OVERVIEW

What are we doing?

▪ Overview of the HWR cryomodule.

▪ Work Authorization and ES&H:
  – Reviews and ANL oversight.

▪ HWR cryomodule work at ANL:
  – Current status, and
  – Future work.

▪ In the next presentation:
  – Schedule to finish HWR cryomodule work at ANL.
HWR CRYOMODULE HISTORY

Reviews

- Review History:
  - HWR Review, Chair = J. Kerby
    - 5 March 2012
  - Half-wave Resonator Cavity Mechanical Design, Chair = T. Mullen (ANL)
    - 17 May 2012
  - HWR Cryomodule Preliminary Design Review, Chair = P. Ostroumov
    - 30 August 2012
  - HWR Review, Chair = R. Laxdall
    - 15 October 2013
  - Cryomodule Design, Chair = T. Mullen (ANL-ESH)
    - 16 May 2013
  - Preliminary Transportation Readiness Review, Chair = J. Holtzbauer
    - 14 August 2018

- Cryomodule Operating Conditions:
  - Defined in the Functional Requirements Specification dated 11 April 2013:
    - modifications happening now, and
    - 2 MV per cavity, < 50 W total 2 K thermal load, High power couplers, etc.
ES&H AND WORK AUTHORIZATION

Work Done at ANL

- Safety is our highest priority.
- Work at Argonne is done in compliance with ANL ES&H.
- Providing a working piece of hardware goes hand-in-hand with work planning and control at ANL (safety).
- FNAL and ANL collaboration on SRF is documented in the FNAL/ANL MOU on SRF Cavity Surface Processing, signed 4/21/2006 with addendum added on 8/15/2014 for cryomodule.
- Hazards addressed at ANL include:
  - Chemical safety,
  - Cryogenic safety,
  - Pressure systems safety,
  - Radiation safety, and
  - Cryomodule component testing and assembly work.

HWR Status
30 August 2018
HWR CRYOMODULE

Layout

Helium Manifold
Conduction Cooled Leads (FNAL)
Helium Relief Port
Cooldown Manifold
Sub-Atmospheric HTXG Output

Ti Strong-Back
Slow Tuner Gas Heat Exchanger
Half-Wave Resonator
Vacuum Manifold
SC Solenoid

2.2 m X 2.2 m X 6.2 m
18,600 lb

HWR Status
30 August 2018
HWR CRYOMODULE WORK AT ANL

To finish the cryomodule.

- Cavity Testing:
  - Acceptance testing
  - Solenoid w/ cavity
  - Dressed testing
    - Couplers
    - Slow tuners
    - RF Pick-up probe
- Fiducialization and alignment
- All major parts are at ANL:
  - Part acceptance testing finished:
    - cold shock
    - leak Test
    - metrology
    - counting
  - Some minor parts to be ordered:
    - Fasteners, gaskets, clean room sundry,
    - Assembly fluids/solids
### REMAINING PARTS TO ORDER

#### Fasteners Spreadsheet

#### Page From Fastener Spreadsheet

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<thead>
<tr>
<th>PART</th>
<th>HARDWARE DESCRIPTION</th>
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#### STRONGBACK PRE-CLEAN ASSEMBLY

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#### CAVITY CLEAN ASSEMBLY

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TEST CRYOSTAT @ ANL

TC3

- Testing configuration is identical to the cryomodule assembly.
- 4.5 K closed loop helium system.
- 2.0 K testing with vacuum pumping.
CAVITY ACCEPTANCE TESTING @ ANL

Cryogenic Power Dissipation

- 8 cavities required for HWR cryomodule.
- 7 finished.
- Next acceptance test during week of 10 September 2018.

HWR Before Testing

Accepted Cavity Q-Curves

2 W, Cavity Power

Goal
MICROPHONICS

RF Power Requirements

- All HWR tested have a $df/dP \sim 11$ Hz/mbar.
- With a helium pressure stability of 0.1 mbar $\rightarrow \Delta f = 1.1$ Hz.
- At 2.0 K we observe $\Delta f_{pp} \sim 20$ Hz.

