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Fluid Systems Design and Quality Assurance Management in Accelerator Applications

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ESS Collaboration Meeting

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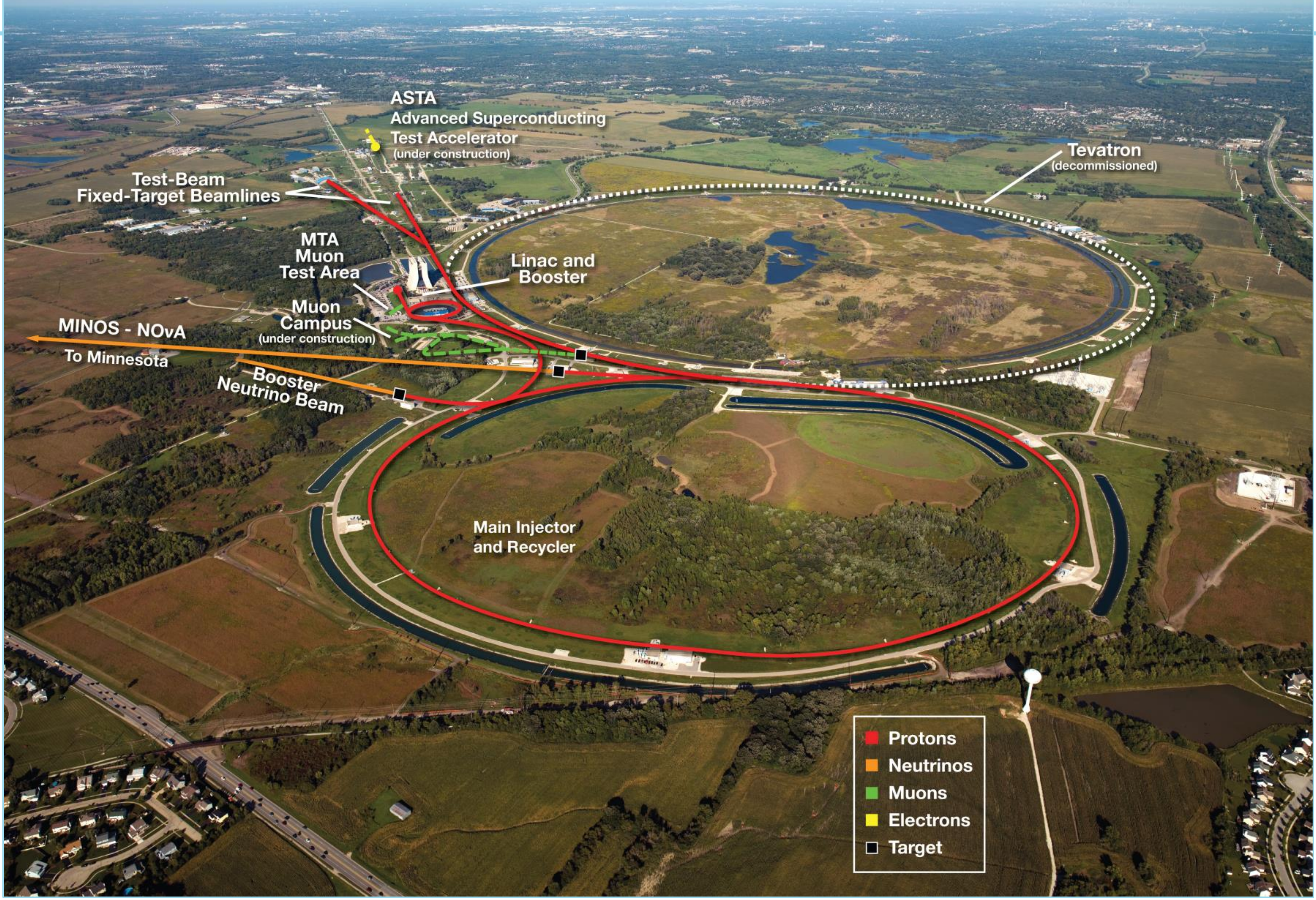
Charge

- Design and Quality Assurance Management in Accelerator Applications
- This topic will include discussions about water quality management such as copper oxide production and control requirements and impact on accelerator operations reliability. This topic will also cover aspects of LCW system design and its impact on project management, including construction, scheduling, and layout of such systems.

Outline

- Overview of LCW and RAW Systems
- Challenges of piping system Design, Installation, Commissioning, Operations
- Radioactive Water (RAW)
- Copper Oxide Particulate

Fermilab Accelerator Complex 2012



Overview

- Typically Category D or Normal Fluid Systems under the ASME B31.3 Piping System code
- Over 50+ LCW and RAW Systems
  - Differential pressures ranging from 10 PSID to 300 PSID.
  - System flows ranging from 5 GPM to 8000 GPM.
  - Temperatures range from 80 F to 100 F
  - Conductivities range 1 MOhm-cm to 18 MOhm-cm
- Over 100 compressed air systems
  - Instrument and shop air applications
  - Moisture down to -40F
  - Pressures cycle between 80 PSIG and 130 PSIG
- Other fluid systems (Fluorinert, compressed gases)

Small Systems (Skids) – Proton Source/LINAC

Medium to Large Systems – Muon Campus Delivery Ring

Systems of a Very Large Scale – Main Injector

Challenges

Engineering Design Process – Fermilab Engineering Manual

- Requirements and Specifications
- Engineering Risk Assessment
- Requirements and Specifications Review
- System Design
- Engineering Design Review
- Procurement and Implementation
- Testing and Validation
- Release to Operations
- Final Documentation

Issues We Have Experienced – Design of LCW Systems

- Accelerator component fluid system engineers must be included in the design process of the accelerator components.
- Getting up to date component information and drawings
- Correct heat loads at actual operating conditions
- Determining Resistivity ranges
- Types/kinds of controls desired (i.e. temperature, pressure, dissolved oxygen, resistivity
- Obtaining actual operating parameters/expectations.
- Result: Incorrect or improperly sized equipment, schedule/milestone delays

Issues We Have Experienced – Installation of LCW Systems

- Timing issues, scheduling
- Coordinating the timing of installation of components (i.e. power, interlocks, controls, piping
- Coordinating with safety, radiation, manpower, and contractor requirements.
- Communication with the stakeholders: landlords, safety, project engineers, and integration groups
- Walkthroughs, toolbox meetings
- Microbiologically Induced Corrosion (MIC)
- Hydrostatic pressure testing very time consuming, especially for big systems. Testing in sections leads to a more thorough and streamlined process.
- Result: schedule/milestone delays

Issues We Have Experienced – Commissioning of LCW Systems

- Timing issues, difficulty with start-up, trouble-shooting, and corrections, system balancing
- Coordinating the timing of installation of components (i.e. power, interlocks, controls, piping
- Coordinating with safety, radiation, manpower, and contractor requirements.
- Pressure to get the accelerator machine operational
- Effective communication, particularly at startup
- Allowing time for verifying valves, system balancing
- Result; component damage and safety problems

