Savannah River National Laboratory®

SRNL Tritium Science and Technology for Fusion Energy

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Senior Advisory Engineer

2nd Annual INFUSE Workshop
December 1-2, 2020

SRNL-STI-2020-00553

SRNL at a Glance

We protect our nation by applying science to international security, the environment and the energy economy

Core Competencies

- Tritium Processing, Storage and Gas Transfer Systems
- Environmental Remediation and Risk Reduction
- Nuclear Materials Processing and Disposition
- Nuclear Detection, Characterization and Assessments

Location: Aiken, SC
Type: Multiprogram
Year Founded: 1951
Director: Dr. Vahid Majidi
Contractor: Savannah River Nuclear Solutions

Multi-Program Laboratory
1,000 Staff
$365M
FY19 Lab Operating Budget

Program Areas

- National Security 41%
- Environmental Stewardship 37%
- Nuclear Materials Management 18%
- Secure Energy Manufacturing 4%

SRNL Priorities Align with Strategic Plan for U.S. Burning Plasma Research

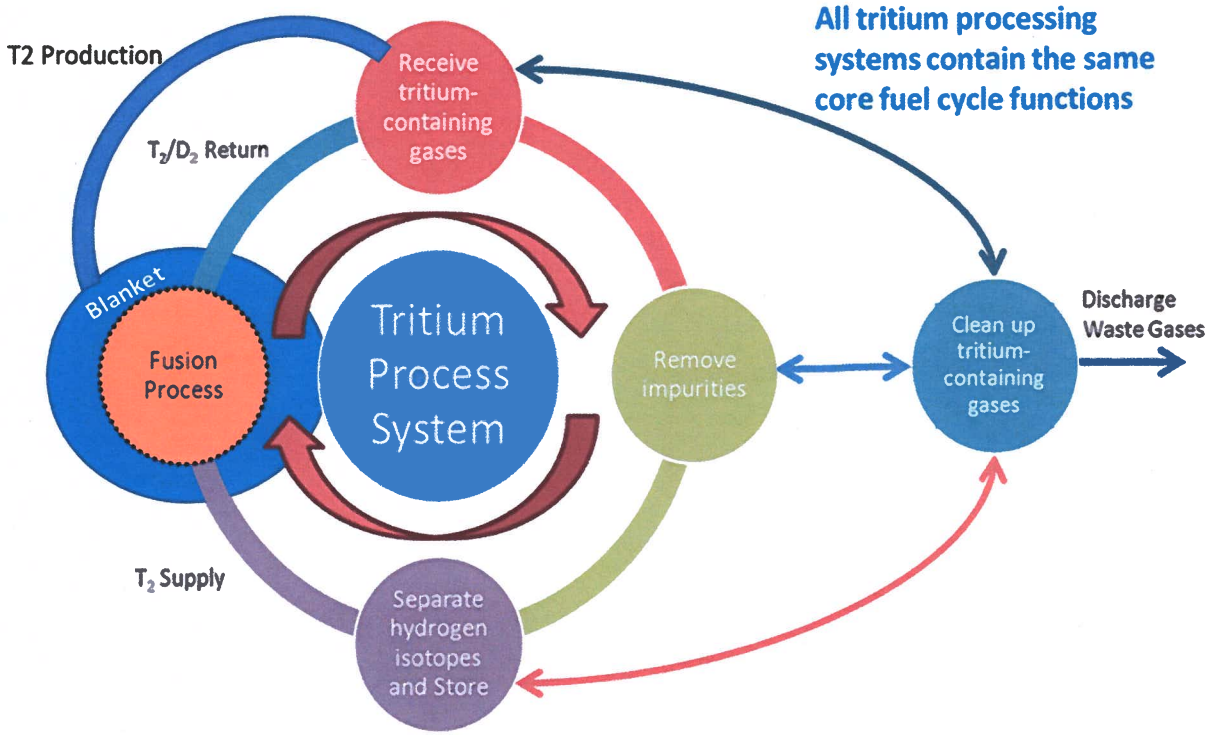
NAS Finding: Innovations and promising new methods to separate and process tritium, will be essential to the development of a compact, lower cost fusion reactor.

- A fusion breeding blanket is an outstanding challenge for fusion because scientific gaps exist related to controlling tritium permeation and minimizing tritium inventory.
- The 2018 FESAC report recognizes this challenge and identifies (the opportunity) to develop…advanced tritium extraction technologies and new fuel recycling technologies that allow for minimization of tritium inventories.
- Novel tritium processing technology may reduce the cost and improve the reliability of fusion nuclear components and systems.
- Fusion nuclear components will need to safely and efficiently fuel, exhaust, breed, confine, extract, and separate unprecedented quantities of tritium.
- Tritium science, extraction technologies, and fuel processing are critical challenges for fusion energy systems, and significant challenges will need to be overcome including the need to develop effective tritium permeation barriers to prevent release of sizable quantifies of tritium.

