Application of Inline Gamma and CZT

ISOE International Symposium

David Perkins
Sr. Technical Executive

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SMART Chemistry and Online Gamma Spectroscopy

- Gamma
  - CZT
  - HPGe
- Benchtop
- Data historian

- Digital twin or real time capabilities
- Fingerprint logic
- Manual or grab sample optimization
- Can we predict or how can we apply Risk Informed decisions

Comprehensive monitoring and diagnosis

Inline Coolant Isotopic Gamma Monitoring

The Why?

Requirements

- Technical Specifications
- Fuel Reliability
- Offsite Dose Calculation Manual

Staff Burden

- Labor intensive (E-Bar, decay counts and so on)
- Analysis frequency ranges from hourly – several days

Analytics

- Data transfer and evaluation
- Advanced diagnostics
- Reporting

- Multiple samples to meet requirements
  - Direct and decayed counting,
  - Power suppression testing support (contractors and staff)
- Staff resources
  - Current process requires collection of samples, sample preparation, sample counting, manual data analyses
  - 24/7 availability and staffing
  - How to automate or streamline
- Data analyses
  - The ability to collect and evaluate data compared to plant conditions
  - Can we model behaviors
  - Reporting - Technical Specifications

Gamma Spectrometry Systems CZT Based

Real-time Isotopic Gamma Monitoring

Example Collimator Configurations

EcoGamma Dose Rate Meter

- Collects associated local dose rates
- Links to Data Analyst

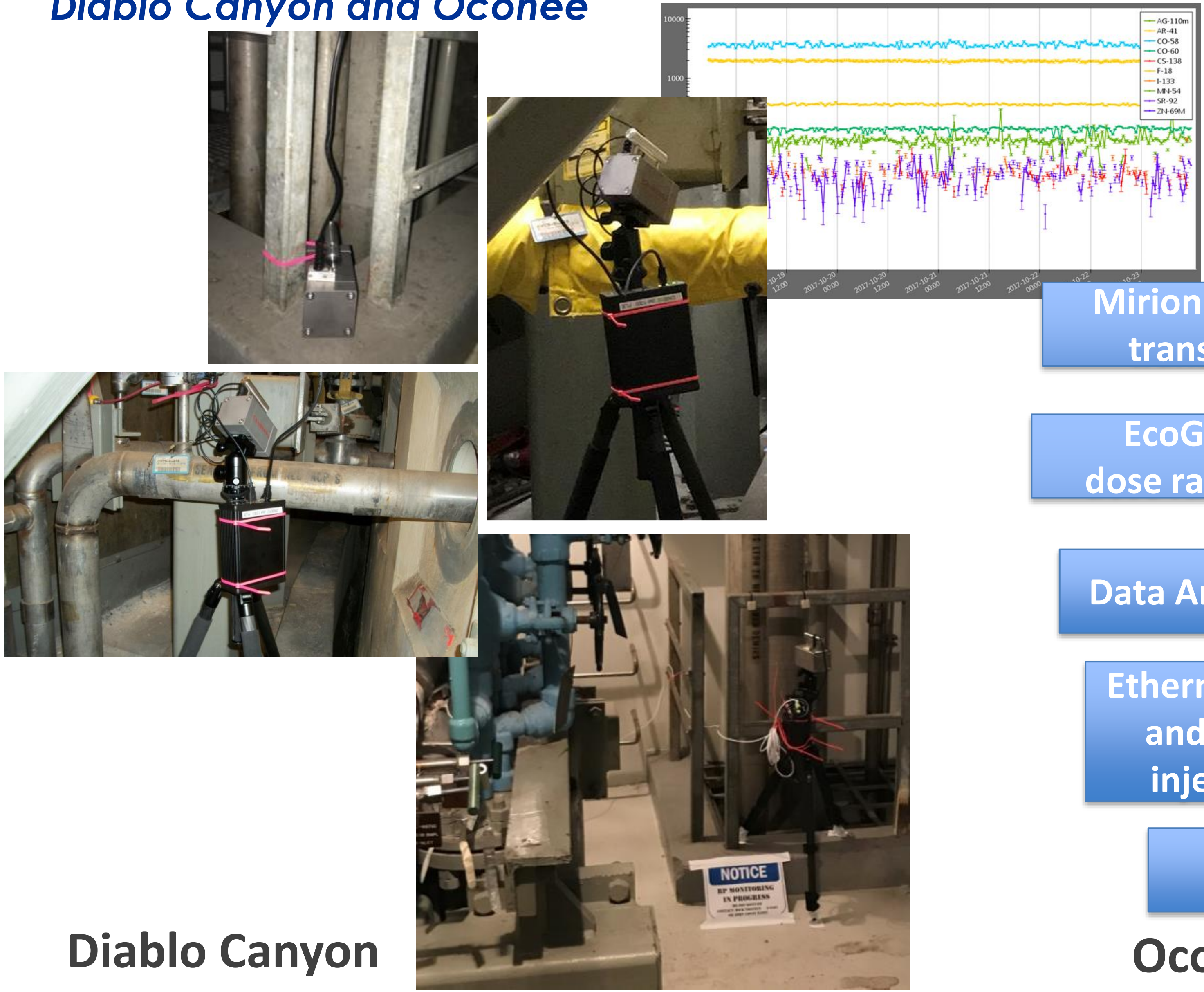
Field Assay Kit

- Detector, Laptop (PC), Multichannel Analyzer (MCA), Software, and Detector
- MCA is internal with detector unit
- PC not needed for operation
- Tripod can be used for stationary monitoring