Issues We Have Experienced – Operation of LCW Systems

- Poor communication of failing equipment
- Addressing issues immediately
- Communicating the gradual decline or concerns.
- Mismatch between stakeholder/user expectation and how the system was designed.
- Viewing fluid system like a public utility instead of a critical process.
- Systems tapped in without consequences.
- Negotiating priority. Allowing time for trip/alarm limits validated
- Result: Interruptions to operations, decreased system reliability

Radioactive Water (RAW) Systems

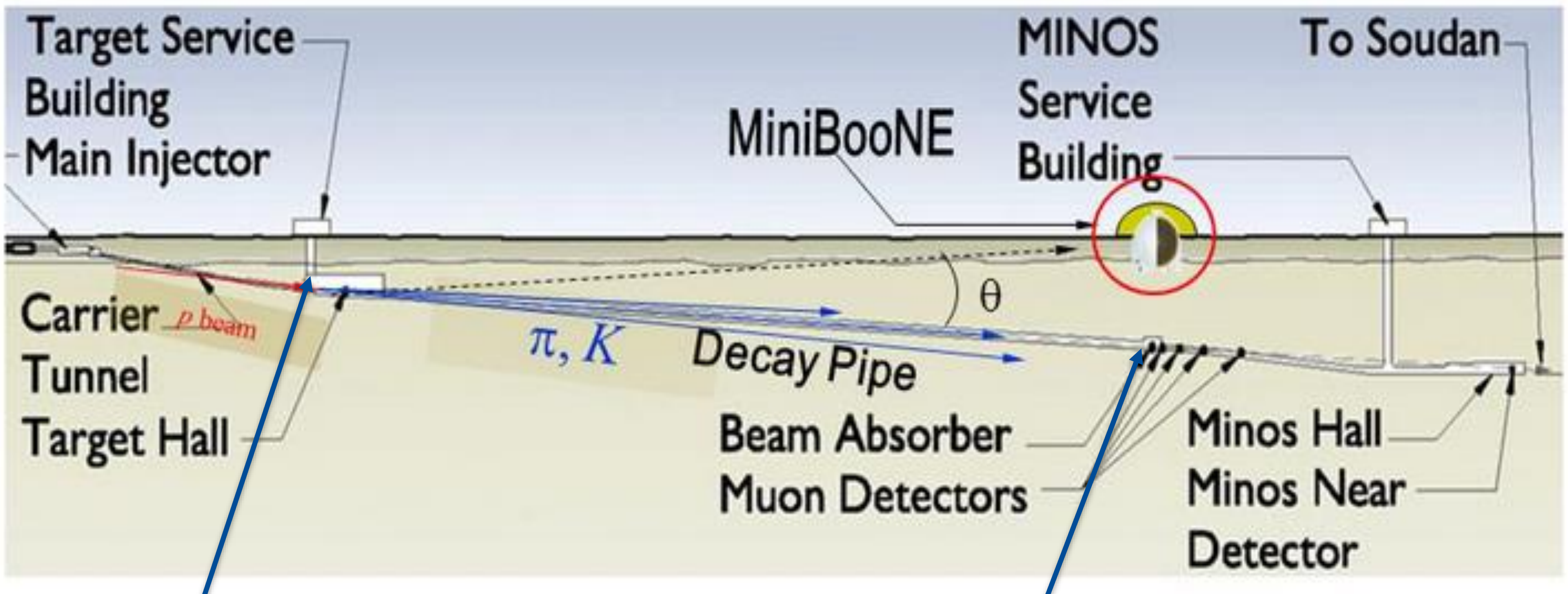
Radioactive Water (RAW) Systems

- Isolated water systems
- Normal Fluid Systems under the ASME B31.3 Piping System code
- Specifically designed to cool highly radioactive devices or accelerator equipment.
- Heat exchange with regular LCW or chill water systems
- Sometimes with an intermediate system in between
- Protects from cross contamination from radioactive water.

Overview

- Introduction to NuMI RAW systems
  - Target Hall RAW room
  - Target Hall DI room
  - Absorber Hall RAW room (Not discussed here)
- Auxiliary fluid systems for RAW systems
  - Target RAW exchange system
  - TGT, H1, and H2 Argon purge systems
  - H1 and H2 spray nozzle high pressure Argon system
  - Absorber RAW exchange system (Not discussed here)
- Future system: H_2 sampling system for H1 and TGT RAW system

Overview



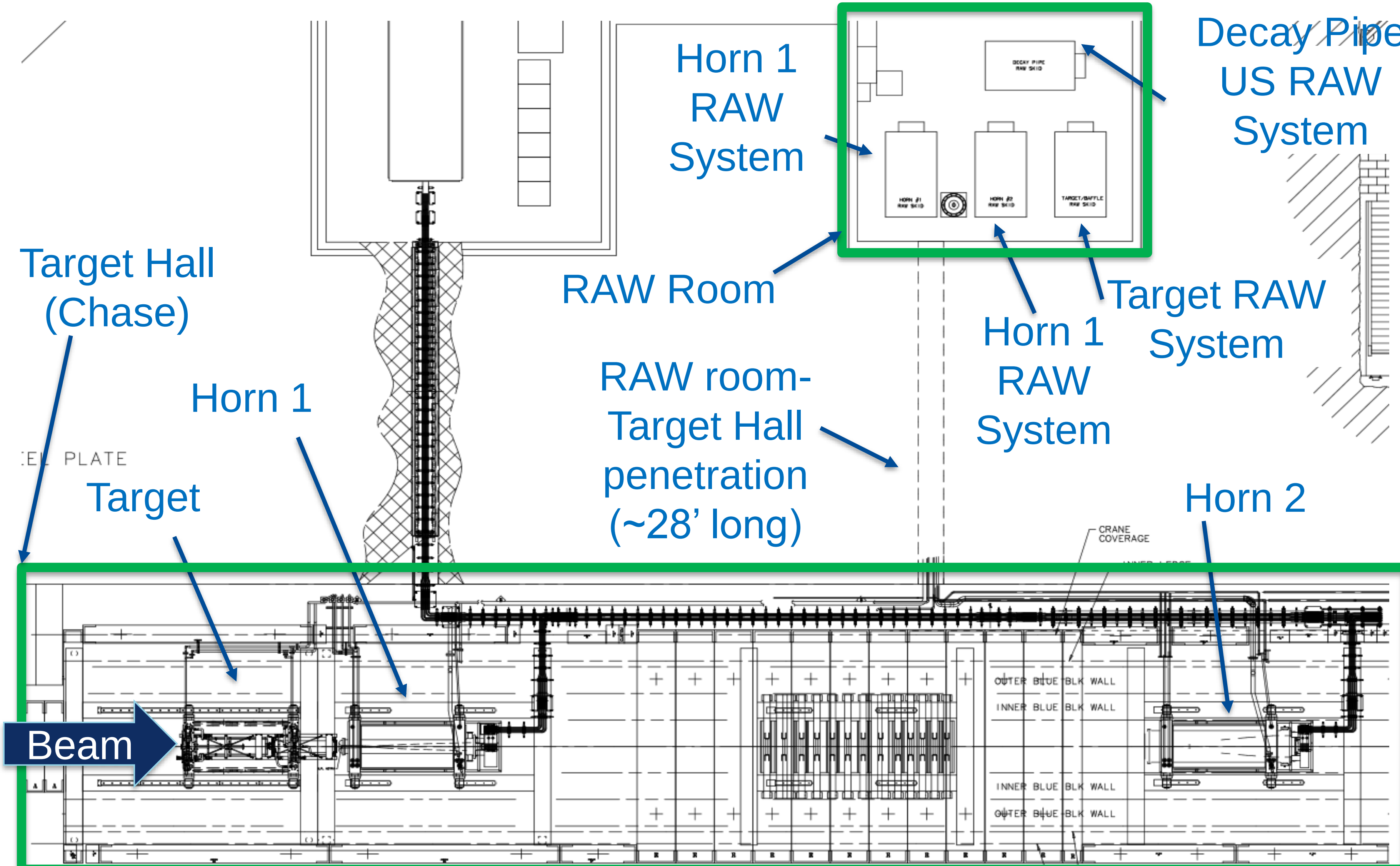
Target, Horn 1, Horn 2, and Decay Pipe US RAW systems