Fusion Challenges will Impact the Entire Fuel Cycle

Fusion Tritium Challenges:

- Process tritium at rate 1 to 2 orders of magnitude higher that has been demonstrated to date.
- Reduce tritium emissions by 1 to 2 orders of magnitude lower than demonstrated performance.
- Demonstrate continuous operation (24/7 – 365) versus current semi-continuous and batch processing.
- Minimize in-process inventory of tritium.



SRNL applies the full range of process development and materials science capabilities to address the key issues of blanket and fuel cycles for fusion science and technology.

Tritium Gas Processing Technology Development

Remove impurities

- **Impurity Removal**
  - Hydrogen separation from impurities
  - He-3 cleanup

Separate hydrogen isotopes and Store

- **Hydrogen Isotope Separation**
  - Thermal Cycling Absorption Process (TCAP)
- **Hydrogen Storage**
  - Metal hydride beds/tanks
  - Material options and vessel designs based on temperature/pressure/purity requirements

Clean up tritium-containing gases

- **Waste Gas/Tritiated Water Processing**
  - Glovebox atmosphere detritiation
  - Tritium recovery from water
  - Detritiation of process effluent gases

- **Secondary Confinement**
- **Pumping (Evacuation/Circulation)**
- **Analytical Systems**
- **Tritium Accountancy and Tracking**
  - In-bed calorimetry techniques

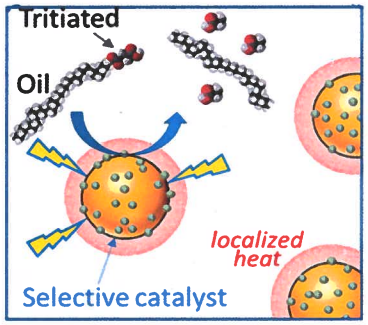
Tritium processing technology development is aimed at improving efficiency, decreasing operational costs, replacing aging technologies, reducing radiological footprint and tritium inventory, and allowing for more flexible operations to meet current and future demands.

Applied Research Center
Hydrogen Technology Research Laboratory

Fusion Fuel Cycle Pumping

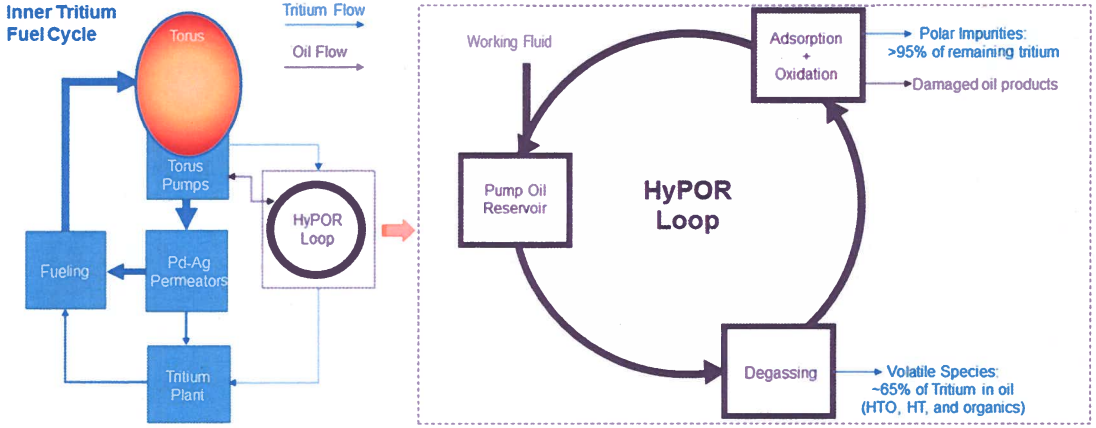
HyPOR Loop Development for Fast Fusion Cycles

George Larsen, Savannah River National Lab
Timothy DeVol, Clemson University
John Regalbuto, University of South Carolina