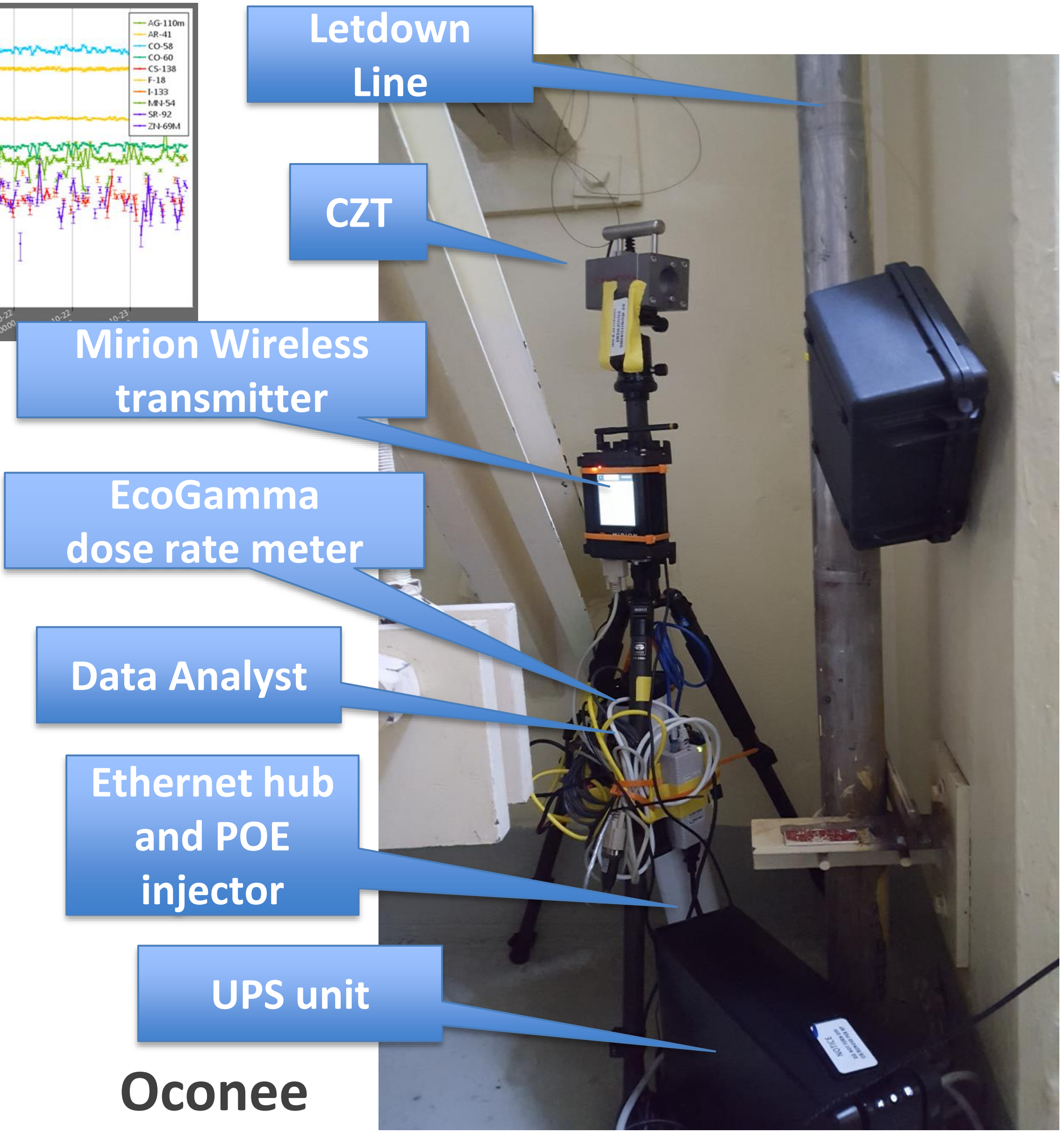
Total equipment weight ~ 30-40 lbs, clean/stable AC power desired, if not feasible UPS would be recommended

