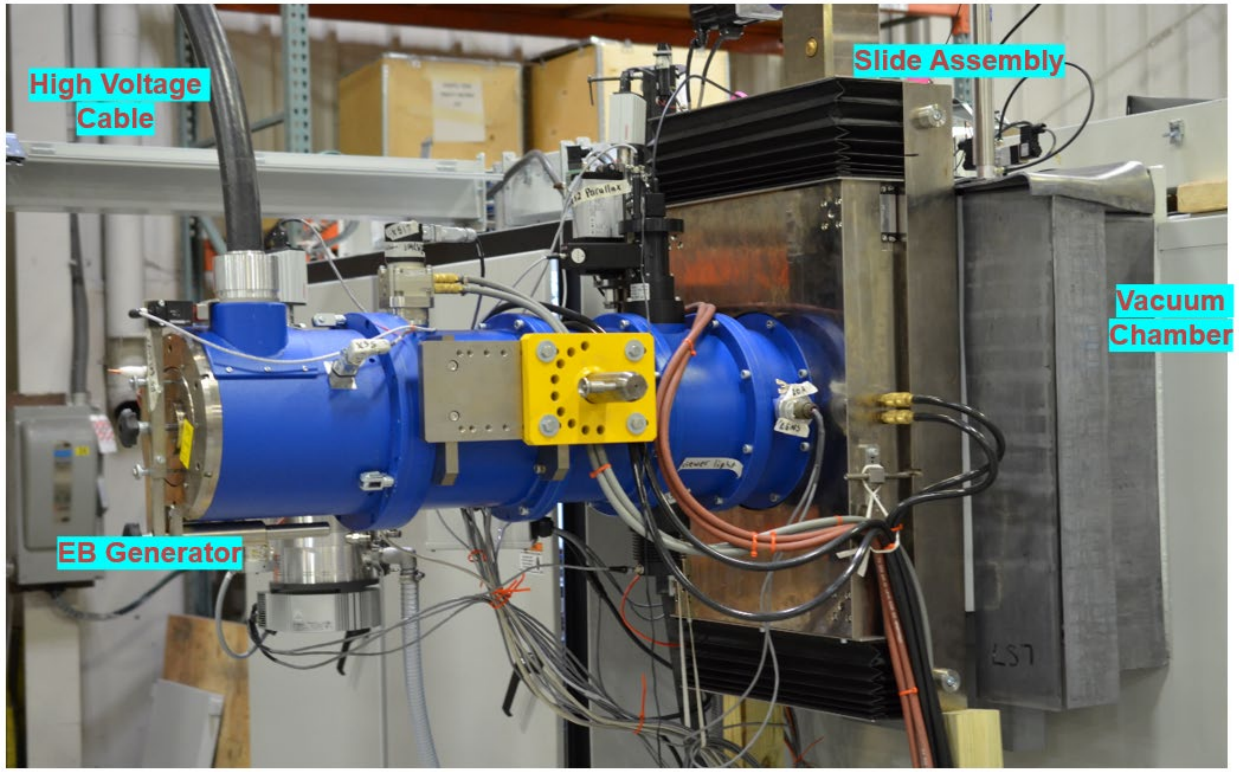
- Pumps and Blowers
- Cryo-pumping System
- Vacuum Ductwork
- Chimney
- Diffusion pumps
- Note: Expected pump-down for full height system is **2-3 hours**