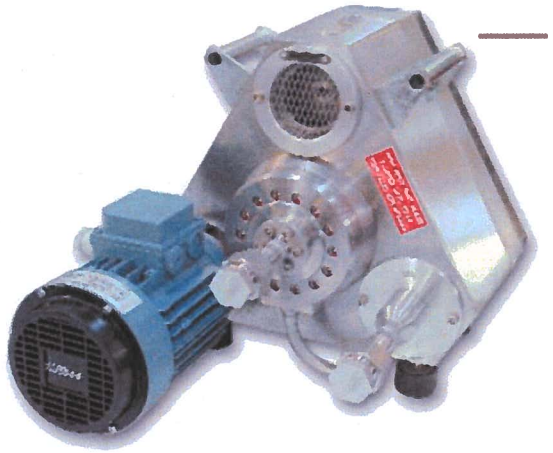


Targeted Tritium release

- **Hydrocarbon Pump Oil Recycling (HyPOR) Loop**

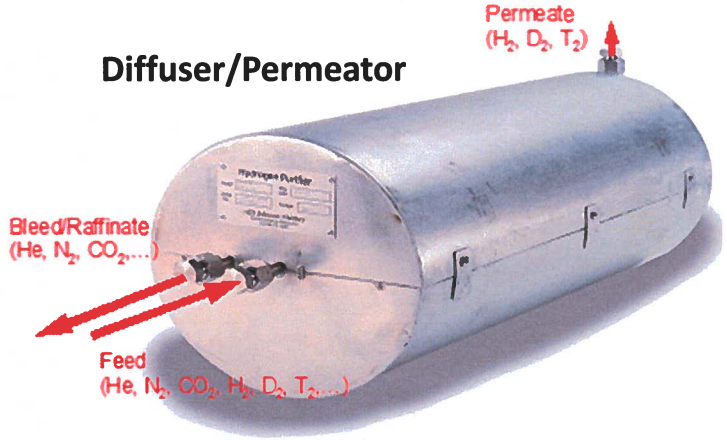


- **Motivation: HyPOR loop will unleash full array of commercial vacuum technology for a continuous fuel cycle, reducing costs, tritium plant size and tritium inventory**

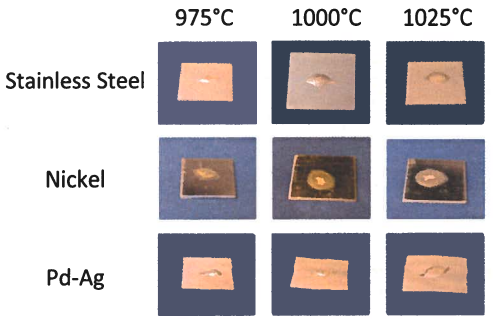


Tritium Gas Processing Technology Development: Impurity Removal

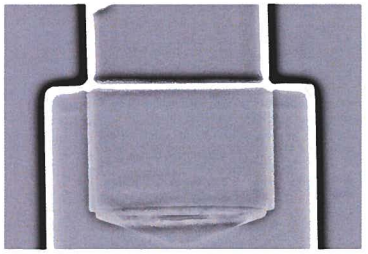
Currently deployed **Pd-Ag diffusers**, used to separate hydrogen isotopes from inert and other non-hydrogen species, are prone to poisoning and their ***future supply chain is uncertain***.



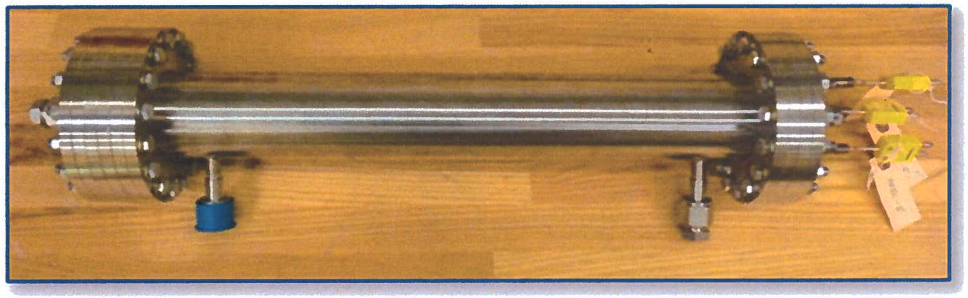
Braze development will allow for robust joints of Pd-Ag and Ni. Welding development will enable repeatable Ni and SS joining. Together they can be used in the ***design of Pd-Ag diffusers for specific processes***.



Braze cups



Ultrasound Tomography



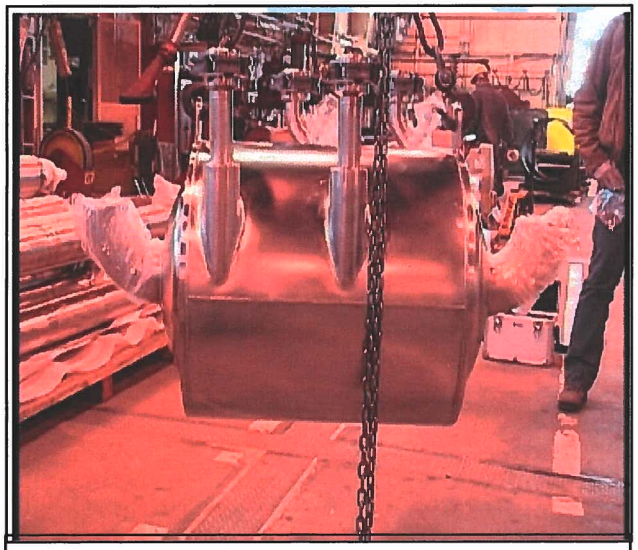
PMR for Ammonia Decomposition

Palladium Membrane Reactor (PMR) will allow hydrogen generated from the "cracking" of ammonia to diffuse out of the reaction zone, shifting the equilibrium toward decomposition and ***limiting the reformation of ammonia***.

