S:IS1 THICK SEPTUM REPLACEMENT AND RECOVERY

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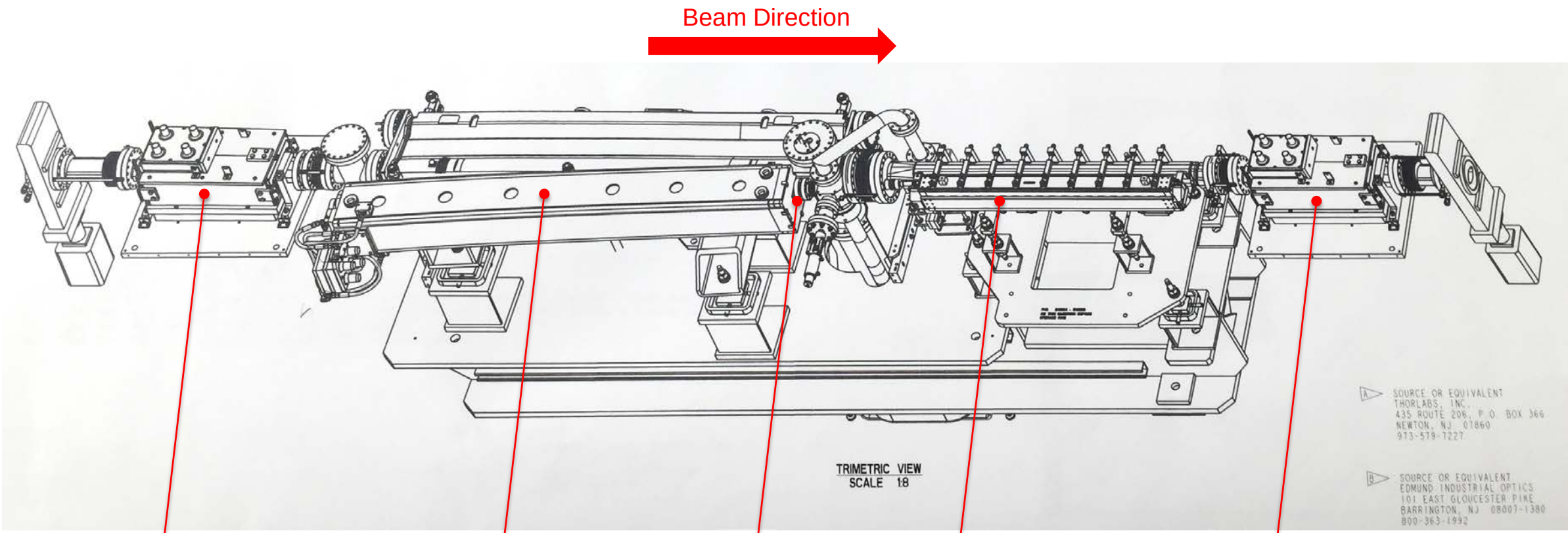
September 30, 2019
Updated October 8, 11, 18 and 22, 2019

BACKGROUND / PROBLEM

- First manifestation of an issue on Tues Sept 24:
  - The S:IS1 septum (thick septum) in Sector 39 of the Storage Ring (SR), pulses once and shuts off
    - Normal operation at 1200 volts (600 A peak current in waveform)
    - Pulses once then shuts off at approximately 300 volts
    - S:IS2 (thin septum) appeared to be functioning normally
  - PS Group suspects a short but needs to troubleshoot supplies, cabling and magnet assembly.
  - Machine studies cancelled as of Tues evening to allow for troubleshooting and repair, if required.
  - Any booster beam directed to the BTX line and dump.

ORIENTATION



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APPROACH / RESULTS

Tues Sept 24

- Troubleshooting started of affiliated systems, components
- 5 AM start Wed with LOTO. Troubleshoot power supplies, cables, isolation and dummy load testing, testing of thin septum and thick septum magnet v. nameplate rating.
- HP survey in tunnel completed
- Spare thick septum located, swiped by HP. Spare later moved to start electrical testing.
- WCD generation started, in addition to all permits (RWP, CCWP, WR)
- Other support groups notified of extended hours support
- POCs identified for duration of work.
- DOE BES notified Wed afternoon

