

Status of 1004B Valve Box / Ring Repair

3 Oct 2023

M. Minty

Key personnel involved:

Joe Tuozzolo (C-AD chief mechanical engineer / EIC)

Jon Sandberg (C-AD chief electrical engineer)

with support from John Escallier and George Ganetis (at NSLS-II, formerly SMD)

Primary groups:

Russ Feder, group leader (GL) / cryo group – valve box repairs

Chaofeng Mi, deputy GL, Don Bruno (GL / EIC), Greg Heppner / electrical group – electrical measurements
(valve box, RHIC tunnel)

supported by:

David Chan, division head of C-AD Experimental Support and Facilities Division and ES&F groups
Experimental Accelerator Operations Support Group (AOSG)

DX Magnet Spare Preparation: Jesse Schmalze and Mike Anerella (Magnet Division), Scott Seberg (C-AD)

Engineering
and Technical

Paul Sampson (ASOG GL) – work planning oversight

Ray Fliller (ESSHQ division head), Mike Dany (work planning and control GL) , Francis Craner (ES&H GL)
and others (ESSHQ) + lab SMEs

Eric Johannsen – Electrical Safety and LOTO

Srikantha Chilakala – Confined Space

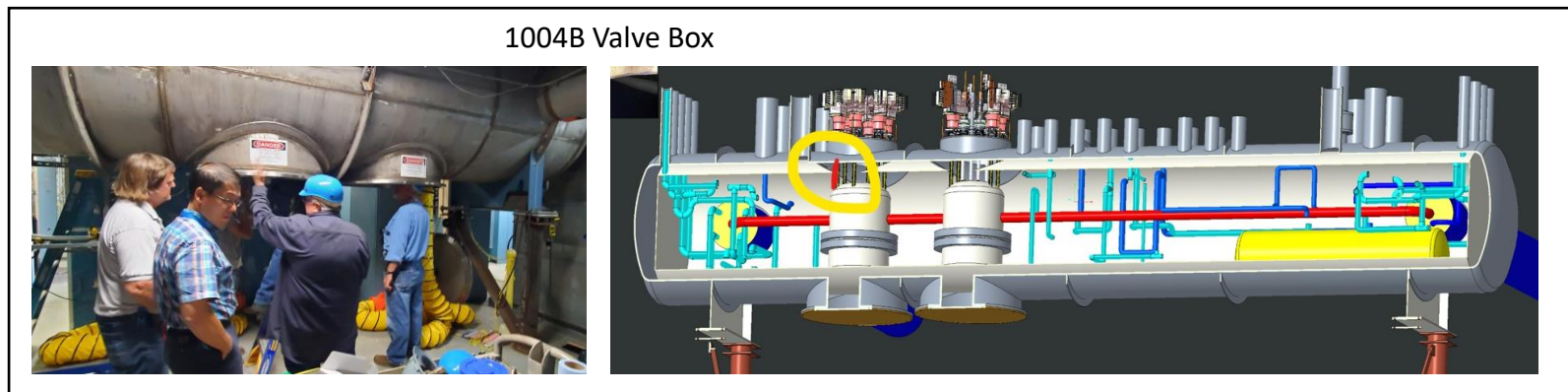
Mike Gaffney – ODH

in coordination with fire department (for hot permits), coordinated by John Benante (AOSG, deputy GL)