Radiation Field Real-time Isotopic Gamma Monitoring Demo

Diablo Canyon and Oconee

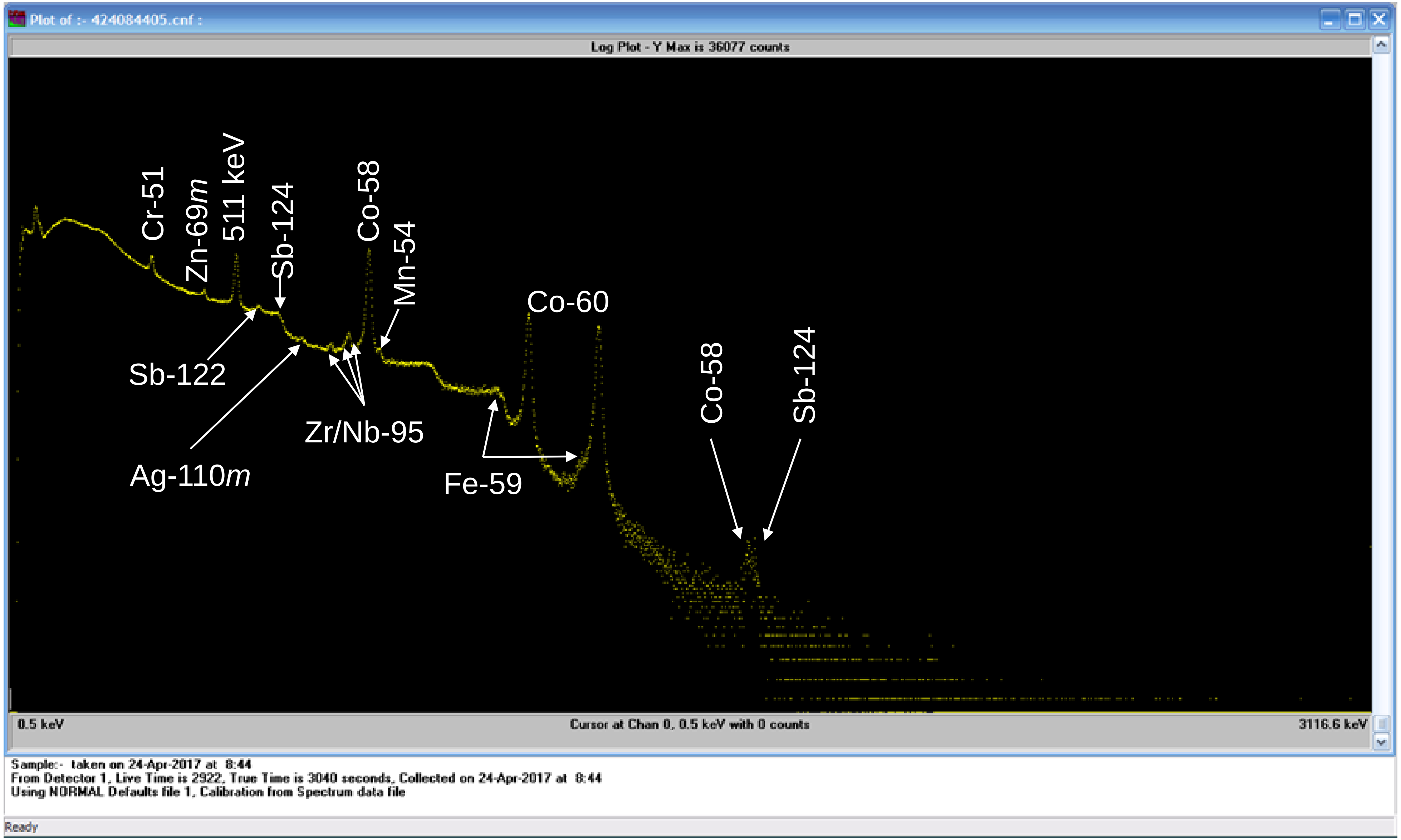


Diablo Canyon



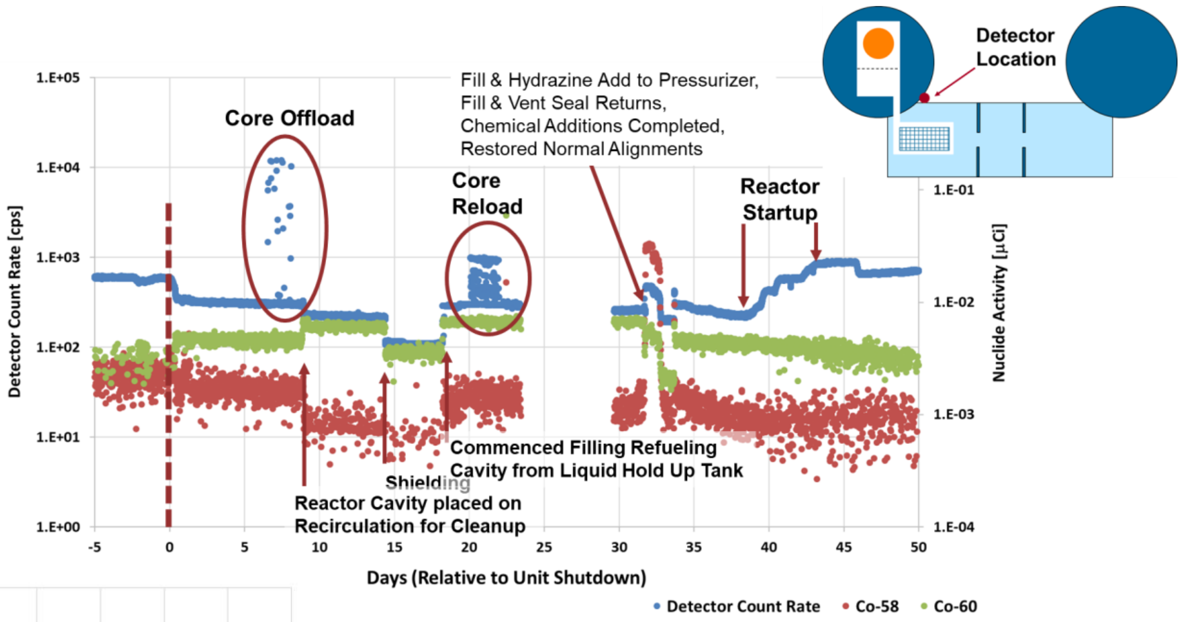
Oconee

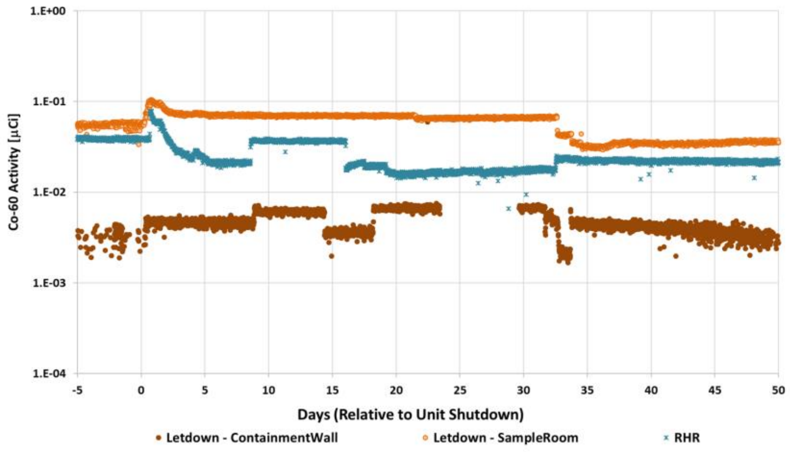
Example: Radiation Field Gamma Spectrum at Start of Forced Oxygenation

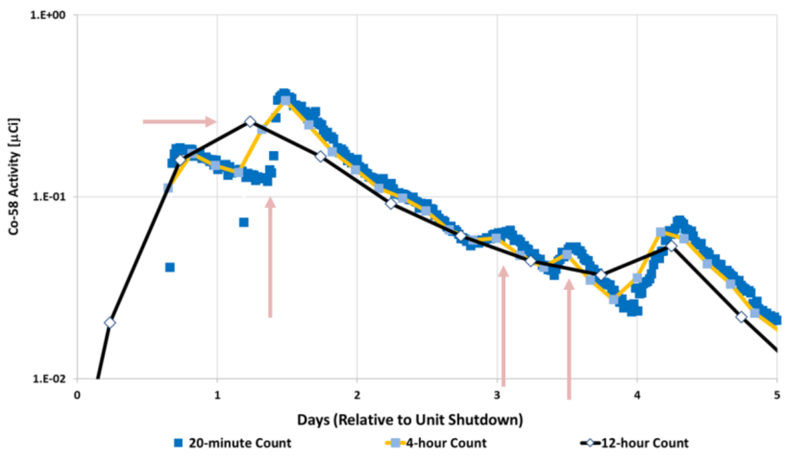


CZT and Operational Data

- Operational actions cause changes in radiological conditions
  - Dose rates may not reflect individual nuclide behavior
  - Nuclide behave differently in different primary circuit locations/systems
- Measurement frequency may matter
  - Needs to be tailored to monitoring/trending purpose
  - Parallel analysis workflows support this need