Wed Sept 25

- Diagnostic testing completed. Decision to replace circa 11 AM. Spare assembly tested with local SR water and power.
- Removal/installation time with bake out on order of 3-5 days.
- X-ray Ops messaging start; stating issue and low probability of infringing on Oct 1 user run start.
- Shift schedules updated; replacement task punch list developed for status meetings
- WCD 66112.0 approvals and authorizations, RWP and CCWP all completed by COB
- Pre-job brief with RWP conducted in MCR
- ALD walk through in evening to emphasize safe, controlled manner for work and stop work authority
- Spare installed and final alignment completed as of ~10 PM

Thurs Sept 26

- VAC Group arrival at 6 AM to start wrapping / heat tape for bake out
- Spare bellows assembly located and installation started, after discovery of dented convolutions on downstream assembly.
- Wrapping completed and bake out started
- Plan still targets handover to AOP / MCR on Sunday evening

Fri Sept 27

Sat Sept 28

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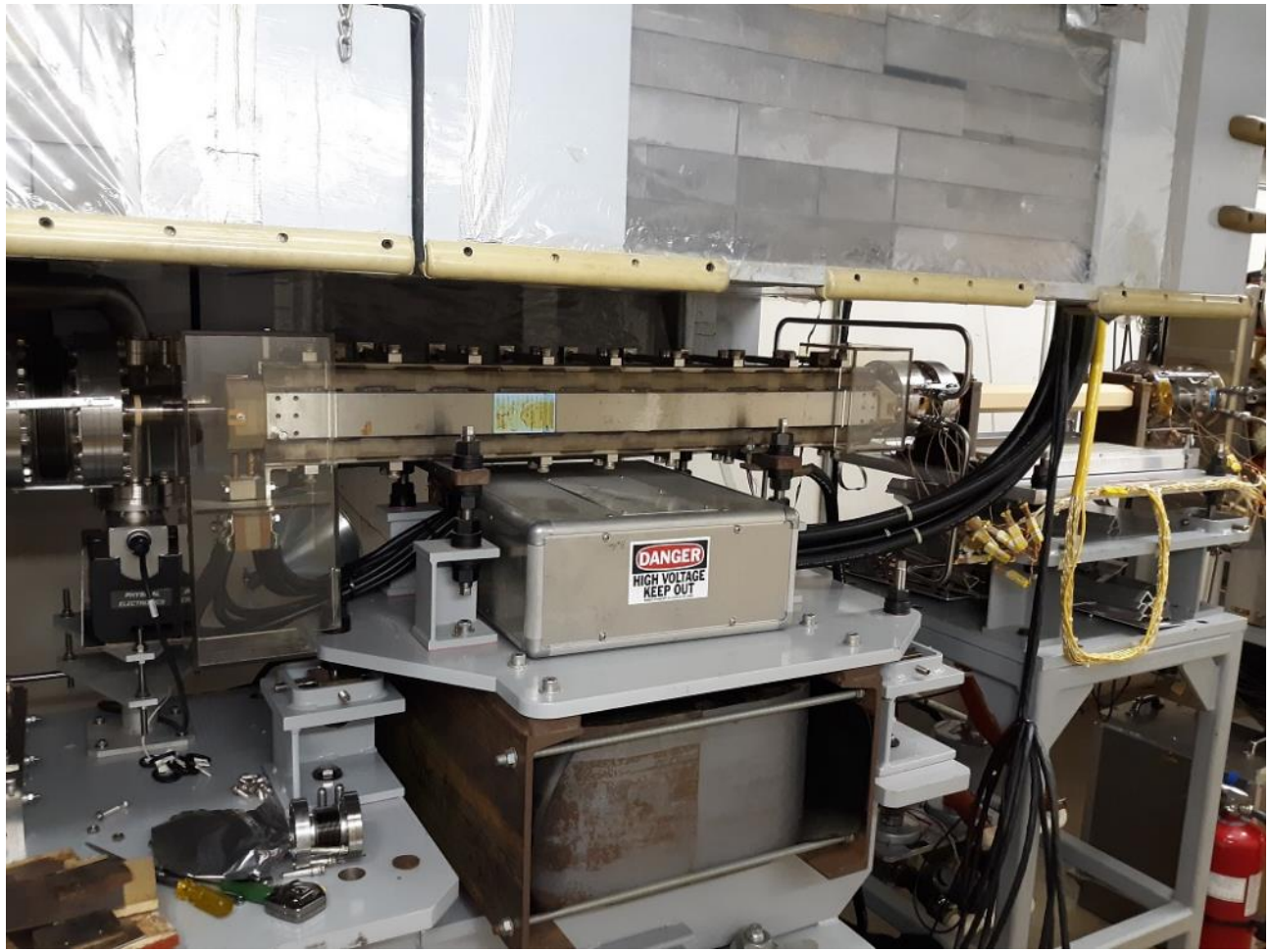
REPLACEMENT EFFORT