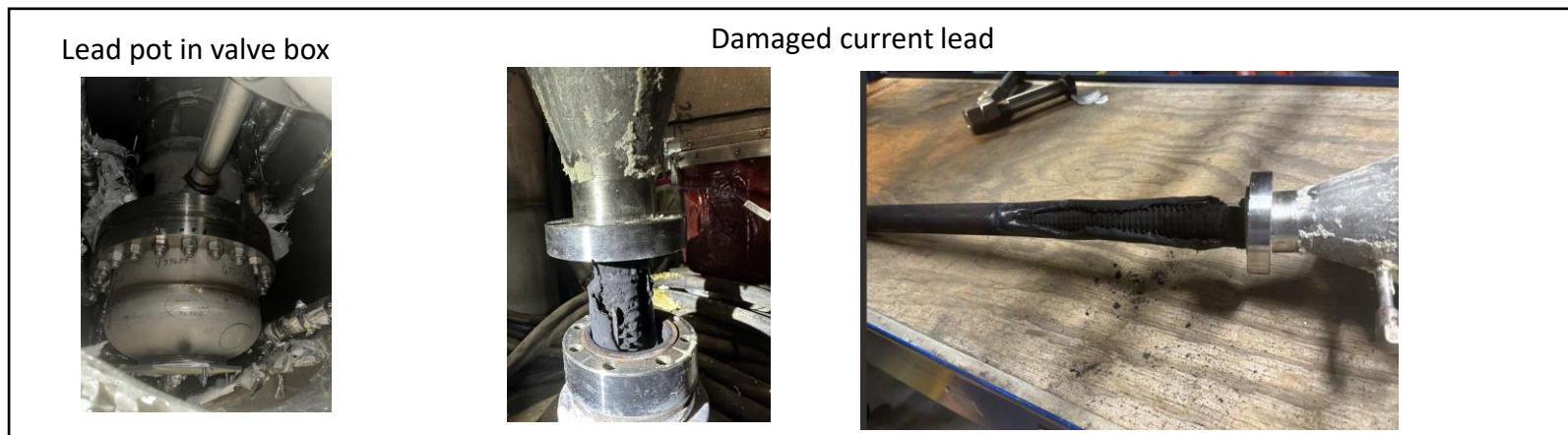
Safety

1004B "Valve Box" Failure Timeline

- At 12:31 on 1 Aug 2023 a spurious trip of the Quench Interlock System commanded the RHIC power supplies to turn off and for the energy extraction system to begin dissipating the stored energy in the Blue Ring. At 12:39 the Cryo control room informed the MCR that the Blue Valve Box in 1004 B was venting Helium to the exterior of the building.
- Decision to end RHIC Run-23 made on 4 Aug 2023. RHIC Valve Box/Short status (30 Aug 2023) at RHIC Retreat.
- Following numerous safety reviews (hazards: electrical, confined-space, oxygen deficiency) and work planning, the valve box was opened on 1 Sep 2023; Helium breach found on warm cable interface at top (of the inside) of the valve box



- Valve box lead pots (LP) accessed on 7 Sep 2023 (VB #1) and 8 Sep 2023 (VB#2). Damage to 12-conductor cold-to-warm, gas-cooled current lead found in LP #1, no trouble found in LP #2.



Helium venting at Bldg. 1004B



1004B Valve Box



Helium leak



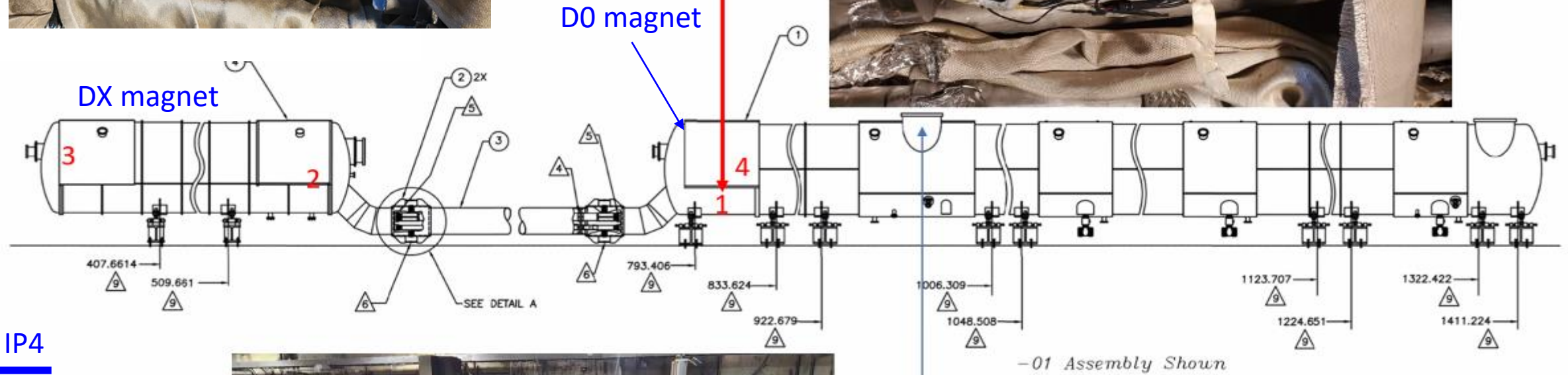
- Throughout this time, extensive electrical tests of the superconducting cable distribution system were made to localize the short(s) of the Blue Ring dipole and quadrupole magnet strings ultimately isolating the presence of a short and unusual voltage tap readings in the tunnel at the IR4 D0 and DX magnet interface in the RHIC tunnel.