Decay Pipe DS and Absorber RAW systems

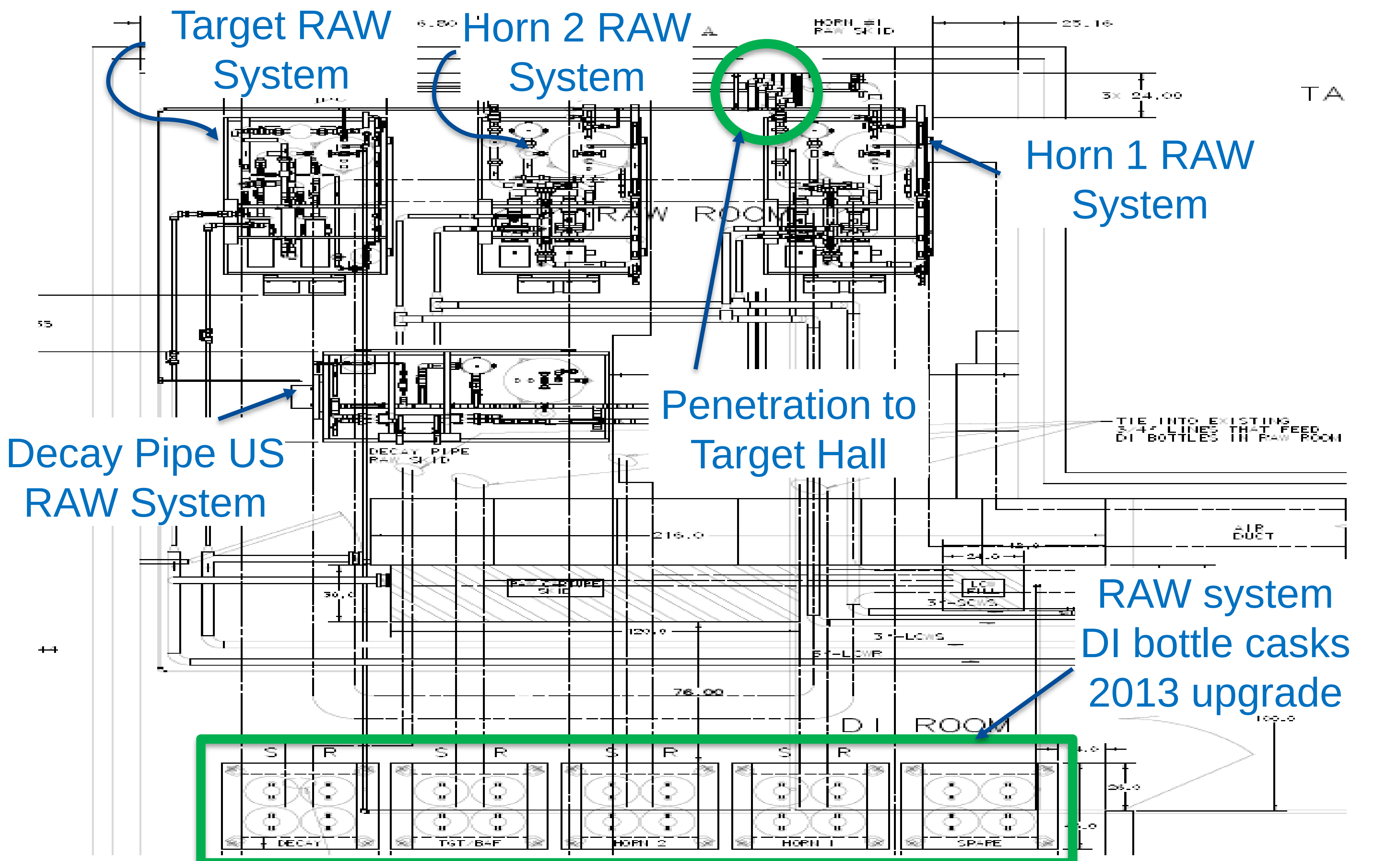
Overview of RAW systems

- Target, Horn 1, Horn 2, and Decay Pipe RAW cooling systems are closed loop systems.
- They provide cooling water to the above components. The water is maintained at a resistivity of 6-8 MOhm-cm.
- There are full-flow filtration and De-Ionization (DI) loops on all of the systems.
- There is a flow, pressure, level, temperature, resistivity, and exhaust gas flow (not on Decay pipe RAW) instrumentation package on all the systems.
- There are other auxiliary fluid systems that support the RAW system:
  - The Argon purge systems to displace the produced H_2 gas.
  - The RAW exchange system to maintain a low concentration of tritium in the RAW systems during operations.