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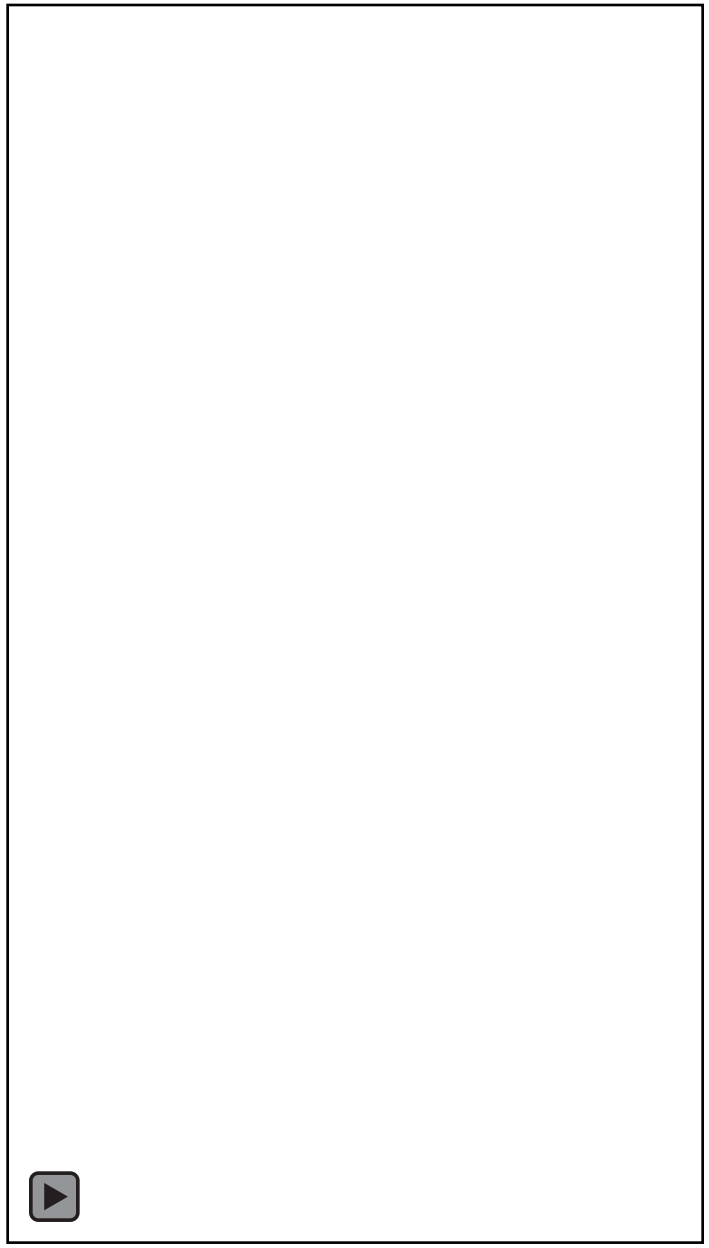
APPROACH / RESULTS

- Sun Sept 29:
  - As of 8:30 AM status meeting, MOM had turned off all heaters and started clean-up as of 6 AM
  - Leak checks to be performed, but current (good) vacuum readings in multiple locations signal good leak performance
  - Once cooled, magnet checked again electrically and then final alignment check
  - Kicker magnets reassembled, water and power connected, diagnostic connections made (BPM cables) and then shielding placed back into position
  - Calls sent out to HP, ASD/DIA, ASD/PS, FAC in anticipation of being a few hours ahead of schedule
    - 15:35 – PS Group satisfied with S:IS1 test results.
    - 15:51 – Good beam through the injectors.
    - 17:38 – Louis Emery is verifying SR injection.
    - 20:09 – Injectors recovered.
    - 20:13 – Beam has been injected into the SR. Downtime #107088 has ended.
  - **Successful return to user operation on schedule by 8 AM October 1st**