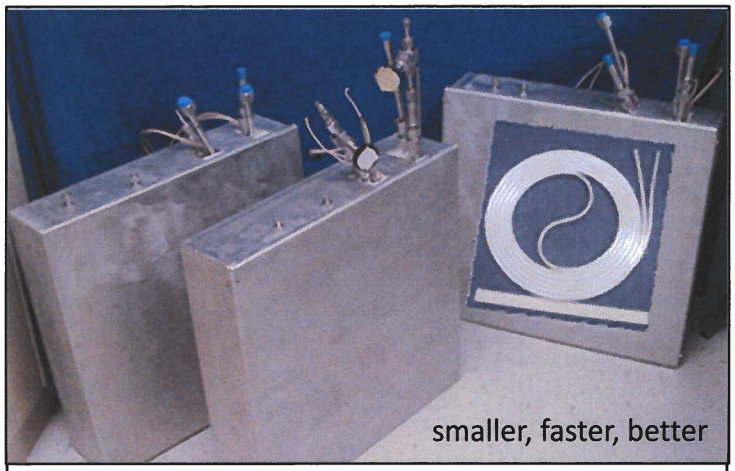
$$NH_{3(g)} \leftrightarrow \tfrac{1}{2}N_{2(g)} + \tfrac{3}{2}H_{2(g)}$$

Comprehensive Tritium Processing Technology Capabilities

SRNL advances in tritium processing technology over the decades have led to decreased footprint, higher throughput, and reduced tritium inventory requirements. This technologies can also be scaled and optimized for various applications.



Thermal Cycling Absorption Process



Miniaturized Isotope Separation Process

- Isotope separation
- Impurity removal
- Water detritiation
- Tritium compatible pumps
- Tritium extraction

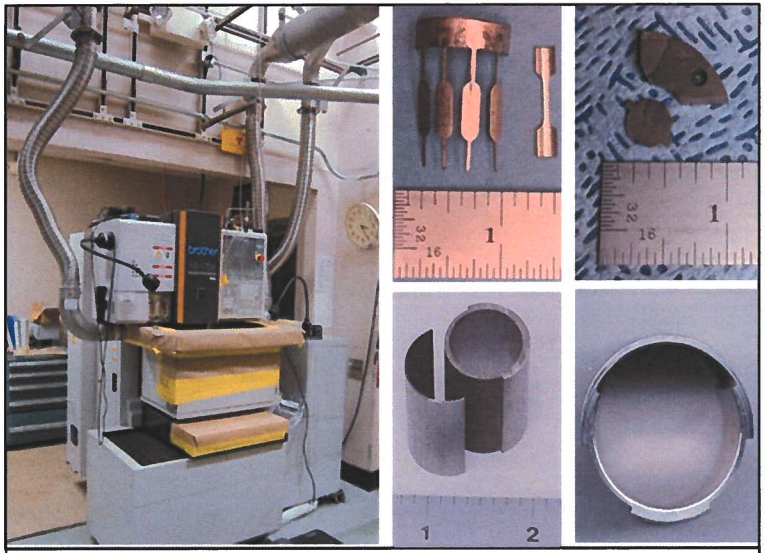
- Mass spectrometry
- Raman spectroscopy
- Infrared spectroscopy
- Gas chromatography
- Ion chambers

- Hydride storage
- Pressure vessels
- Transport vessels
- Modeling and simulation
- Accountability

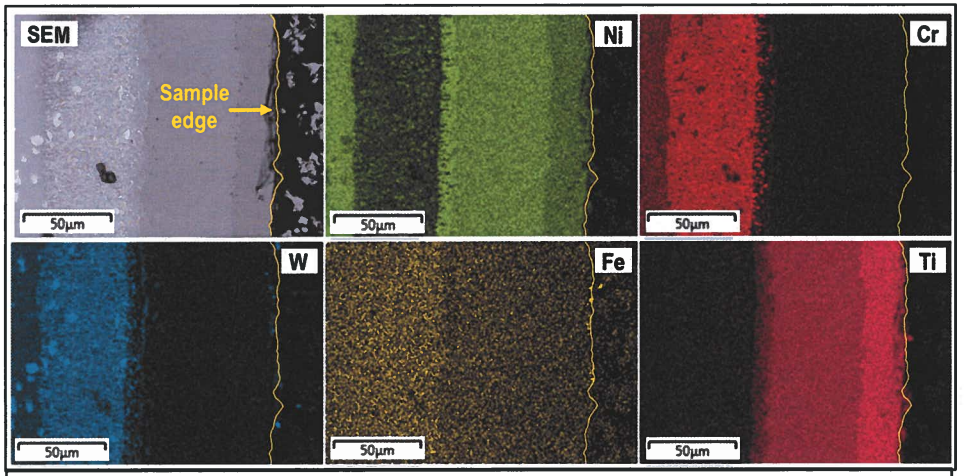
Unique Capabilities in Fusion Materials

SRNL provides the Nation's fundamental knowledge of material performance in tritium environments.