Overview: Plan view of Target Hall



Overview: RAW and DI Rooms



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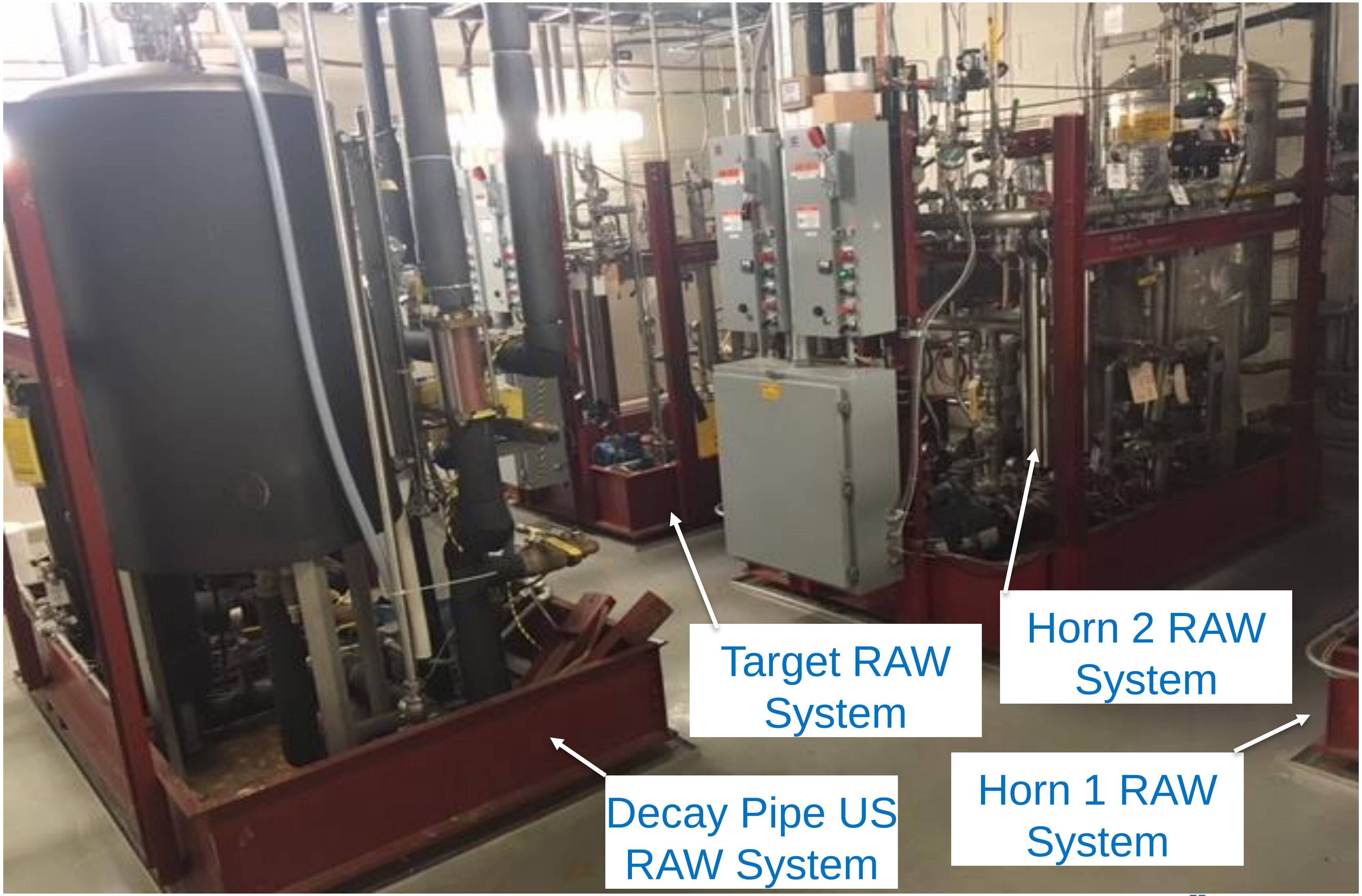
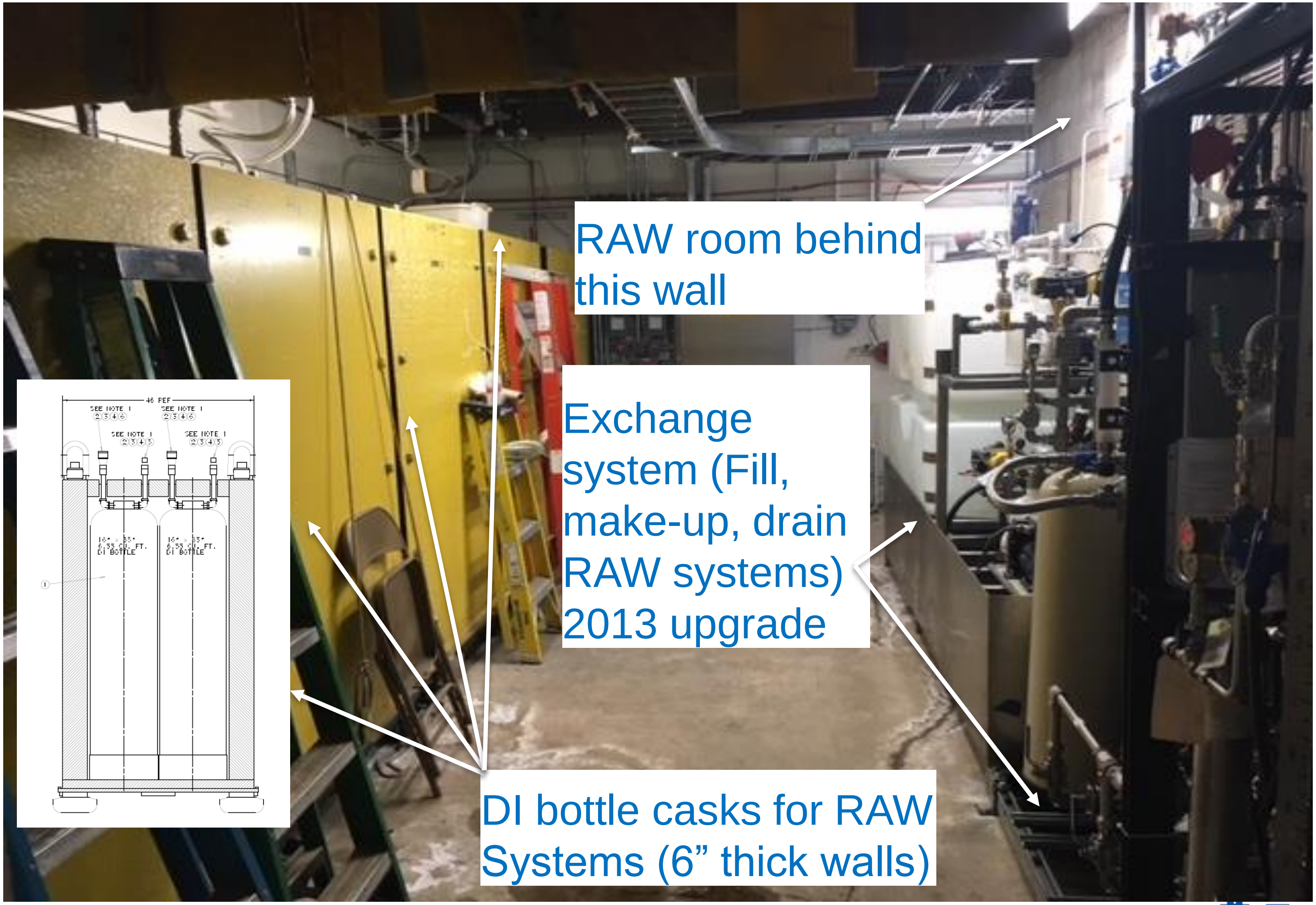
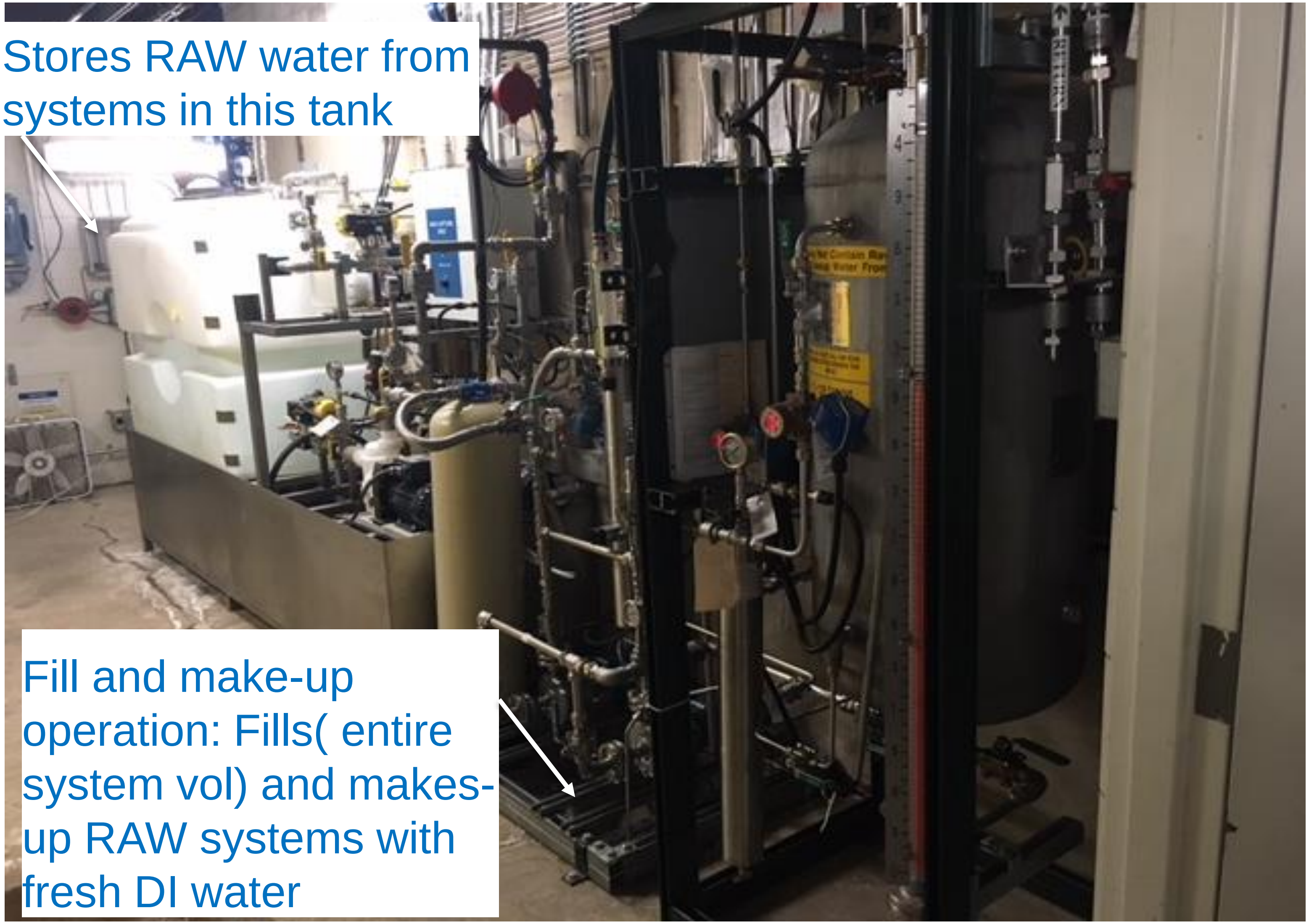
Overview: RAW room