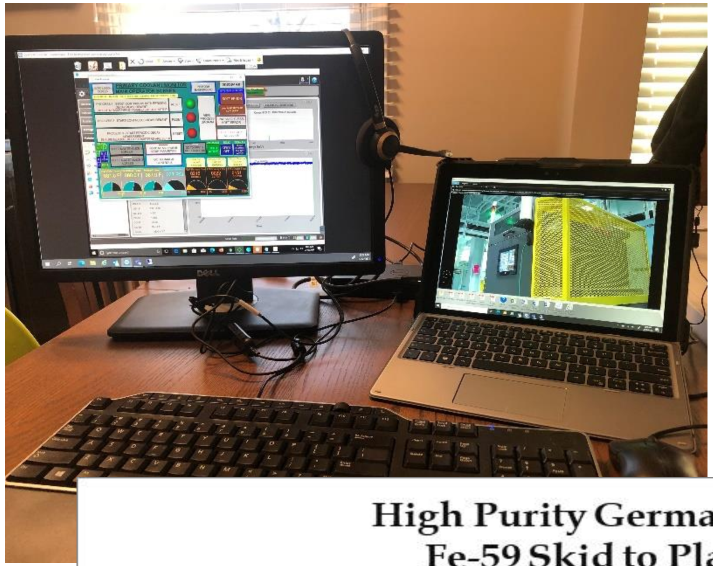
Gamma Spectrometry Systems HPGe Based

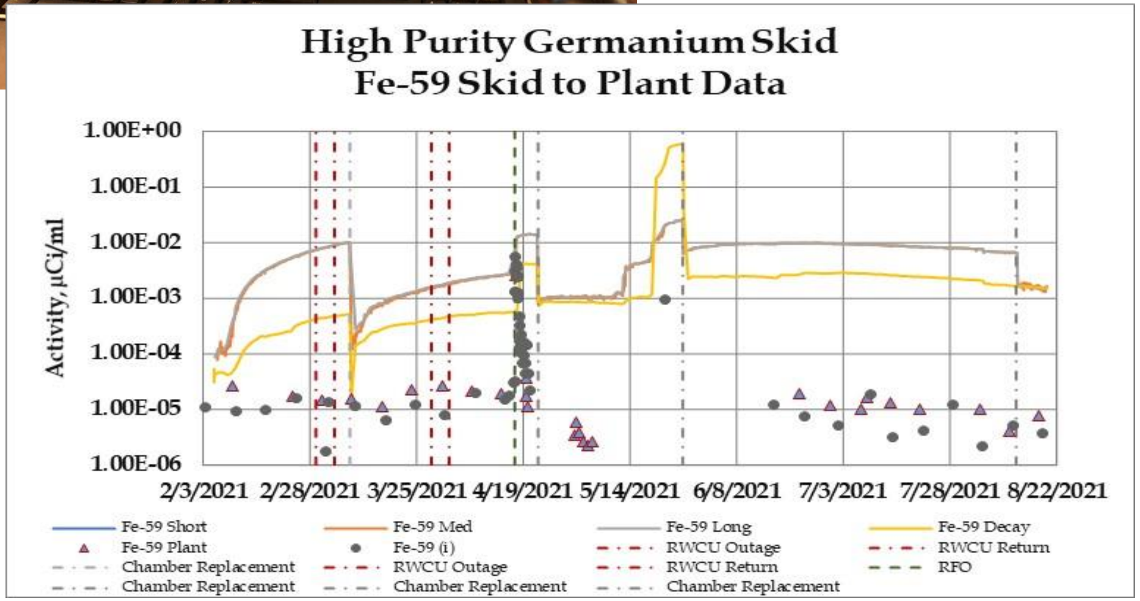
Thank you to the HPGe Team for their support.
Leah Whiteker, Monticello, for continued operating support and the successful implementation of the skid.
Monticello team for their efforts in overcoming the installation hurdles
Frazier Bronson, Mirion, for his continued support and effort for the data analysis and review
Richard Kohlmann, RSI, for the installation, startup, and ongoing maintenance efforts

Radiation Field Real-time Isotopic Gamma Monitoring Demo

High Purity Germanium Skid

- Skid Performance Observations / Takeaway (DRAFT)
  - High Reliability - some initial setup challenges, but after initial setup, minimal operator actions are required.
    - Operated from February 2021 until the demonstration ended the week of August 23, 2021 with minimal operators actions.
  - Flushing, background, and other staff operations were performed remotely including the ability for the vendor to access remotely.
  - Radionuclide Behaviors
    - All data is ***preliminary and should only be considered as such***!
    - Several of the soluble radionuclides are showing within a factor of 10 of plant data.
    - Insoluble species are challenging
  - Plant transients are clearly captured





Radiation Field Real-time Isotopic Gamma Monitoring Demo

High Purity Germanium Skid

- Feasibility and Functionality Evaluation
  - Equipment reliability – can the system operate with minimal hands-on operations
  - Minimization of staff resources - the ability to use online sampling to address plant gamma spectroscopy analysis (e.g., backshifts)
  - Identification of plant transients to support SMART Chemistry fingerprint logic and ongoing efforts
  - Evaluation of the ability to collect and analyze an increased number of samples capturing plant events