- SRNL Tritium Materials Expertise and Capabilities
- Tritium charging/aging for lifecycle analysis
- Mechanical testing for characterization of tritium embrittlement
- Mechanics of materials modeling and analysis for tritium applications
- Hydrogen Isotope permeation barrier development and testing
- Spectroscopic characterization of 3He formation SEM-FIB and EDM with tritium contaminated samples for advanced localized characterization of tritium effects on materials
- Passivation of SS and other alloy surfaces for tritium service
- Qualified Additive Manufacturing vessel development
- Corrosion testing and corrosion inhibition in high temperature environments
- Neutron scattering for analysis of hydrogen behavior in bulk materials



*Mechanical testing specimens **aged in a tritium environment** and incubated to give desired levels of T_2 or ^3He in the microstructure*

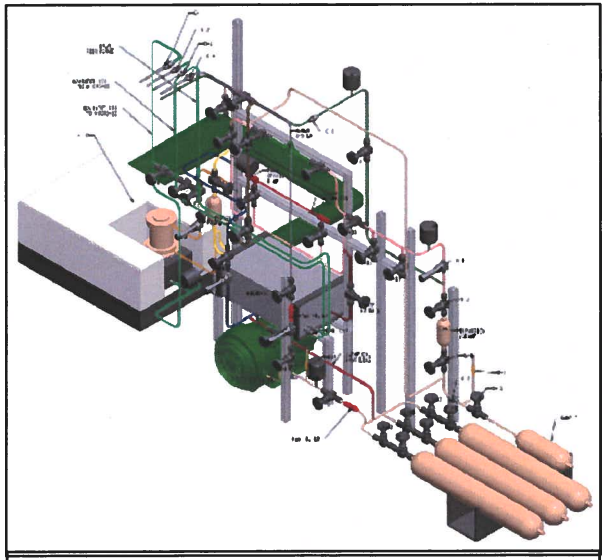


Development of functionally graded coatings/substates that act as corrosion and tritium containment barrier

SRNL Maintains Wide Range of Unique Tritium R&D Capabilities

- Hydrogen Technology Research Laboratory
- Hydrogen Processing Demonstration System
- Tritium Instrument Demonstration System
- Mass Spectrometer Development Laboratory
- Mechanical Systems and Custom Equipment Development
- Instrumentation and Electronics Development
- Packaging Technology and Transportation Engineering
- Design, Manufacturing, Logistics & Pressurized Systems
- Imaging, Robotics, and Radiation Systems

Hydrogen Processing Demonstration System Provides Integrated Process R&D at Prototypical Scale with Tritium Simulant (H/D)

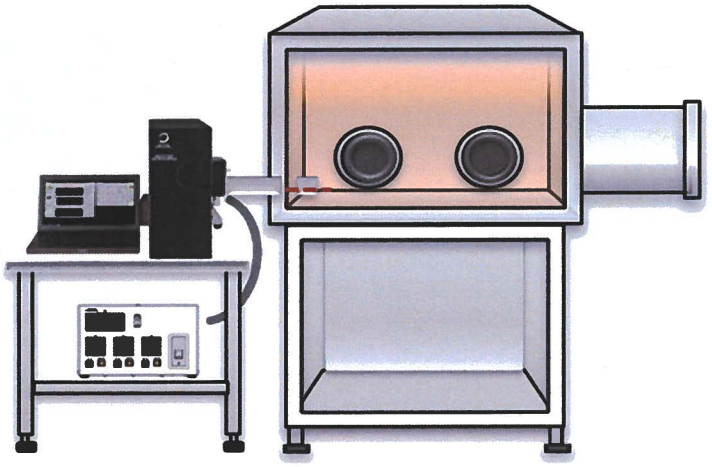


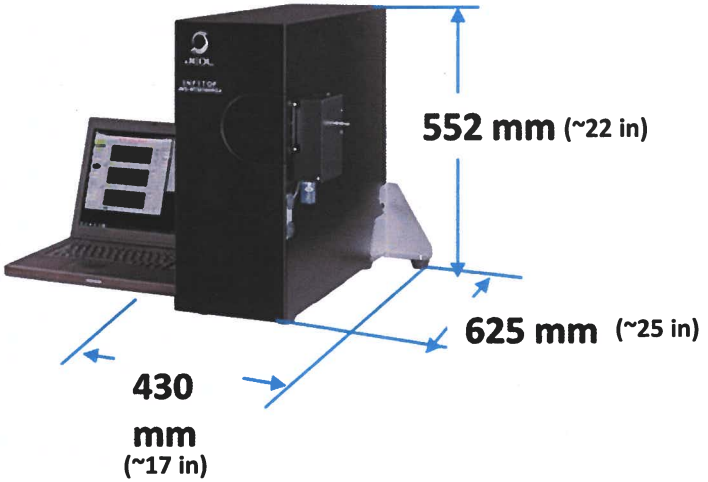
Tritium Instrumentation Demonstration station (FTIR, micro-GC, Raman cell) shown connected to a tritium-compatible gas handling manifold.