Overview: DI Room



Target RAW Exchange system

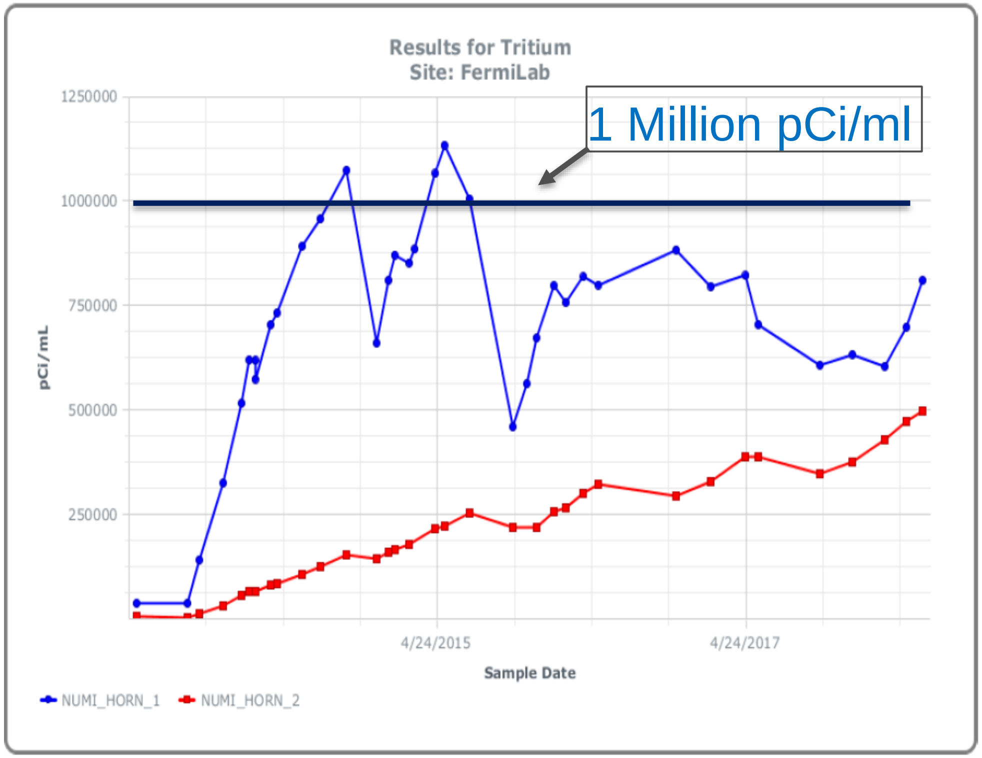


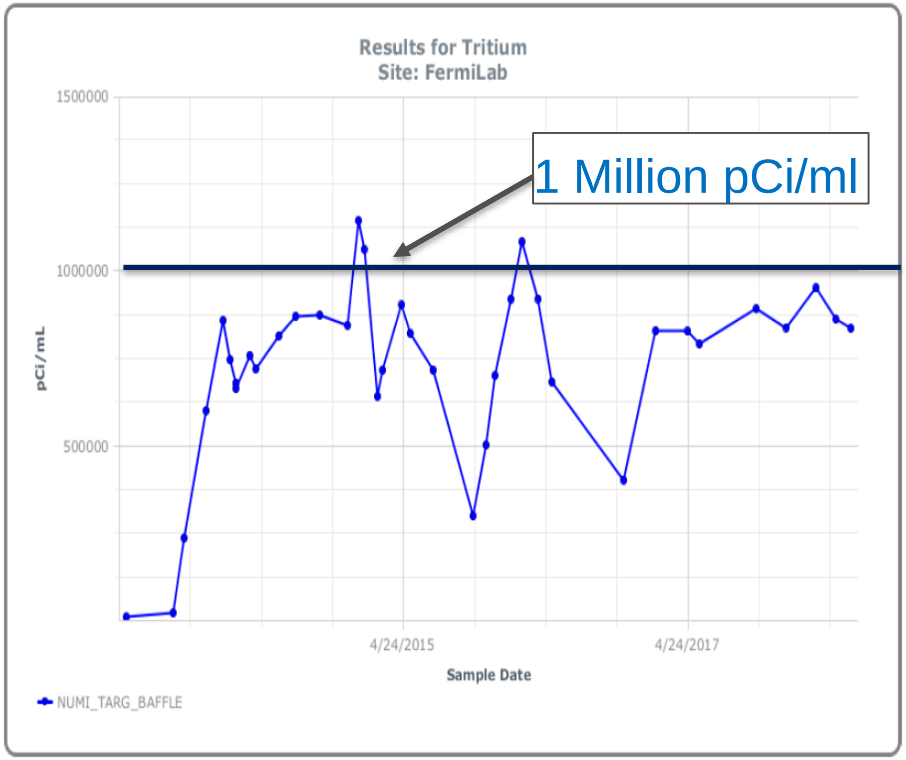
Stores RAW water from systems in this tank

Fill and make-up operation: Fills(entire system vol) and makes-up RAW systems with fresh DI water

Target RAW Exchange system

- During operations, try to maintain tritium concentration to values <=1E06 pCi/ml. This is not a hard limit.
- This is done by draining some water from the RAW systems and adding fresh DI water on a weekly basis.



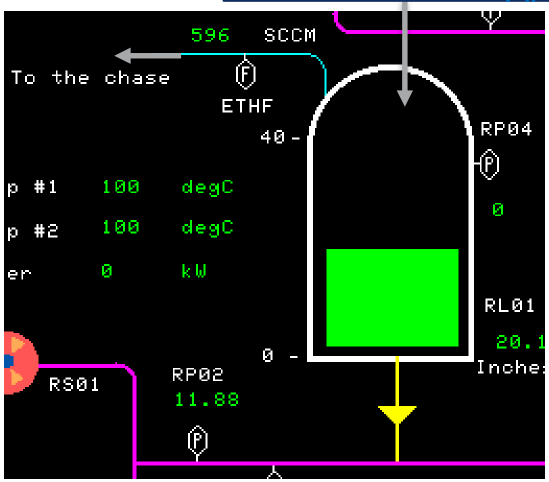


Source: Abhishek Deshpande, Tony Busch, and Matt Quinn

TGT, H1, and H2 Ar purge systems

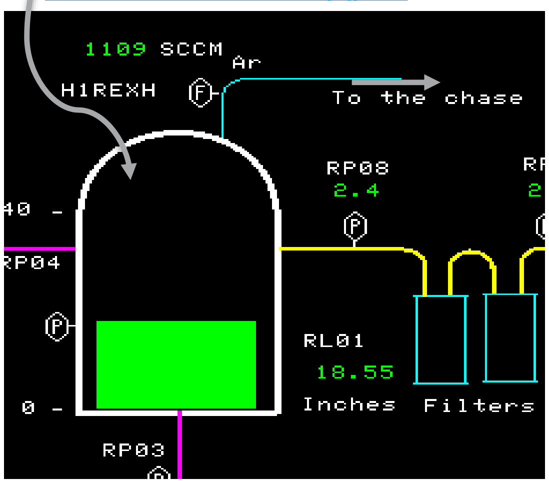
- RAW system expansion tanks have low pressure Argon gas flowing into them.
- This is to displace the H_2 produced during beam operations. Outlets of the tanks open Target Hall Chase.