Inline Coolant Isotopic Gamma Monitoring

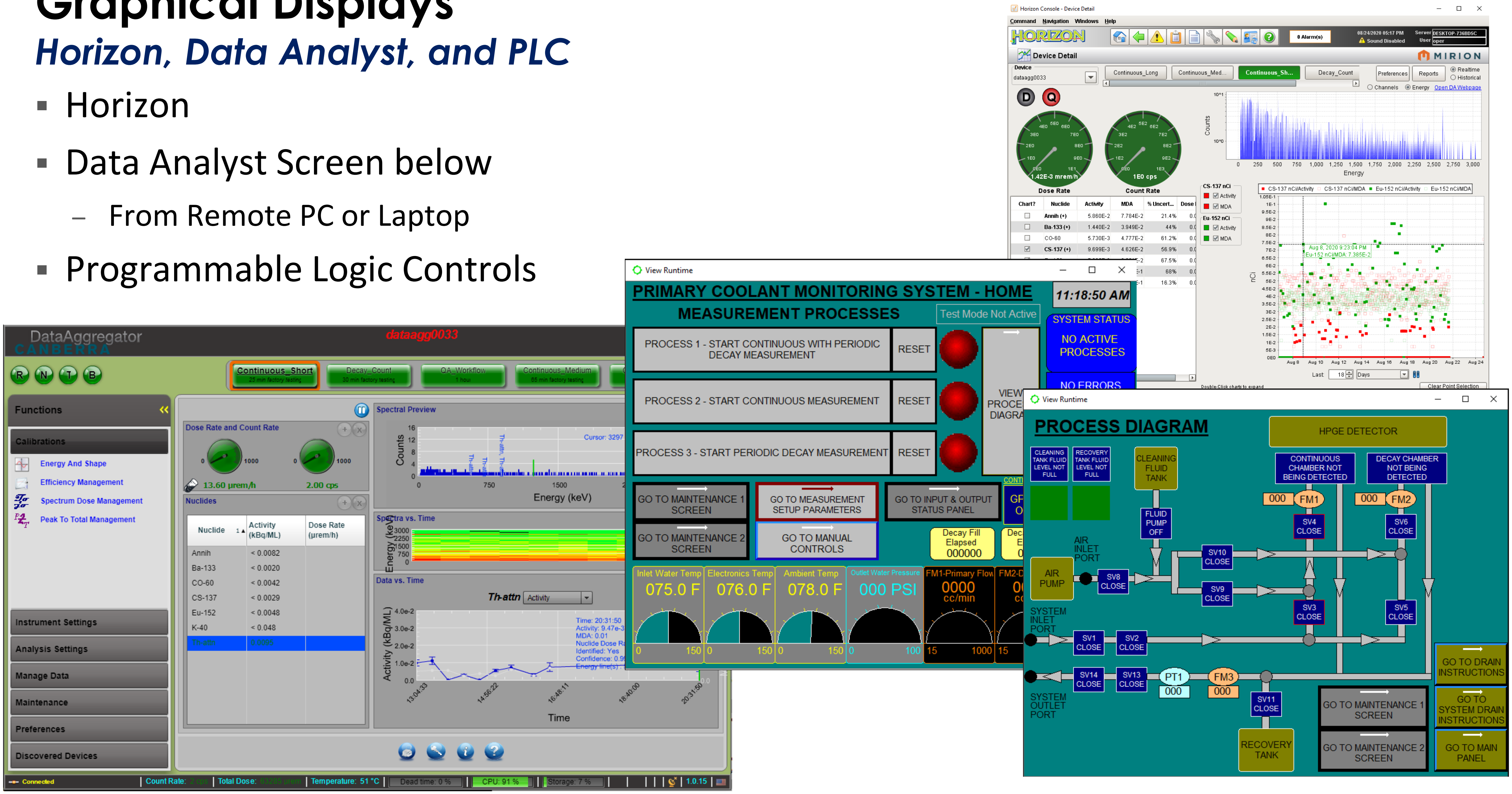
Skid Overview

- Automated/PLC controlled – decay sample on demand
- Sample chambers move on sliding track to position in front of detector
- Piping, valving, flow and temperature sensors will be located below detector
- Sample chambers
  - Shielding and each chamber can be connected to a distributing piping (Swagelok quick-disconnect fittings with integral shutoffs)
  - Replaceable if contamination buildup is noted.
  - Flow path & mechanisms enable draining, flushing, and background analysis
  - “In flow path” decay line can be added as needed
- System will be contained in water-tight catch pan with leak sensor and shutoff valves
- Flow sensor will verify flow in the piping and generate appropriate alerts

Graphical Displays

Horizon, Data Analyst, and PLC

- Horizon
- Data Analyst Screen below
  - From Remote PC or Laptop
- Programmable Logic Controls