SRNL is an ideal location for demonstrations with large quantities of tritium.

High Resolution Low Mass (HRLM) Mass Spectrometry Solutions

JEOL USA

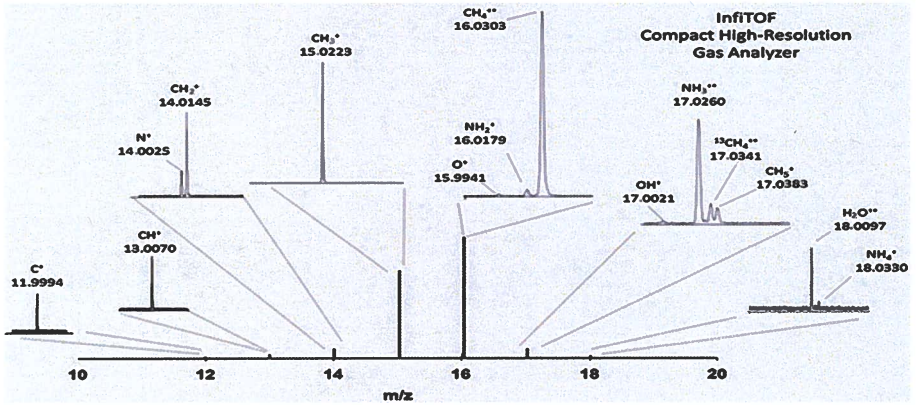




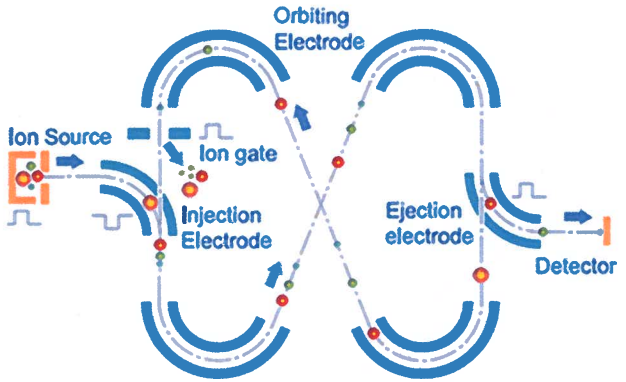
Compact system comparable in size to a desktop computer (~40kg). Image courtesy of JEOL Inc. USA

Ammonia in methane: Resolution≒6,000 (*m/z* 16)

A gas sample was directly loaded using a capillary column for measurement. Molecular ions and fragment ions of ammonia, methane, water, and their isotopic peaks were all separated. Exact mass errors were all within ±0.001 u.

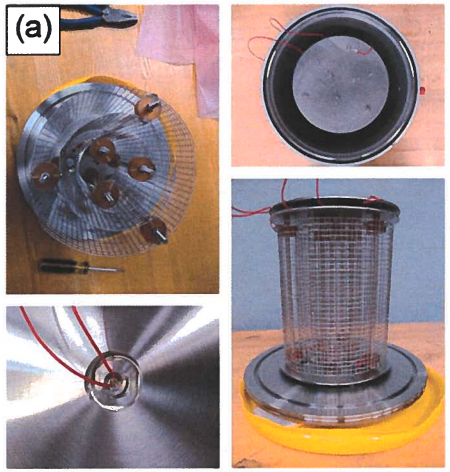


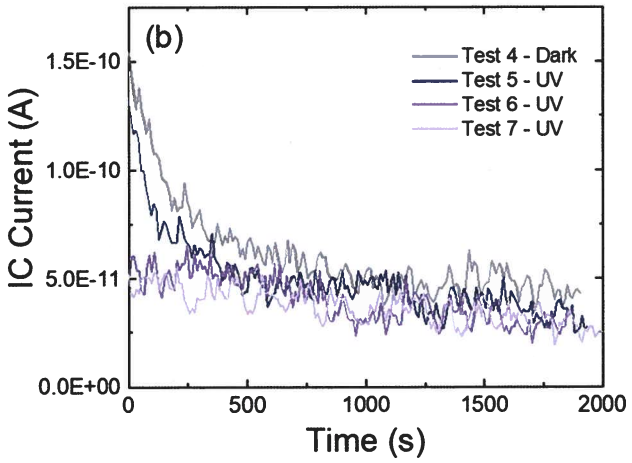
Free application notes are available at the JEOL USA website.
For details, visit http://www.jeolusa.com/.