THE NEW ISSUE

- After a week of flawless operation…



Video of water leak – upstream end of S:IS1

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APPROACH / RESULTS

Mon Oct 7

- A significant water leak appears. Coming from the center of the thick septum magnet.
- Not repairable and not present when spare was tested before installation.
- Coils blown out with dry nitrogen. Fans left on overnight. Intention to run at reduced power to forego water cooling.
- Spare preparation started in parallel. Messaging started on Tues to users.
- MOM and PS Group in at 6 AM for testing, after LOTO and switchgear racking.
- First tests: Inductance and DC resistance well below nameplate rating, at an inoperable level.
- Second tests (3 hours later): Repeated as inoperable results. DOE BES notified.

Tues Oct 8

- Successful pulse testing (following other tests) of spare in Storage Ring tunnel
- Spare moved to Bldg 382 for vacuum chamber cleaning / certification
- Vacuum leak discovered and repaired during certification
- Decision to forego bake out to let roughing + ion pumps achieve minimum acceptable vacuum for injection
- Replacement task list and schedule developed for replacement effort
- Difficult installation completed with final alignment late Wed evening
- Projection pump down following installation will start by late evening. Targeting 10^{-7} or 10^{-8} scale vacuum by Thurs morning.

Wed Oct 9

- Overall vacuum level at 10^{-7} level, later slightly improved to just inside 10^{-8} range
- Throttle valve added to reduce water flow to minimum cooling required, as conservative measure
- Flag station repaired and camera installed in downstream window from septum.
- All work groups have completed scope and exited the SR tunnel as of noon
- S&A remains on call by MCR, if needed, after first beam diagnostics
- Projection refined that return to user operations could occur by 8 AM, Friday, October 11
- 102 mA achieved by 1 AM Oct 11, shutter permits at 8 AM

Thurs Oct 10

Fri Oct 11

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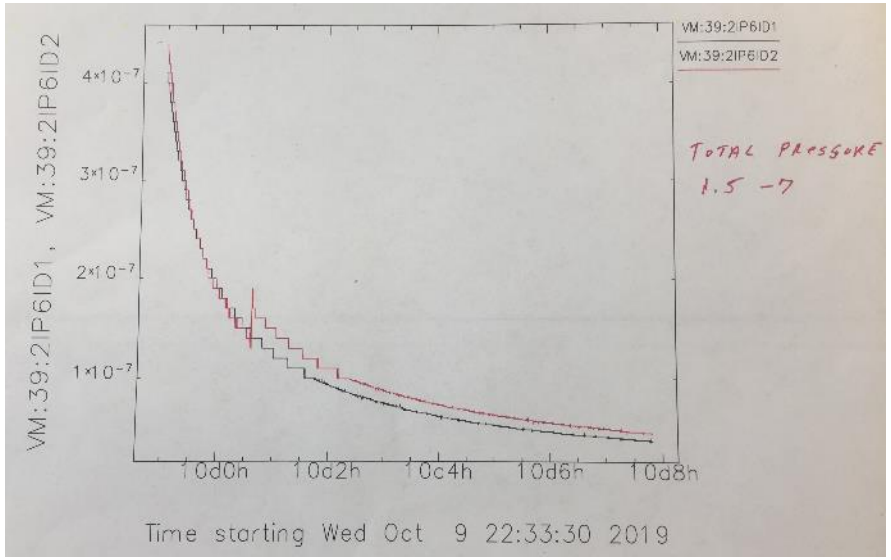
REPLACEMENT EFFORT