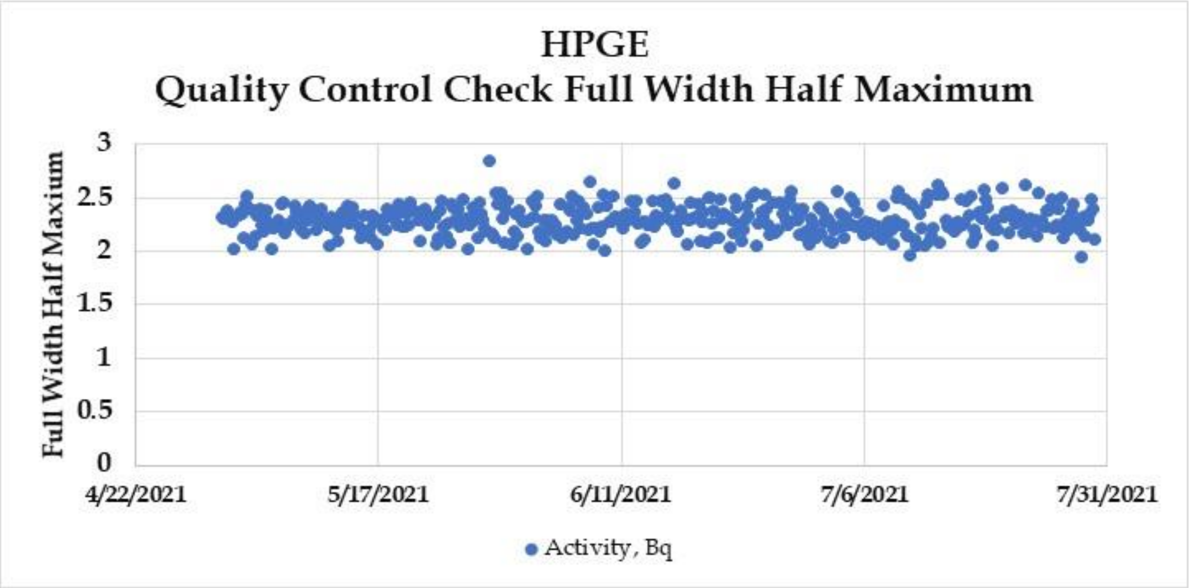


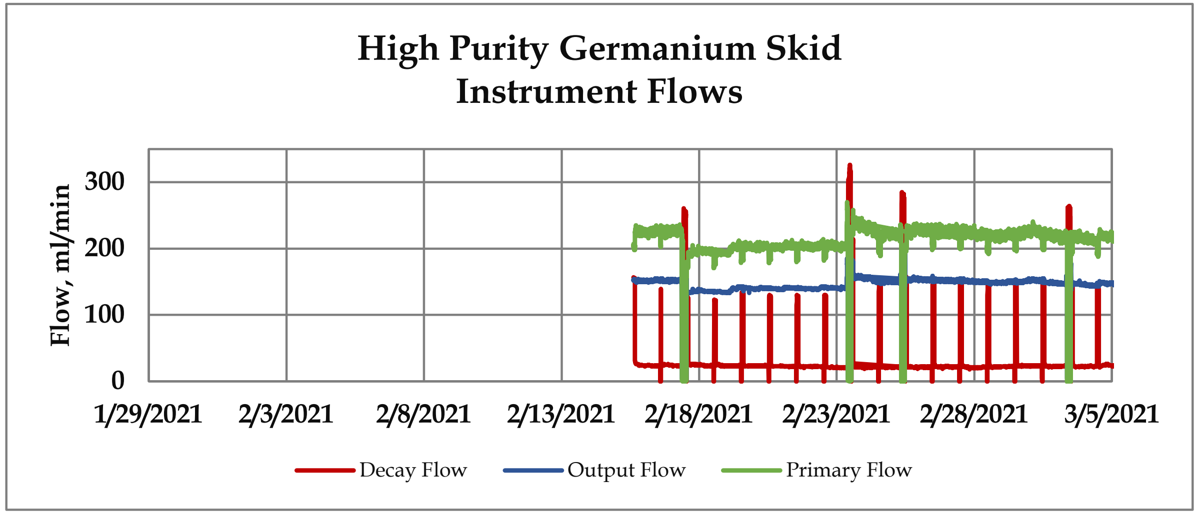
EPRI

High Purity Germanium Skid

Quality Check Review

- Instrument quality controls
  - The skid uses a commercially available welding rod with natural thorium filtered to remove low energy lines for the check source
  - Source activity continuously acquired and analyzed every 4 hours for Activity [efficiency], Peak Centroid [gain], and FWHM [spectral quality]
  - Quality control checks are consistent and within a simple 2-sigma calculation
  - Mirion staff noted that a stable Activity value indicates the gain and efficiency are stable
- Instrument flow and other diagnostics
  - This original flow control valve was supplemented with a finer control valve allowing plant staff better flow control adjustment. Flow is now being maintained as expected.
    - The red spikes on the lower graph indicate decay chamber flow initiation and chamber fill