598 $Sccm_{Ar}$



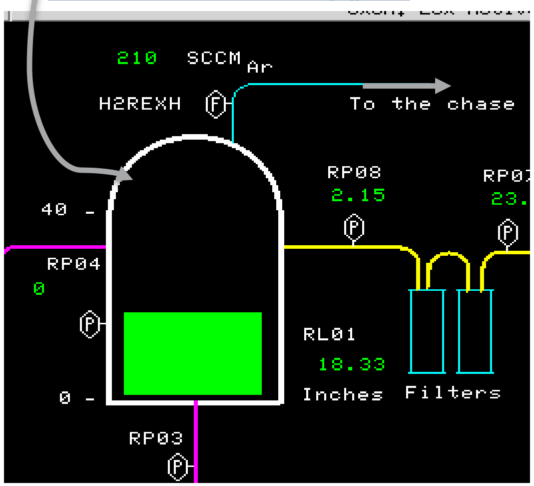
Target RAW

502 $Sccm_{Ar}$



Horn 1 RAW

120 $Sccm_{Ar}$

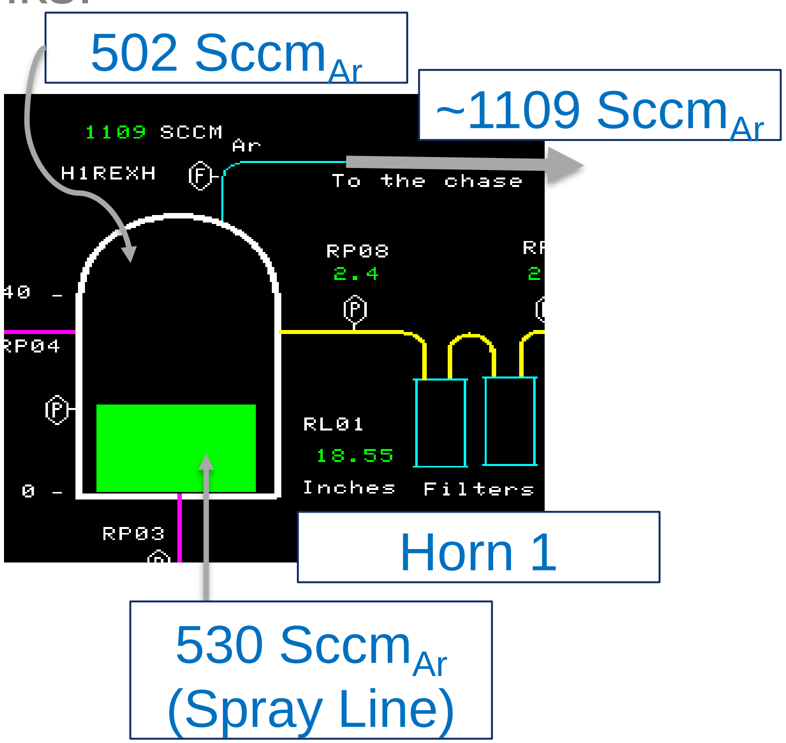


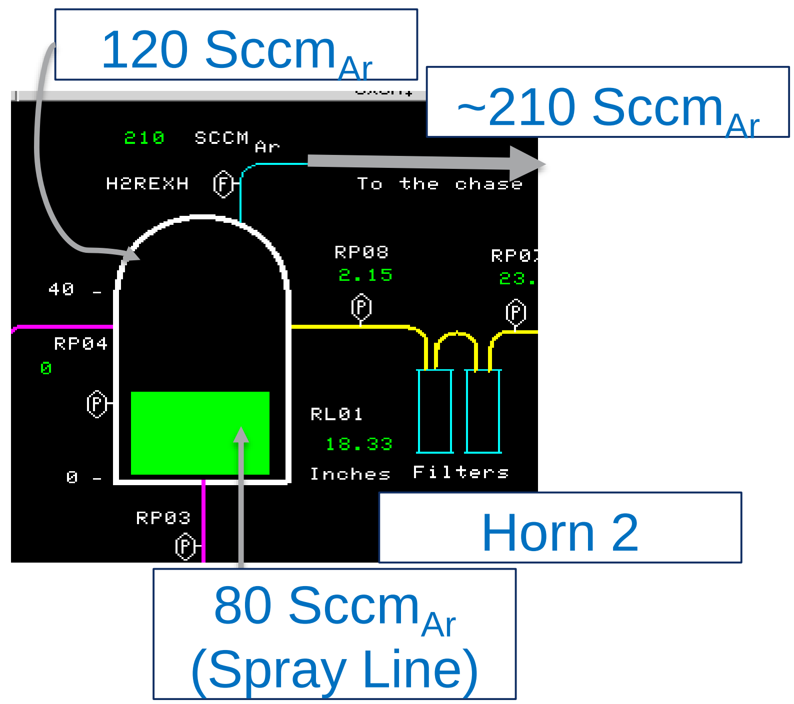
Horn 2 RAW

- Above measurements are made during downtime (Sept. 25 2018) conditions with newly installed gas mass flow meters.

Horn 1 and Horn 2 Spray Nozzle Ar purge systems

- Argon is also induced through the Horn 1 and Horn 2 inner conductor water spray nozzles.
- This Argon shows up on the exhausts of the H1 and H2 expansion tanks:





New instrumentation

- A gas analyzer to measure H_2, O_2, and water vapor concentrations inside the head space of the RAW system expansion tanks will be purchased.

- The sampling line infrastructure has been installed and tested during Shutdown 2018.

Operational experience

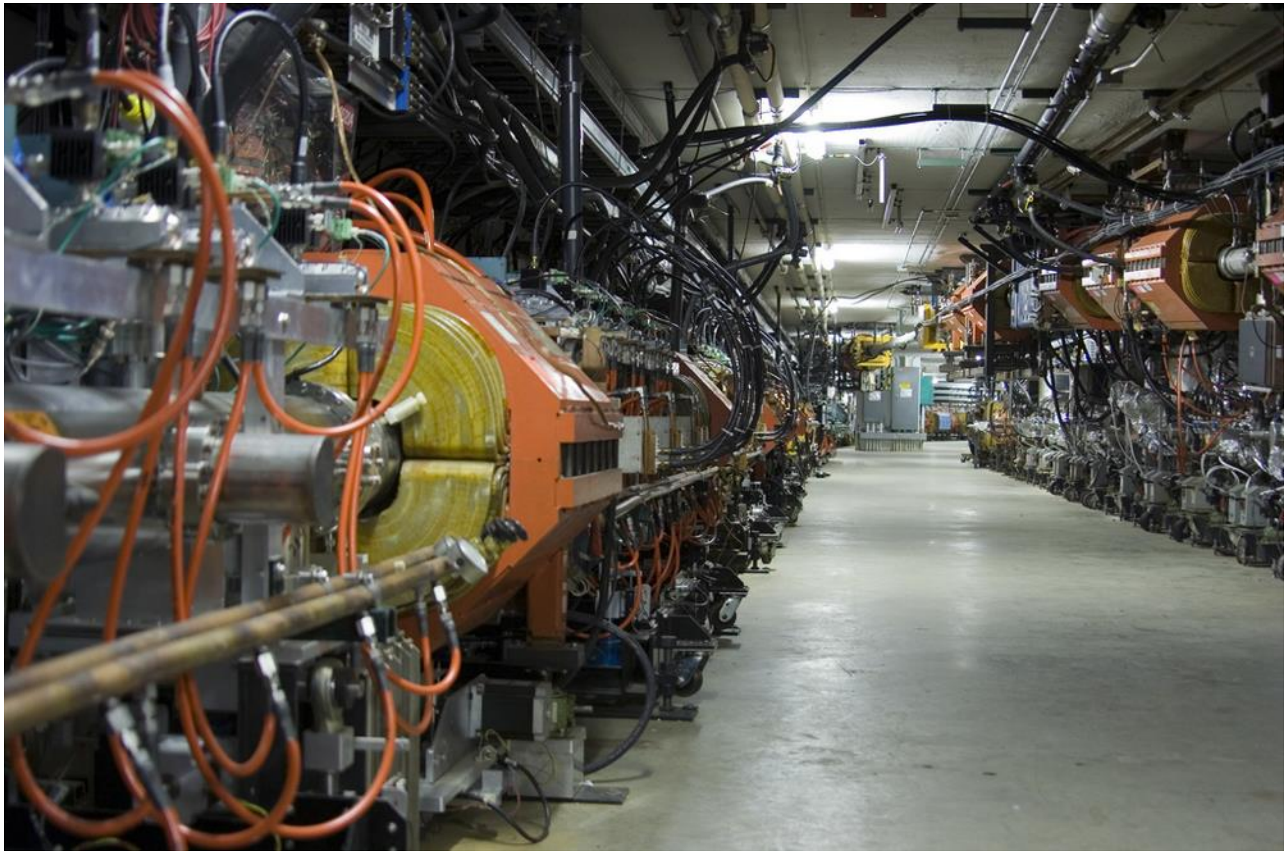
- DI bottles used to be in the RAW room. They have been upgraded, put into casks, and moved to the DI room in 2013. Less radiation in the RAW room. Prolongs the life of the bottles.
- DI bottles have pre and post filters. Increases life of the bottle.
- DI bottles not used continuously, 3-way valve loop maintains system resistivity between 6-8 MOhm-Cm. This also increases the life of the bottle.
- Filter cartridges are changed every 4 months of beam-time. This too prolongs the life of the DI bottle.
- Conventional off-the shelf process instrumentation fails due to radiation in the RAW room. Rad-hard instrumentation or instrumentation with remote signal conditioning capabilities is selected. A radiation map of the RAW room is created by placing dose monitors in various locations. This map is used to install instrumentation that is not rad-hardned.
- Copper oxide is an issue with systems with copper piping: Decay Pipe RAW system. There are 3 full-flow filtration loops with 5 micron absolute filter cartridges. They are replaced every 4 months of beam-time.
- In the copper systems, water is replaced every 2 years.
- Argon purge on all the system expansion tanks prevents carbonic-acid and nitric acid formation.