On-hand spare injection septum installed as of evening of Oct 9



Minimum vacuum for injection achieved by morning Oct 10

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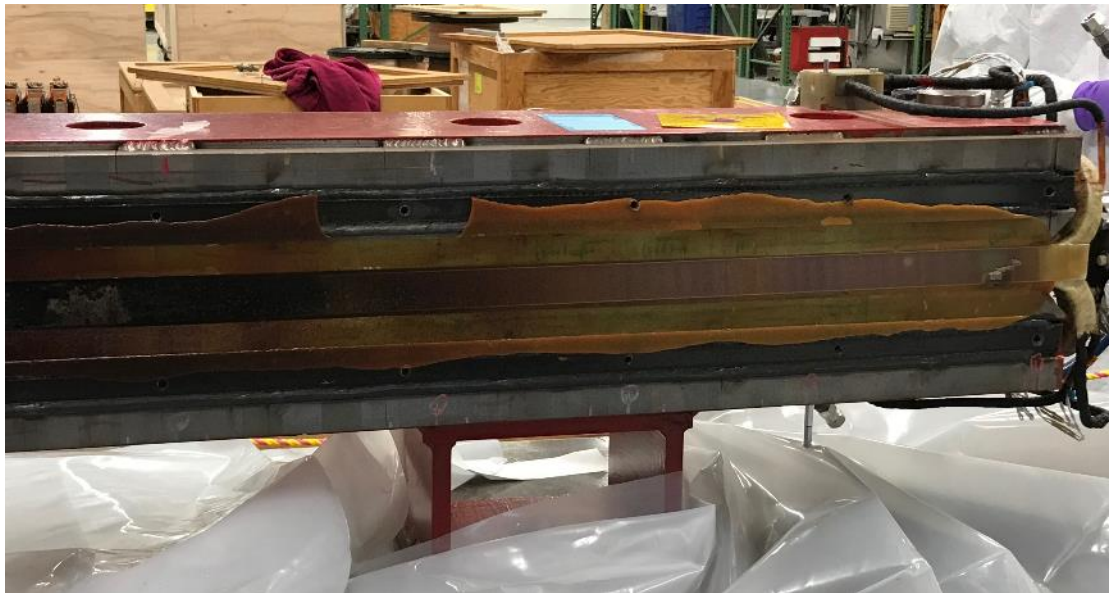
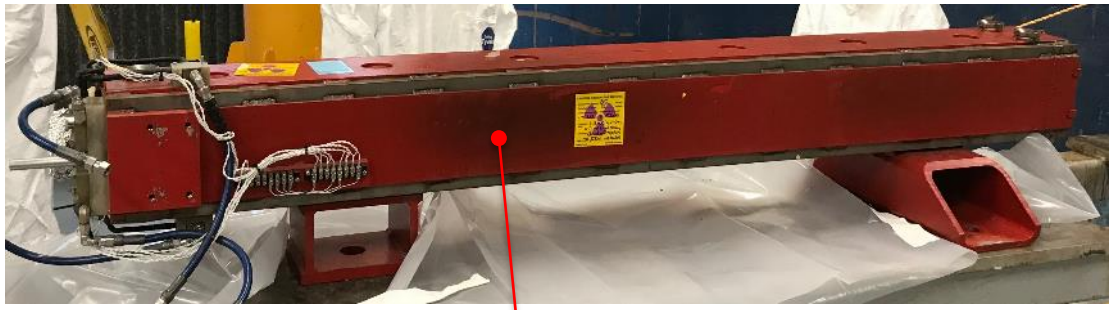
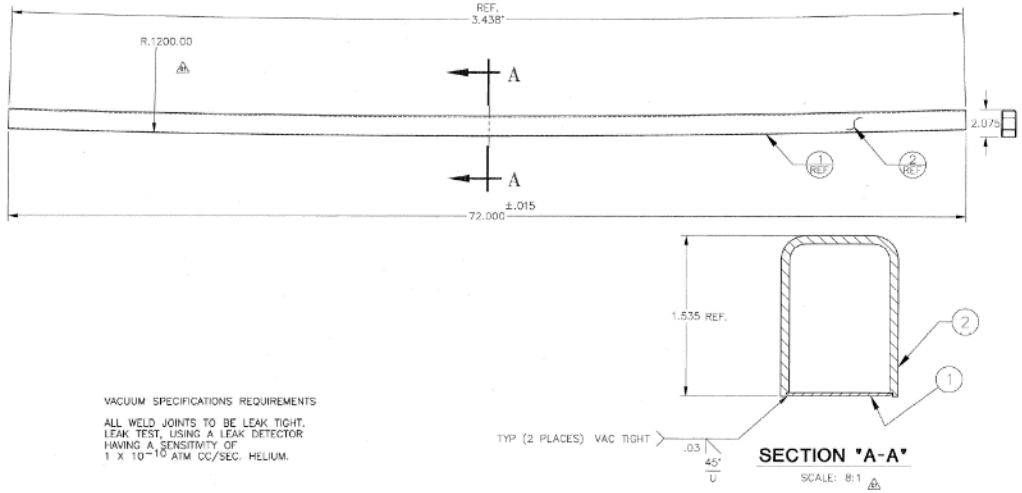
ROOT CAUSE AND CONTINGENCY DEVELOPMENT