Vacuum Equipment set up at PTR



Assembly of the EB welding equipment for the MIC-EBW system



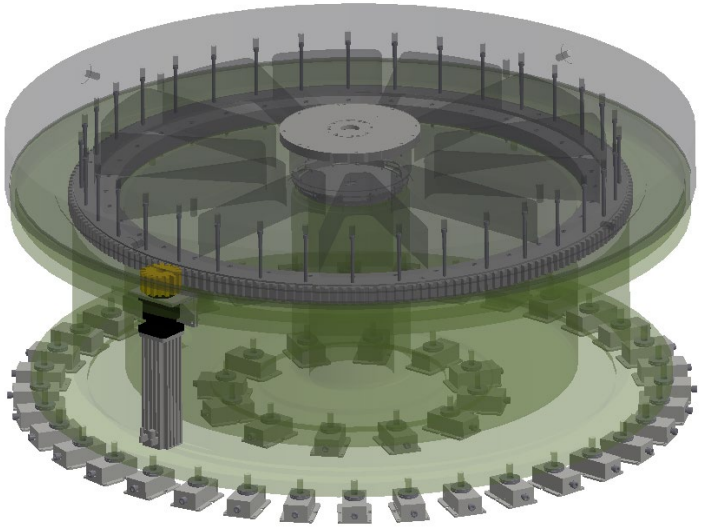


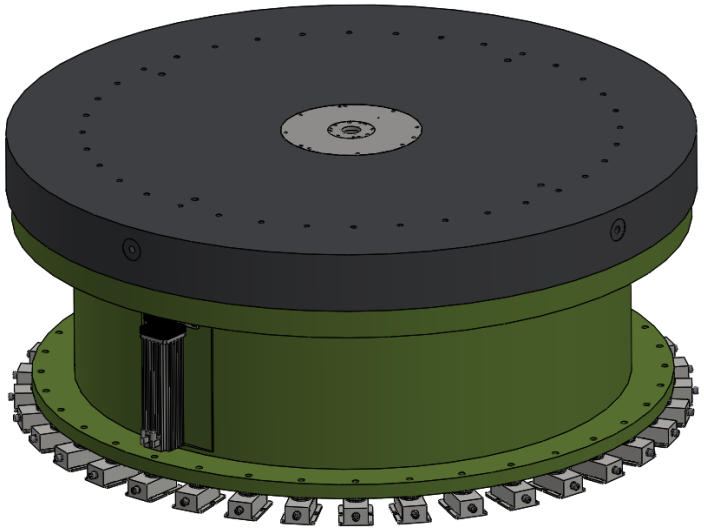
Phase 2 – In-Progress

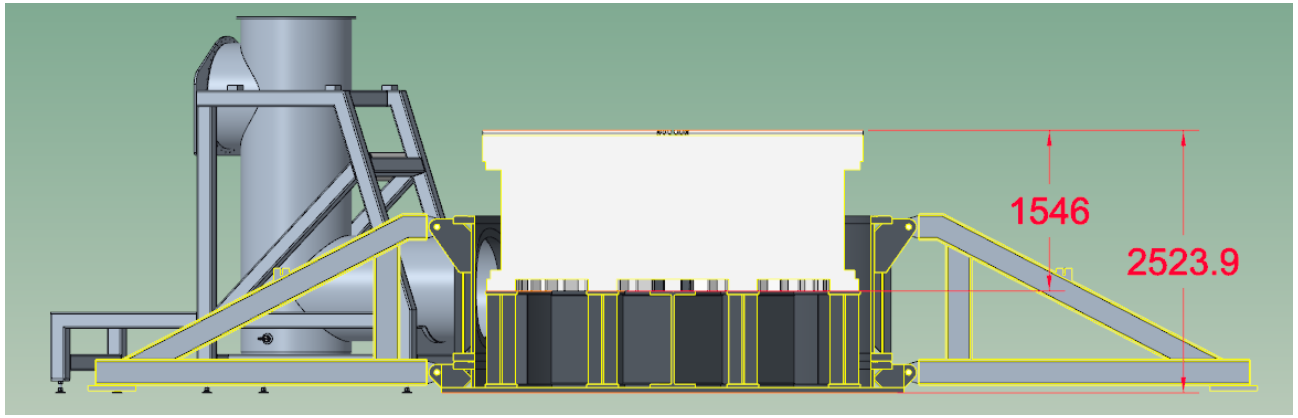
Phase 2. Full-Scale Modular In-Chamber EB Welding Demonstration (24 months)

5. Design/Manufacture of the Rotary Manipulation Stage (Rusach) – **95% complete**
6. Produce Modular Ring Sections and Fabricate Modular Vacuum Sections for SMR Welding/Joining (RVI) – **100% complete**
7. Demonstrate Modular EB Welding Capabilities for Large Scale—10 feet (3.05m) Diameter Shells (BWXT/PTR)
8. Benchmarking & Technology Transfer (AMRC) – **10% complete**
9. Develop/Demonstrate NDE of Final Welds (EPRI NDE)
10. Facility Readiness & Support (BWXT) – **80% complete**

Milestone 5 – Design/Manufacture of the Rotary Manipulation Stage







Rotary Table (shown in white) is 144 inches in diameter and sets on the base assembly