Copper Oxide

History of the Copper Oxide Problem in Muon Campus (formerly Pbar)

- Oxygen introduced into the LCW system during maintenance activities combined with copper in solution to form copper oxide
- Copper oxide accumulates in the system and plugs narrow flow paths in water cooled devices
- Water cooled devices overheats.
- Shutdown accelerator operations, requiring intrusive back flushing procedures

Copper Oxide



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SOLDER BUILDUP
Handyman

Copper Oxide - Resolution

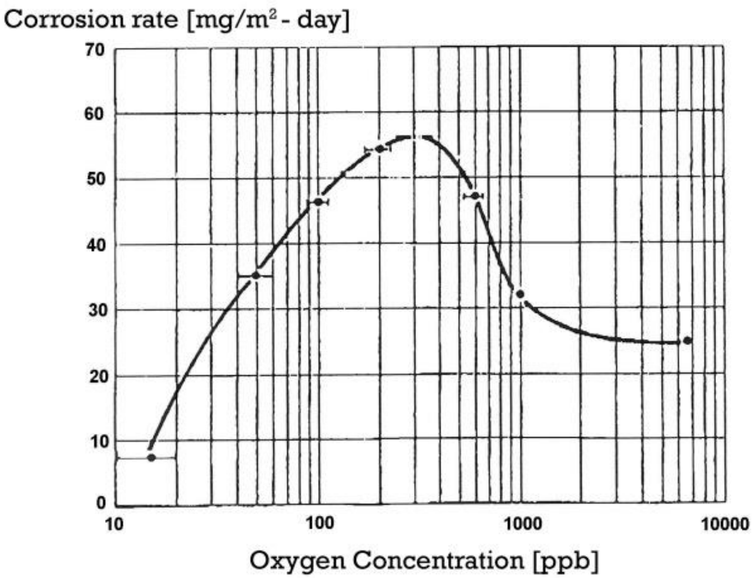
- Monitor, trending of oxygen and particulate levels via DO and TDS sensors
- Remove the oxygen, Prevent new oxygen from entering
- Remove copper oxide particulate, via full flow filtration

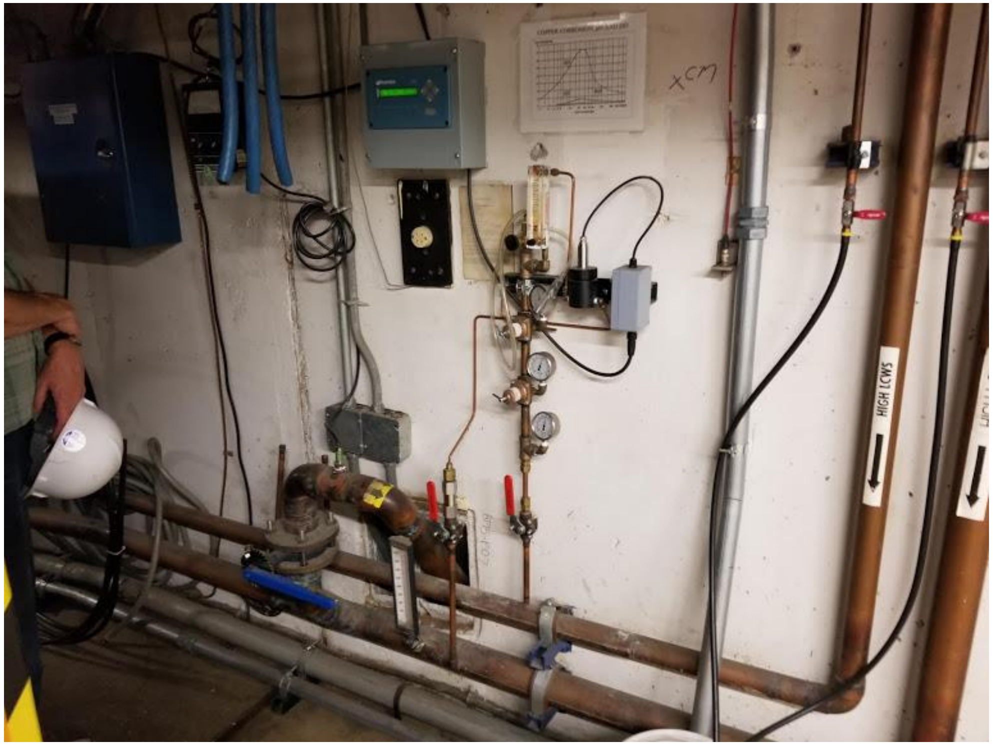
Copper Oxide – Action Plan/Implementation

- – Full-Flow Filtration (PIC)
- – Maintenance Program

Copper Oxide – Action Plan/Implementation

- Dissolved Oxygen/TDS Sensors (PIC)
- High maintenance
- Constant calibration





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Copper Oxide – Action Plan/Implementation

- Oxygen Removal Skid – Liqui-Cel Technology
- Uses Nitrogen gas to pull a vacuum through a cel membrane

Summary

- Fluid Systems require careful consideration, care, and respect.
- Not just plumbing - “Its not just water”
- Fluid systems are critical process systems.
- Serious consideration must be taken regarding
  - Design
  - Installation
  - Commissioning
  - Operation
- Other issues That Require Engineering Input/Consideration
  - Radioactive Water (RAW) Systems
  - Copper Oxide Mitigation

References/Acknowledgements

- The Chemistry Of Copper In Water And Related Studies Planned At The Advanced Photon Source - R. Dortwegt , Advanced Photon Source, Argonne National Laboratory, Argonne, IL 60439 E.V. Maughan, College of Knowledge; Duisburg, Germany D-47198
- Experience With Copper Oxide Production In Antiproton Source Components At Fermi National Accelerator Laboratory- Christine R. Ader (FNAL), Elvin R. Harms, Jr. (FNAL), James P. Morgan (FNAL), Fermi National Accelerator Laboratory
- Abhishek Deshpande, Fluids Machine Engineer, Beamlines and Muon Campus, AD/Mechanical Support Department, Fermi National Accelerator Laboratory
- David Hixson, Fluids Machine Engineer, Proton Source and Main Injector/Recycler Machine, AD/Mechanical Support Department, Fermi National Accelerator Laboratory
- Karl Williams, Deputy Head, Project Engineering Group, AD/Mechanical Support Department, Fermi National Accelerator Laboratory
- Jerzy Czajkowski, Fluids Machine Engineer, Fermilab Accelerator Science and Technology (FAST) Facility, AD/Mechanical Support Department, Fermi National Accelerator Laboratory

Questions?