- “splice cans”, which provide electrical continuity of super-conducting cables (locations of suspected shorts) were accessed starting 18 Sep 22023

Splice can (#1) before opening



Splice can #1 after opening (no trouble found)



to IP4
←



DX magnet

Inside the RHC tunnel

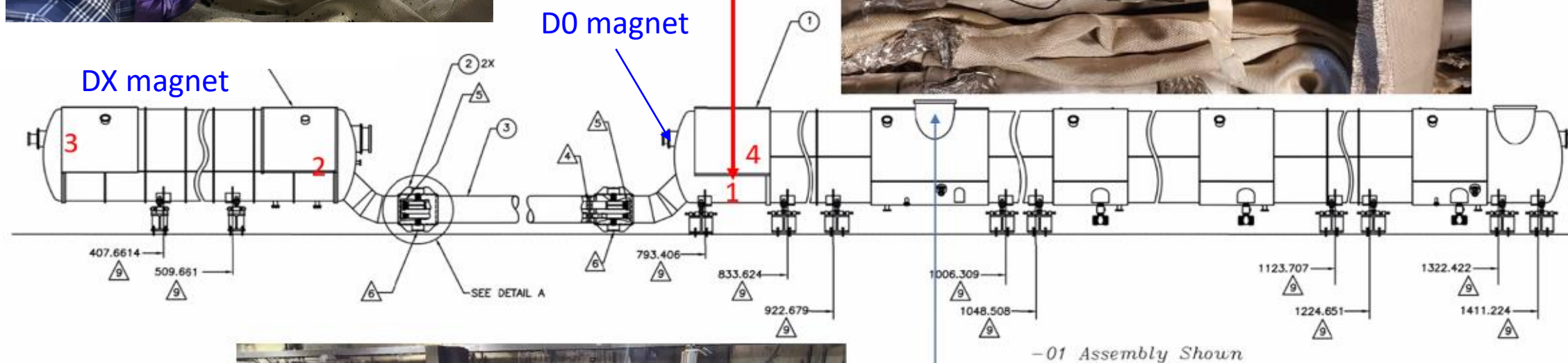
Location of electrical connections to 1004B valve box

- “splice can #2” at IR4 DX magnet found severely damaged 27 Sep 2023

damage inside splice can



splice can #1 after opening (no trouble found)



to IP4



DX magnet



Inside the RHIC tunnel

Location of electrical connections to 1004B valve box

- “splice can #3” on other side of DX magnet found damaged as well 29 Sep 2023
- DX magnet being removed starting 2 Oct 2023

Repair Status, 12-conductor cold-to-warm, gas-cooled current lead in 1004B valve box / lead pot

- Spare lead assembly under test
 - passed vacuum leak checks
 - electrical and pressure tests underway

Spare 150 A current lead



Vacuum test setup (using another, partially-built current lead)



- Plan B (if pressure test fails)
 - build new lead
 - mine existing lead assembly for parts
 - have identified technician support for this as well as for building new spares

Repair Status, DX Magnet and Splice Cans

- The DX magnet from the tunnel and two other magnets from storage (spare and prototype) being moved to Bldg 912.
- Spare DX magnet to be built-up for installation, tested warm, and re-installed. Scott Seberg is lead engineer.
- Samples of the Cold Crossing Superconducting bus (CCB) will be used to train and test staff on doing the SC cable splices.
- Causal analysis not complete, contingent on inspection of DX magnet.
- Schedule yet TBD, contingent on inspection of DX magnet.