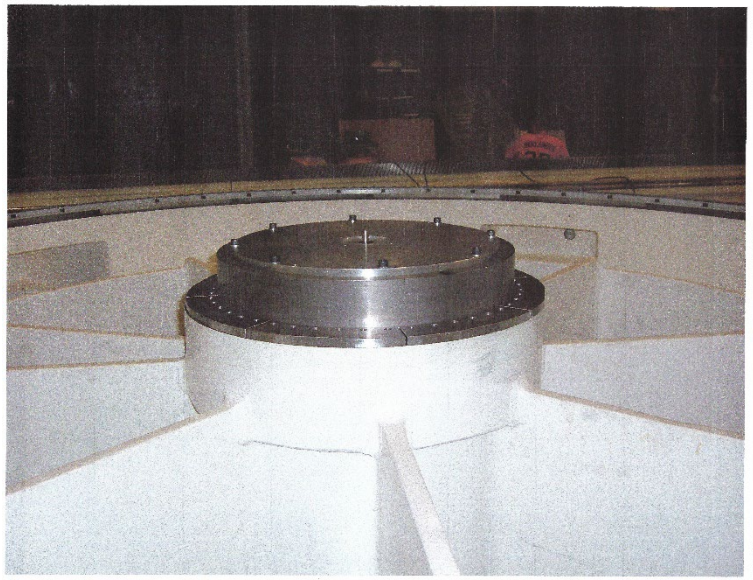


Table Base

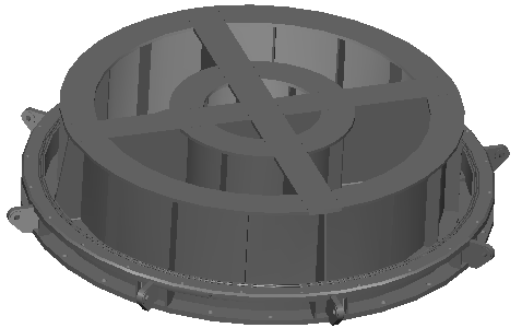
Table Platen (upside down)

Milestone 6 – Produce Modular Ring Sections and Fabricate Modular Vacuum Sections for SMR Welding/Joining (RVI)

--Status: Completed & Set in Place at BWXT

Base Assembly & Support

- ~12ft in diameter
- Capable of supporting 150 tons
- Carbon steel
- Supports rotary table & RPV welding
- High tolerances required



Base Module -- Completed

Base Module: shown upside down after coating

Vacuum Module

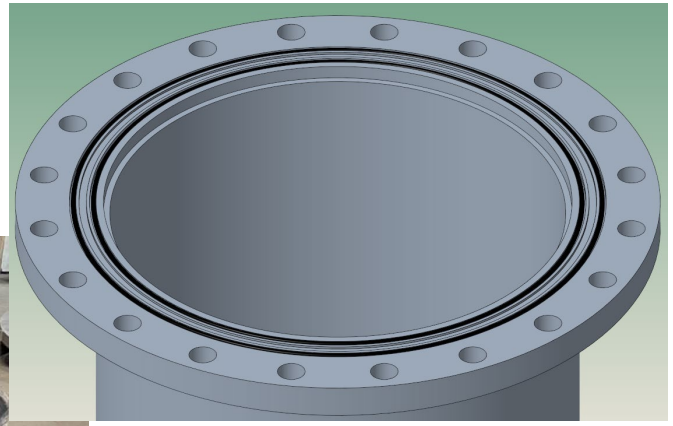
- Module fabrication is completed.
- Has been Coated and to BWXT site.

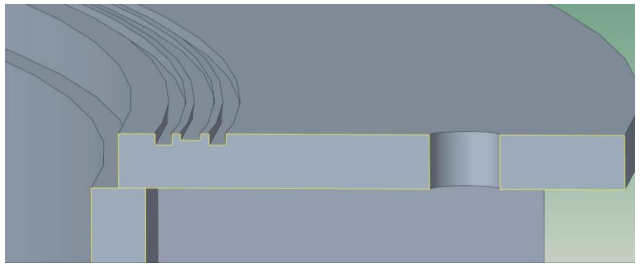
Base Module

Alignment Features

Penetrations for Electrical Wiring

Modules -- Progress





30-inch Module

- Complete
- Has been coated and delivered to site.

Upper Lid

- Complete
- Has been coated and delivered to site.