Multi-turn technology provides a variable-length ion-flight path (up to 200 m) in a very compact analyzer (20 cm x 20 cm). Image and caption courtesy of JEOL Inc. USA

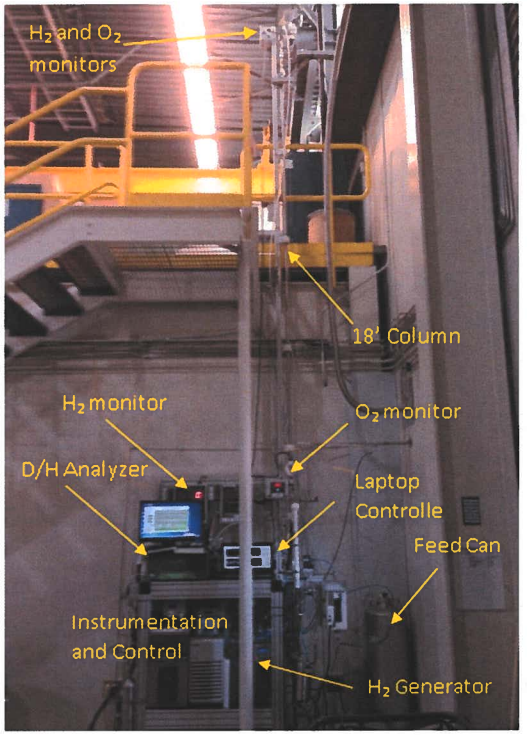
Photo-cleaned "Backgroundless" Ion Chambers





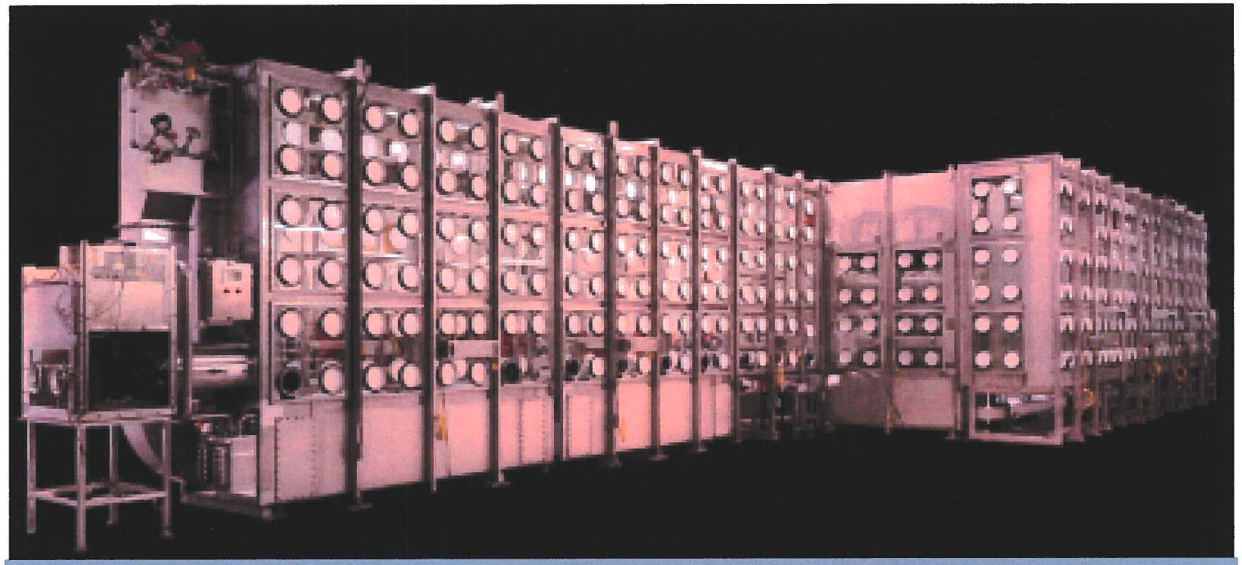
Water Detritiation Technology Development

- Concept proven with both HDO and HTO data
- H/D demonstration pilot plant constructed
- Benefits: glovebox moisture treatment, nuclear power operations, environmental mediation
- H/D Demonstration Pilot Plant
  - 18 ft tall, 1" OD, 2.5 gal/day



SRNL Stewards the U.S. Core Technical Competencies in Tritium Process Systems

- **Advancing the science and technology for tritium processing and handling is recognized as essential for achievement of economically viable fusion energy.**



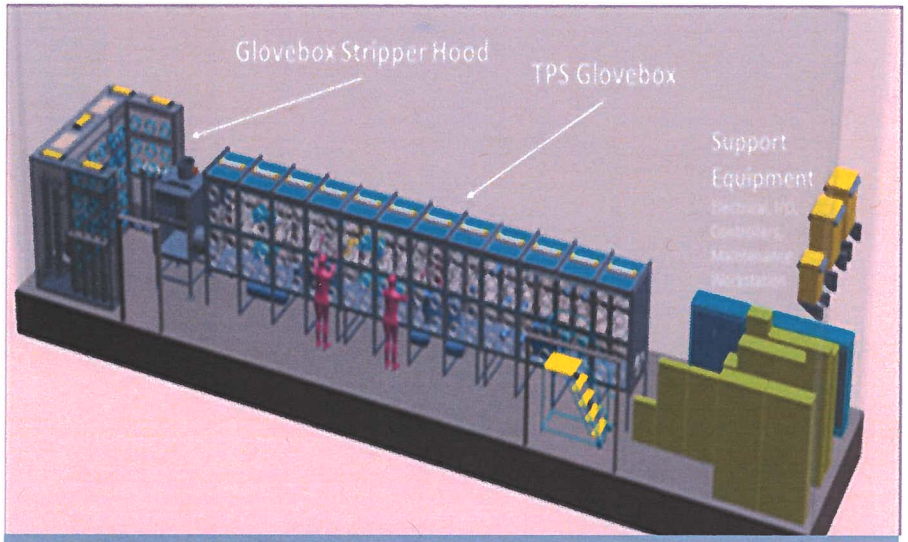
SRNL provides the core competencies, technology, and R&D to sustaining our nation's nuclear deterrent