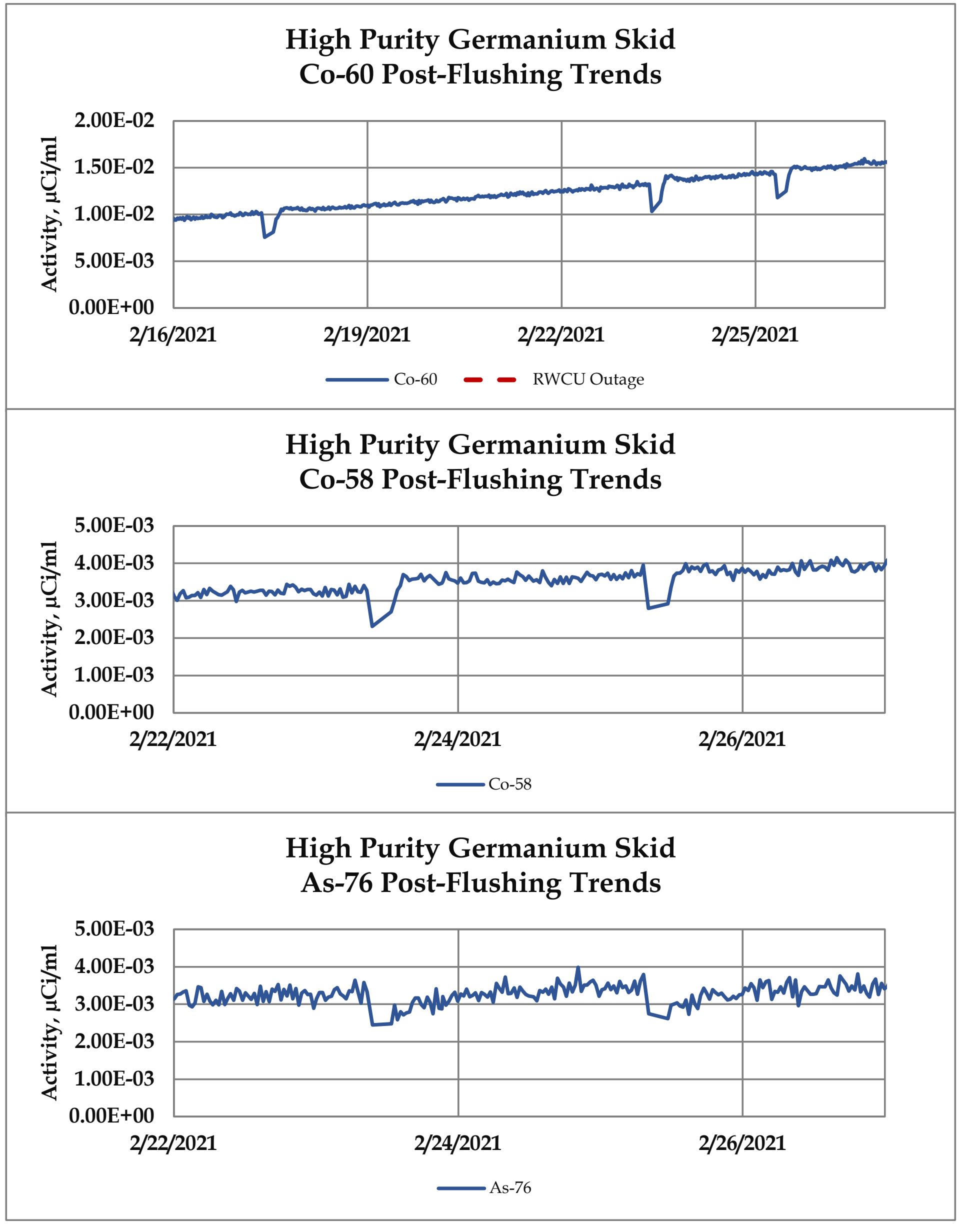




EPRI

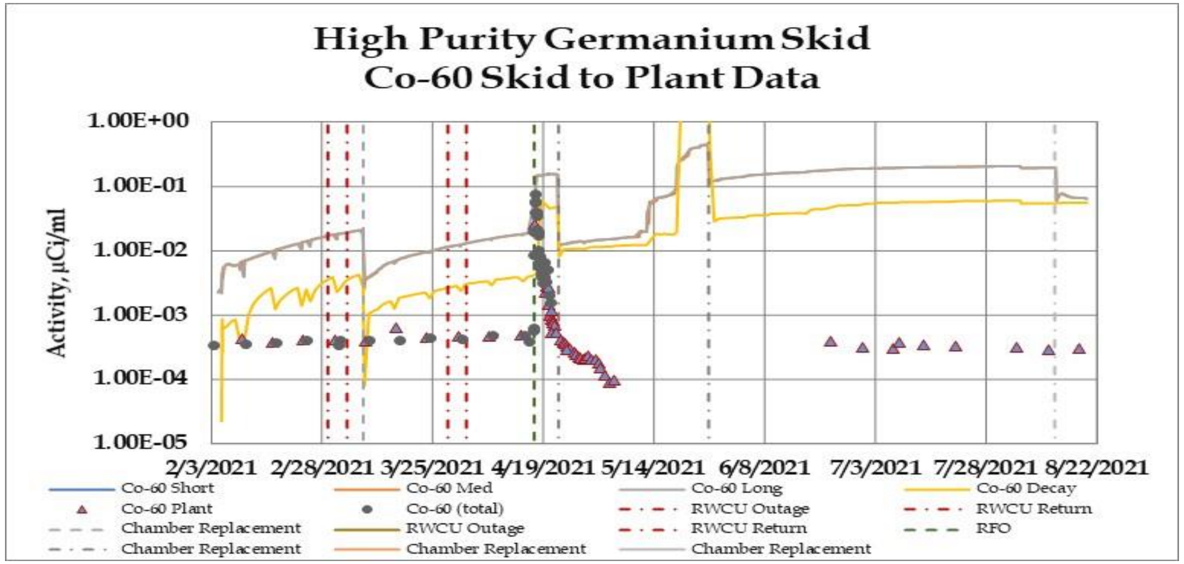
High Purity Germanium Skid
Flush Observations (Recovery)

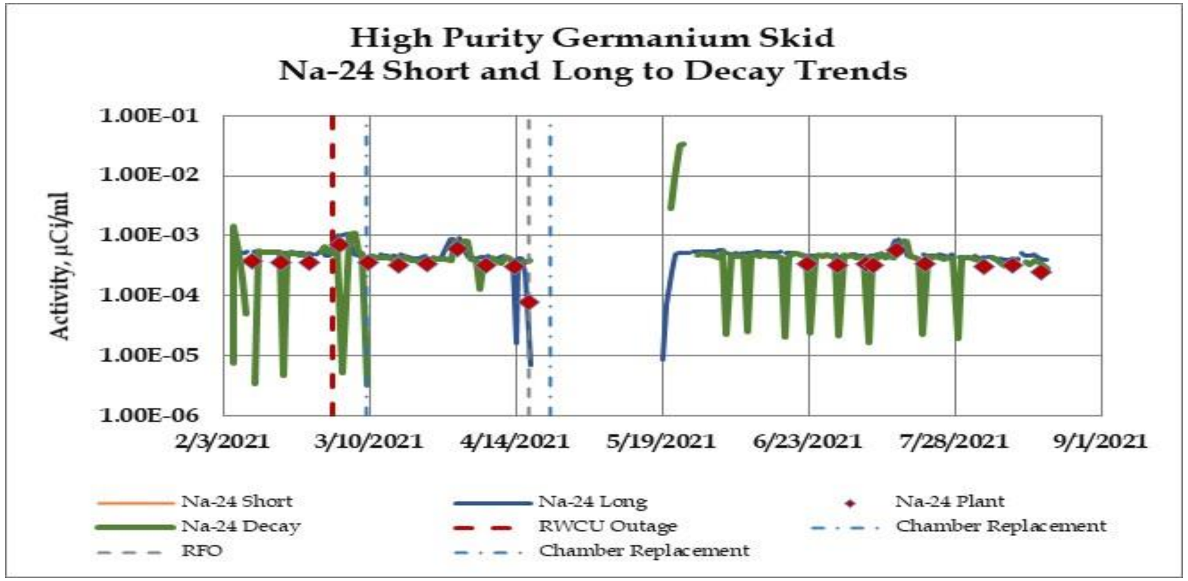
- Flushing Operations
  - Flushing operations are part of the background process.
  - Monticello staff with Mirion worked to optimize the flush times and attempted to optimize the required flushing based on the radionuclide behaviors.
  - The time for flushing and background is ~4-hours
- Post-Flushing Observations
  - Mn-56 and Co-60 activities increase above the prior to activity.
  - Co-58 is an example of a short or quicker recovery back to the activity prior to the flush
  - As-76, Zn-65, and Zn-69m are examples that take a longer period to reach the activity prior to flush operations (bottom graph)