EB Module – Coated and delivered to site

Vacuum Testing

Modules on Site at BWXT

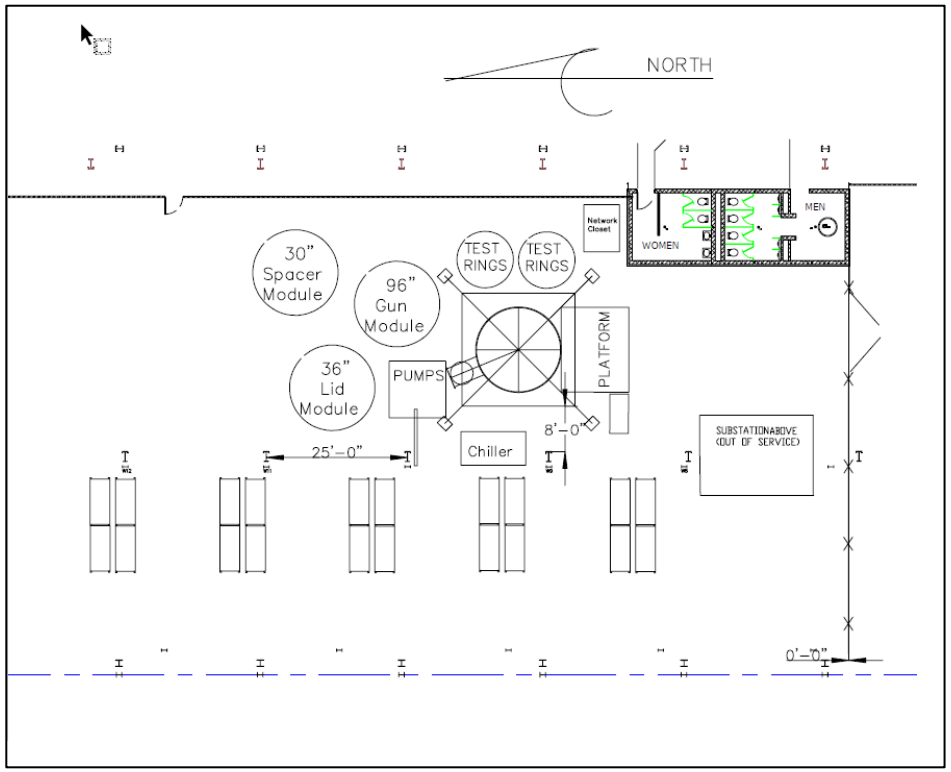
Milestones 7-9 -- Next Q3-2023

7. Demonstrate Modular EB Welding Capabilities for Large Scale—10 feet (3.05m) Diameter Shells (BWXT/PTR)
   - Acquiring rings for welding
   - Performed several 4ft diameter welds with system

8. Benchmarking & Technology Transfer (AMRC)
   - Limited discussions thus far

9. Develop/Demonstrate NDE of Final Welds (EPRI NDE)
   - Evaluated two 4ft diameter x 4.5inch thick welds to date

10. Facility Readiness
Concrete Pad Excavation & Re-Pour



- Facility design/retrofit layout finalized in Barberton (by BWXT).
- Concrete rework completed.
- Electrical and water connections completed.

Base Plate Assembly In-Place and Ready for Rotary Table

Schedule Discussion—A few key dates

2022 Major Milestones

- Building Modifications & Site Prep – Oct 3
- Install Base Assembly – Nov 1 (revised to late November)
- Install/Test Rotary Table -- (revised to mid-May 2023)

- **Rotary Table Delays have moved schedule back ~16 weeks.**

2023 Milestones (Revised)

- Install EB Gun Module – June 30
- Install Remaining Vacuum Equipment – June 30
- Install Power Supply & Control Panels – July 2023

2023 Testing (Revised)

- Vacuum System Testing – Aug 15
- Radiation Testing – Aug 30
- EB Generator Tests – Sept 30
- Final MIC-EBW System Tests – Sept 30
- Training of BWXT Staff – Oct 30

Schedule Discussion—A few key dates

WELDING Demonstrations

2023 Milestones Continued

- Perform 1st and 2nd full diameter welds – Nov 30
- Perform 3rd and 4th full diameter welds – Jan 15--2024

2024 Milestones (Revised)

- Perform 5th and 6th full diameter welds
- Perform 7th and 8th full diameter welds
- All Welding and Testing Complete
- **Project Complete** – June 30

Summary

- MIC-EBW system is a “first-of-a-kind modular” vacuum chamber and electron beam welding system in USA.
- Modular design allows manufacturer to perform welds at multiple heights.
- **Provides USA with major capability for manufacturing**.
- Design is flexible
  - Can be used for RPVs, pressurizers, steam generators, or other.
- Coupled with PM-HIP (or other), the MIC-EBW system will re-establish the USA as a major player in manufacturing of nuclear components.

Acknowledgements – The TEAM!!!

- **DOE** -- Dirk Cairns-Gallimore
- **Advanced Manufacturing Research Centre (UK)** – Billy Redpath, James Coupe, Merv Alfred
- **Bridger Welding Engineering**—Keith Bridger
- **BWXT**—Pete Goumas, Ben Smeiles, Nick Hillard, Jason Miller
- **EPRI NDE Center**—Brett Flesner, William Ratcliff
- **EPRI**—David Gandy, Marc Albert, Greg Frederick, Randy Stark, Kurt Edsinger, Craig Stover
- **PTR-Precision Technologies** – David Tremble, Dan Fein, Derek Meyers, Al Green, Wilfried Klein, Justin Snowden
- **Rusach International**—Jeff Hatfield, Kevin McIntosh
- **RVI-Industries**—Bob Combs, Pete Keogel, James Littlewood

~30 people to date….

Progress

Many **hurdles addressed** to date:

- Penetration of electric cables into vacuum system
- Sensing potential vacuum leaks
- EB generator coupling and disconnection via gun slide assembly
- Impingement bar & shielding to absorb x-rays
- Parallelism of base assembly and machining
- Design of platform (removes personal from welding area)
- Viewing of electron beam via secondary viewing system
- System speed – extremely slow for welding
- Outriggers for stability