- **SRNL's unique expertise and sustained ability to effectively apply its tritium capabilities have been demonstrated over 65 years of experience with multi-kilogram quantities of tritium.**

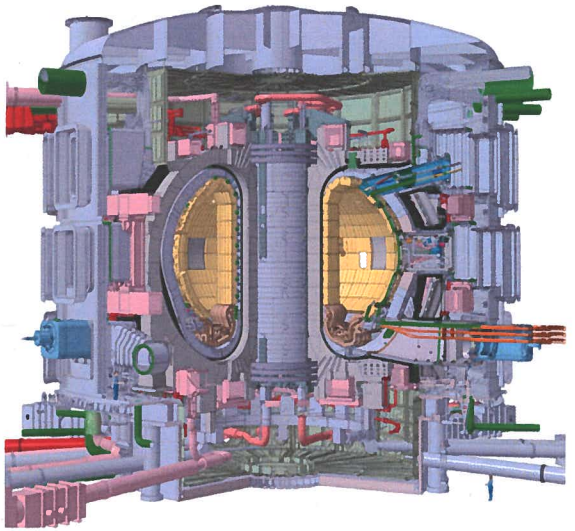
As a Federally Funded Research and Development Facility, SRNL provides tritium and hydrogen isotope technology to enable other vital national programs including Fusion Energy Sciences.

SRNL Delivers Tritium Science and Technology Across the Nation

As a Federally Funded R&D Facility (FFRDC), SRNL provides enabling tritium technology and expertise across the nation for other vital programs including the NA-113 Experimental Science Program, medical isotope production, helium-3 supply, fusion energy research, intelligence, and nonproliferation.

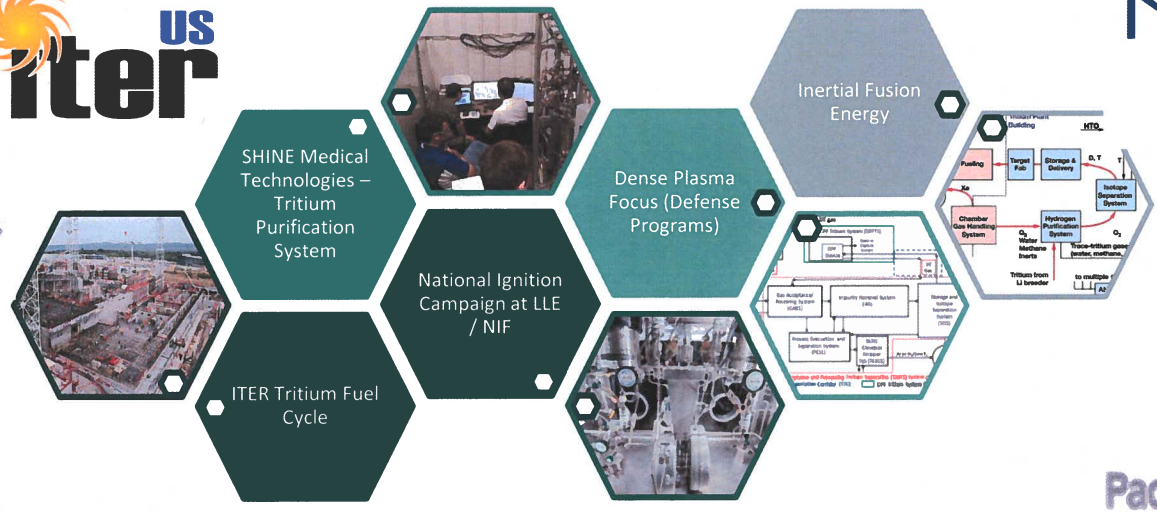


SRNL designed and optimized the Tritium Purification System and Accelerator Target Interface System for SHINE to meet their production needs and regulatory requirements. SRNL also designed, built, fabricated, and installed a SHINE-configured isotope separation system.



SRNL is responsible for 100% of the final design, fabrication, assembly, testing, and shipment of the Tokamak Exhaust Processing (TEP) system.

Ready to Partner for Fusion Success



- **Joint proposals**
- **Cooperative Research and Development Agreements**
- **Strategic Partnership Programs**

Contact: David *Babineau, Director of Defense Programs Technology, SRNL*
Email: Dave.Babineau@srnl.doe.gov */ phone:* 803-725-8936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