HWR Cavity Power
SOLENOID TESTING

@ ANL

- All solenoids tested at Cryomagnetics.
- One solenoid tested at ANL.
- To decrease the accelerator lattice length the x-y steering coils are integrated with the solenoid package.
- Important design issue:
  - Minimize stray field @ the RF cavity to prevent performance degradation due to trapped magnetic flux.
- Measured RF surface resistance with a sensitivity of ±0.1 nOhm before and after each quench of the cavity.
- The cavity was quenched with the solenoid and the steering coils energized.
- No quantifiable change to the cavity RF surface resistance.
RF PICK-UP ACCEPTANCE TESTING
Part of Dressed HWR Testing

- Goals:
  - 250 mW output @ cryomodule.
  - Redundant pick-ups.

- Dual loop coupler with $Q_{\text{ext}} = 4 \times 10^{10}$
  - $Q_{\text{ext}}$ should be $6 \times 10^{10}$ for $P_{\text{out}} = 250$ mW.
  - Extra coupling to account for line losses.
  - 6 of the 8 production units tested cold:
    - $2 \times 10^{10} < Q_{\text{ext}} < 7 \times 10^{10}$
    - Have 2 extra units.
    - At room temperature $3.8 \times 10^{10} < Q_{\text{ext}} < 4.6 \times 10^{10}$
SLOW TUNER ACCEPTANCE TESTING @ ANL

Cryogenic Power Dissipation

- Slow tuner range > 120 kHz with 0-60 psig.
- All cavities tested with slow tuner.
- Range varies from 152 kHz to 166 kHz.

Slow Tuner Test Results

Frequency Deviation (kHz)

0 60 120 180

Time (seconds)

2-60 psig

+/- 83 kHz
ENGINEERING COOL-DOWN

Cold Leaks and Alignment

- Cryomodule with cold-mass rail system
- Cooled to 80 K.
- Measured alignment of titanium strongback, measured thermal load on heat shields, and checked for cold leaks.
- All tests found good performance.

Cryomodule Alignment
MOCK ASSEMBLY

Do we have everything? Does it fit together?

- Mock assembly = practice before final clean assembly.
- Used 5 cavities and 8 solenoids.
- 3 missing cavities were being tested, cleaned or polished during this work.
REMAINING WORK
CRANE WORK AUTHORIZATION
Hoisting and Rigging

- Ordered new lifting beam and rigging hardware for half-wave resonator crane operations.
- Delivery in 4-6 weeks.
- Lid work to start then…
- Safety paperwork approval is going on in parallel.
HWR CRYOMODULE TRANSPORTATION

From ANL to FNAL

- ANL personnel working on this are assigned cryomodule assembly tasks.
  - Which set of work to delay?
  - J. Kilbane, ME

- ANL transportation preliminary concept reviewed on 14 August 2018.

- After review work focused on refining ANL design.
  - No transportation frame.
  - Use cryomodule mounting feet or gussets to secure cryomodule to trailer bed.
  - Drive slow.
    - As is done at ANL.
HWR CRYOMODULE ASSEMBLY

Finish the cryomodule

- Finish acceptance testing:
  - 1 HWR
  - 2 couplers + 1 retest
- Clean parts for SRF low-particulate clean assembly.
- Clean assembly of beam-line.
- Hang assembly from lid and install all remaining components.
- Testing at ANL:
  - Instrumentation
  - Alignment
  - Vacuum integrity
- All remaining tests to be done at FNAL.
- More details on schedule in next presentation.
SUMMARY

HWR Cryomodule Status

- All major parts are in hand.
- Practice assembly done.
- Need to finish acceptance testing of HWR and couplers.
- Need to finish final assembly of the HWR cryomodule.
- Schedule details in next presentation.