DX Cold Mass/Yoke assembly - without end volumes (from special process spares inventory)



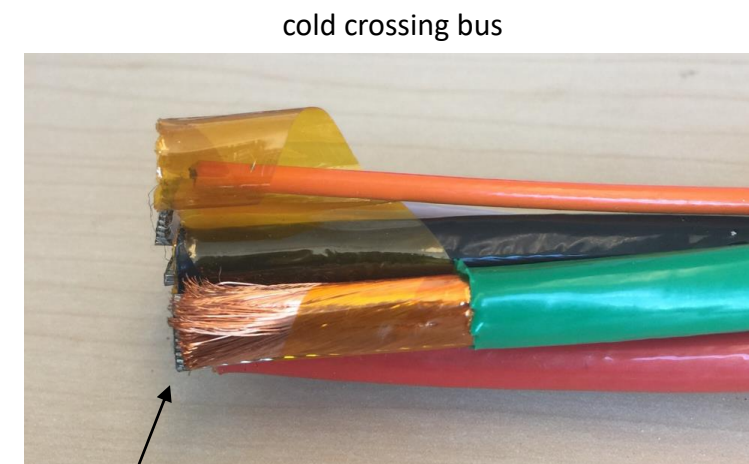
Unreviewed Safety Issue (USI) development

- new issue: Helium release into building - He breach filled 1004B valve box, pressure relief to outside worked as expected but some He released into building unexpectedly (likely that large access port O-rings froze and cracked).
- ODH evaluation underway to determine maximum concentration levels
 - C-AD ES&F engineering evaluating fresh-air makeup rates as input
 - C-AD cryo evaluating leakage rates for components that can fail
- Results will inform if existing ODH monitors (which did not trip, nor did the personal oxygen monitor worn by fire rescue first accessing site) must be made credited controls.
- If that were the case, then the RHIC ASE would need to be modified and approved by BHSO. Scope of that effort, if needed, similar to effort required at sPHENIX last summer.
- Presents potential schedule risk.
- USI development by C-AD ESSHQ (Ray Fliller)



Supplementary slide – details on Electrical Testing of superconducting cable distribution system (25 Sep 2023)

- Background (reference RHIC Retreat - “4B Valve Box Failure”, J. Sandberg)
 - The energy extraction system worked as intended (post mortem data).
 - But after about 50 ms a ground fault was detected in both the Blue Main Dipole Bus and the Blue Main Quadrupole Bus.
- Subsequent measurements showed that all the Trim Quadrupole (TQ) magnets were also shorted to ground. The place where the TQ, Quadrupole, and Dipole magnets are in close proximity is in the cold crossing bus (CCB) that runs from the valve box to the magnets in the ring.
- Results from electrical measurements (applying a floating current source to various portions of the Blue Main dipole bus and measuring the voltage drop to ground at various voltage taps and power supply input leads):
 - Measurements showed high resistance somewhere either in the cold crossing bus
 - between the 4 o’clock side of the valve box to the D0 magnet, or
 - the cold crossing bus to the 4 o’clock DX magnet.
 - Further measurements indicate there is a ground somewhere between the 4DX and 4D0 Magnet.
- The splice box at the D0 magnet has been opened and the return bus has been isolated. Measurements suggested a ground either in a short section of cold crossing bus or the DX magnet, or in the cold crossing bus between the DX magnet and the valve box.
- Measurements on the rest of the return bus going to the other DX magnets indicated 40 ohms to ground which is not understood.



flat superconducting
cable (hard to see)

Late addition (3 Oct):

The very last sentence mentions the 40 ohm measurement that as not understood. That value has increase to many megaohms after the bad splice joints were opened. It was an artifact of all the cables in the spice can being shorted together and the soot that covered many things.