Discoloration noted in magnet coil/epoxy assembly after side plate removed on first failed injection septum magnet

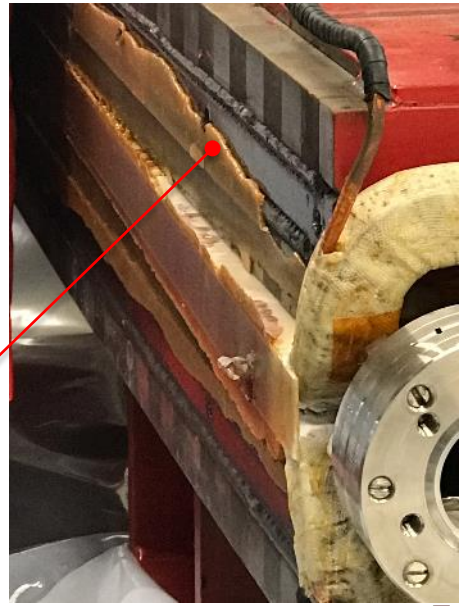


Discoloration noted on plate opposite of removed side plate, on first failed injection septum magnet



Injection septum vacuum chamber (weldment subassembly)

Loose laminations as-found on first failed septum



Mechanical separation of epoxy from magnet core

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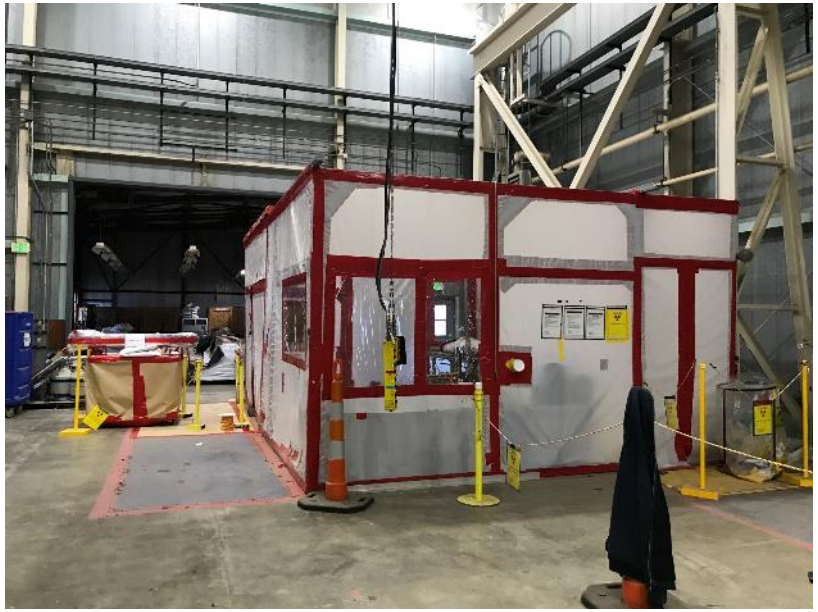
ROOT CAUSE AND CONTINGENCY DEVELOPMENT



First failed septum prepped for entry into Bldg 367 work area on October 16 (left)

End pack machining step and separation from magnet core (above)

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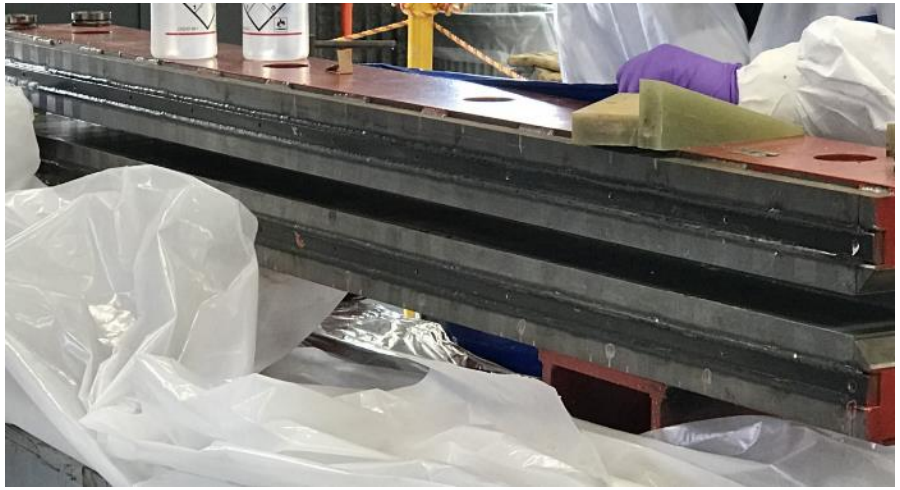
ROOT CAUSE AND CONTINGENCY DEVELOPMENT