High Purity Germanium Skid – Challenges

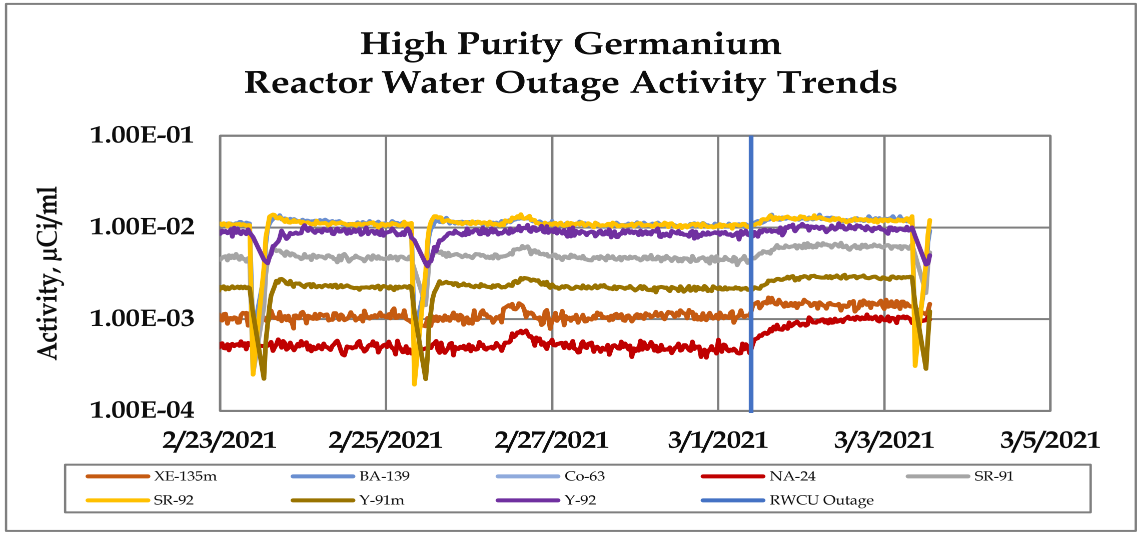
- Background Growth
  - The demonstration evaluated 5 different chamber coating processes to evaluate and attempt to minimize sample chamber contamination.
    - These chambers included stabilized chrome, platinum coating, and electropolishing.
- Background Observations
  - A ***wide range of reduction in activity*** is noted when the chamber is flushed with demineralized water.
    - The soluble radionuclides show a better flushing result while the activated corrosion products show little change, and some nuclides are completely flushed
    - Activity ***appears to start building quickly*** on some nuclides and much more slowly on other nuclides.
  - The decay chamber does not show the chamber reaching an equilibrium.

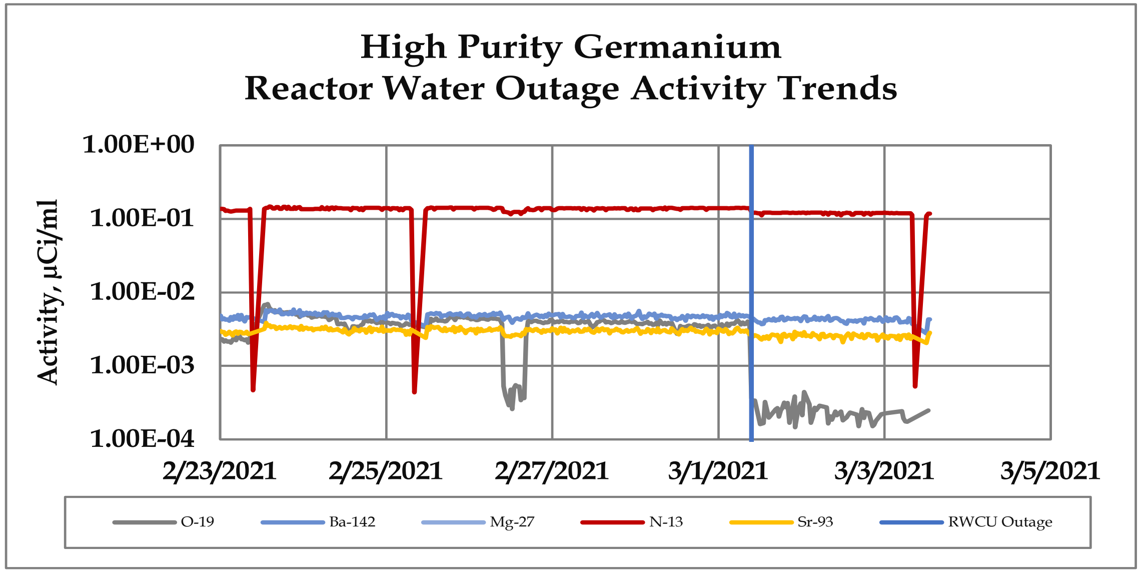




High Purity Germanium Skid – Plant Transient Observation

- Reactor Water Cleanup Outage
  - On March 1, 2021 09:30 am reactor water cleanup (RWCU) was bypassed for demineralizer backflush and regeneration
  - Returned to service on March 5, 2021 18:07
- Observations
  - Na-24, Sr-91, Y-91m, Xe-135m, and Ba-139 increased during the event.
  - N-13, O-19, Mg-27, Mn-56, and Ba-42 reductions were observed
  - This data provides input in the impact of RWCU cleanup changes is part of the larger Smart Chemistry Project fingerprint logic





High Purity Germanium Skid

Next Steps

- Skid shipment
  - The skid was removed, drained, and placed in a DOT shipping container
  - Shipped and undergoing decontamination at a vendor facility
- Skid plan
  - Test the onboard flushing system and if possible, evaluate a mild decontamination solution impact.
  - Remove components that cannot be decontaminated (e.g., valve gallery, etc.)
  - Release components, where possible
- Report
  - Complete the data evaluation and document results in a report

HPGe and SMART Chemistry

Connect the Data

- Apply real-time sampling of all essential chemistry parameters
- Apply automated diagnostics and trending
  - Enhanced monitoring and early warnings
  - Application of automated chemistry controls (chemical adds, systems IS/OS, etc.)
- Application of Augmented Limits
  - Account for value of sampling, diagnostics, and control technologies and life expectancy
  - Risk-informed, where possible

The *CORRECT data*, monitoring, and evaluations with the *RIGHT* responses can lead to: Improvements in safety margin and reduced operating cost

Together…Shaping the Future of Energy™