Discoloration with magnet coil, epoxy, chamber removed from core

Separation of laminations and discoloration corresponding to location in image above



Cleaned magnet core as of Oct 22 (above)

Machined end of septum, showing location of separated, broken laminations

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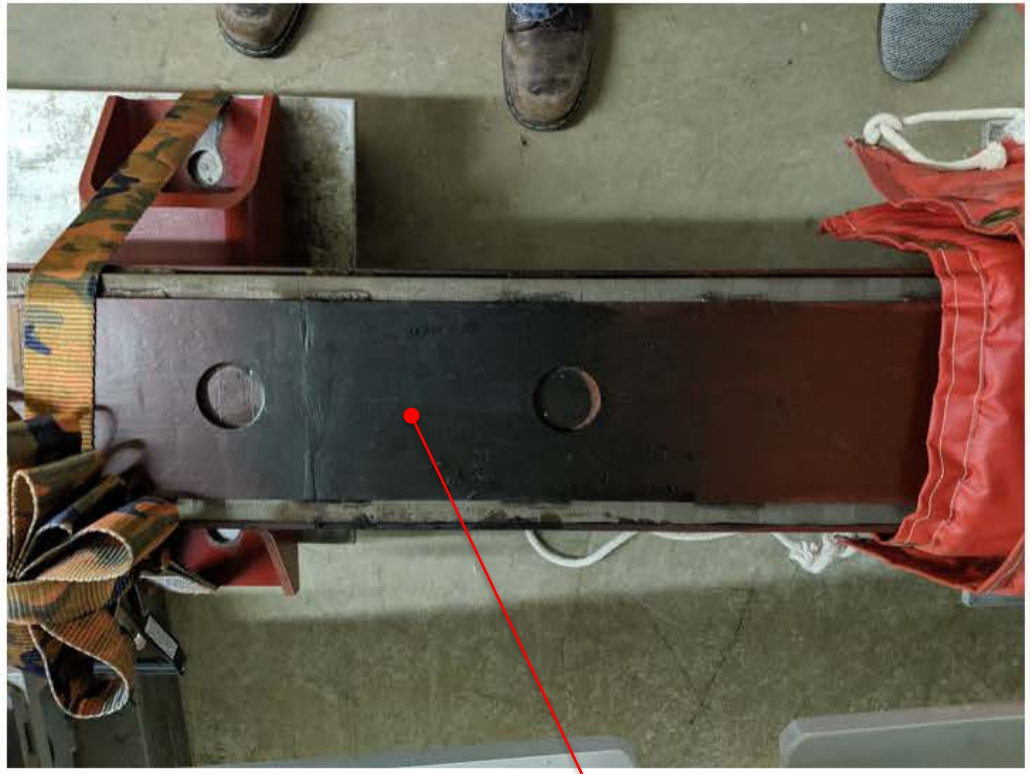
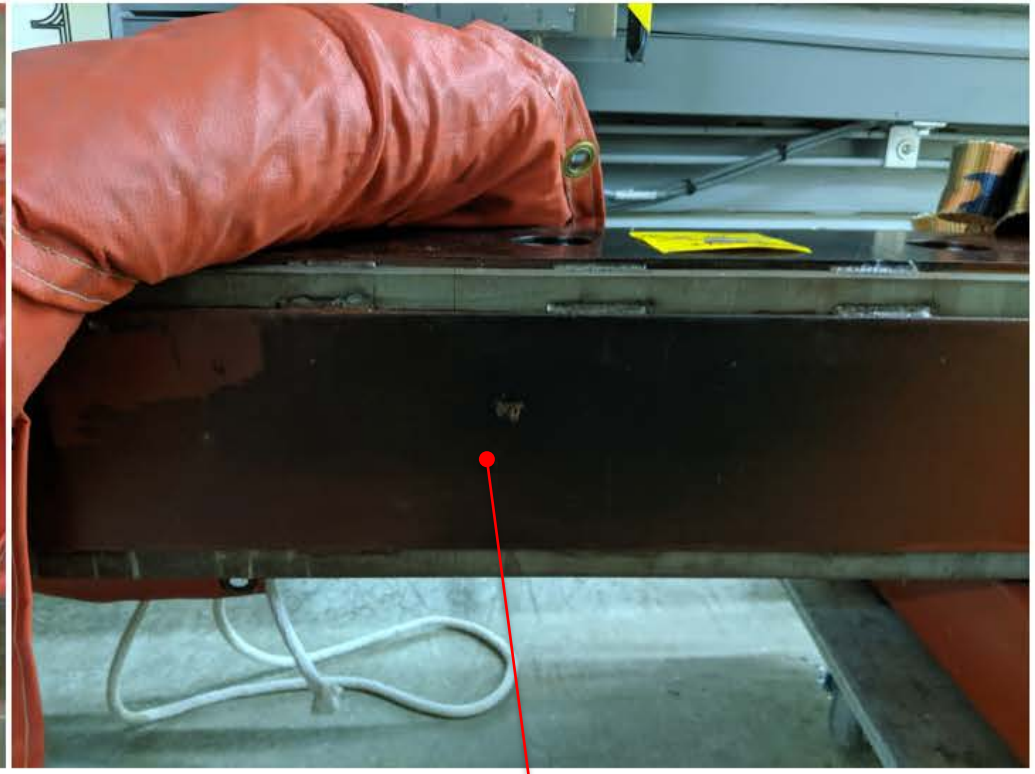
ROOT CAUSE AND CONTINGENCY DEVELOPMENT



Significant discoloration on top of downstream end second failed injection septum, as found after removal and placement in Storage Ring tunnel



Significant discoloration noticed on side of second failed injection septum

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ROOT CAUSE AND CONTINGENCY DEVELOPMENT

Spare Booster extraction thick septum assembly in crate in Bldg 378

Spare septum magnet coils (3) in spare stock, from circa March 2004

Calibrated tool for epoxy separation

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COMMUNICATIONS

- Communications and user impact
  - Replacement / repair team status meetings in rally point of MCR up to 3X per day
  - DOE BES notification early and ongoing for both issues
    - Additional update provided during previously scheduled DOE-APS Operations bimonthly call
  - Xray Ops notification to users on Oct 8. Estimated 1-week duration to return to user operations by Oct 15
    - Due to vacuum progress, duration significantly decreased after spare installation
  - At least daily updates through duration of downtime made via Xray Ops
  - APS website updated for user notification

LESSONS LEARNED

- Extremely robust response by all personnel involved to get to recovered state in both failures
  - Too many people to mention. Groups include PS, MOM, VAC, AOP, MCR, DIA, EFOG, HP, FAC, Rigging & Lifting
- Work performed safely and in line with WPC expectations
  - Task based WCDs generated specifically for replacement scope (66112.0) and, separately, disassembly and repair (66278.0)
  - Authorizations of personnel performed in the WCD via Aware application
  - Access protocols and work clearances followed: WR, CCWP, RWP, pre-job briefs
  - Required personnel / groups given advance notice of changing schedules and off-hours need
- Lessons learned / next steps
  - Evaluate failed thick septums for failure mode. Continue expediting repair efforts to ensure, at minimum, a functional spare is on hand. All material and parts on hand. Reassembled and tested spare forecasted to be complete by Wed Oct 30
  - Review / re-catalog and determine risk profile for special, one-of-a-kind components like septa, kickers, RF components, power supplies etc. which could significantly impact user operation time. Pending
  - Immediately order and expedite replacement bellow assemblies unique to thick septum assembly. Completed
  - Increase concentration of technician base trained and certified to Rad Worker 2 level. Pending
  - Optimize switchgear racking process. Consumes downtime waiting for permit generation from ESC rep. to allow Building Maintenance to then rack switchgear. Scheduled for Nov 8th with Electrical AHJ, ESHQ reps

BACK UP SLIDES

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APPROACH / RESULTS