



Minutes of the Beryllium Health & Safety Committee (BHSC) 2023 Spring Meeting



The Beryllium Health and Safety Committee (BHSC)
Washington, DC, U.S.A.

URL: <https://berylliumhealthandsafetycommittee.com/>

Minutes of the Beryllium Health & Safety Committee (BHSC) 2023 Spring Meeting

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The Beryllium Health & Safety Committee (BHSC) 2023 Spring Meeting was held on 9-10 May 2023 at the Lawrence Livermore National Laboratory (LLNL) in Livermore, California. The meeting has been held annually since 1995, with a break due to the recent pandemic.

The Minutes of the Spring Meeting have been compiled from the documents generated by the meeting organizers, combined with the abstracts and presentation files submitted by the participants in the event.

The BHSC 2023 Spring Meeting was organized by the BHSC's Meetings & Symposia Sub-Committee, with local support from LLNL. The meeting was held both in-person and online. Overall, participants came mainly from the U.S., but also from Canada, the UK, France, Germany, Japan, China, India, and Russia.

Keywords: Beryllium Health & Safety Committee (BHSC), Beryllium, Beryllium Oxide, Fusion Engineering, Irradiation Effects, Beryllide Intermetallic Compounds, Plasma-Facing Materials, Neutron-Multiplier Materials, Health and Safety, Chronic Beryllium Disease, Beryllium Sensitization, Fusion Start-Ups, Molten Salt, FLiBe, National Ignition Facility (NIF), FLiBe Purification, FLiBe Corrosivity, Tritium Extraction, Fluorescence Analysis, Lawrence Livermore National Laboratory (LLNL)

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Introduction & Post-Meeting Overview

The Beryllium Health & Safety Committee (BHSC) 2023 Spring Meeting was held on 9-10 May 2023 at the Lawrence Livermore National Laboratory (LLNL) site in Livermore, California. This meeting has been held annually as an in-person event from 1995-2019. Due to the pandemic, the Spring Meeting was not held from 2020-2022, and it was finally resumed again this year. There is also an annual Fall Meeting, and a larger BHSC Symposium that typically happens bi-annually.

Mission Statement

The BHSC is committed to promoting activities/efforts that will help to understand and prevent beryllium-induced conditions and illnesses, including beryllium sensitization (BeS) and chronic beryllium disease (CBD), that may be caused or exacerbated by workplace exposure to beryllium. The BHSC mission is primarily educational in nature, and is accomplished through generation, collection, and dissemination of information to members and other interested parties.

The Spring Meeting is an activity resulting directly from carrying out the foregoing Mission Statement. This year's meeting was organized by the BHSC's Meetings & Symposia Sub-Committee, with major technical support from LLNL staff. Participants came mainly from the U.S., but also from Canada, the UK, France, Germany, Japan, China, India, and Russia. Some key aspects to this year's meeting:

- Run in a hybrid format with both in-person and online attendees and presenters
- Highlighted beryllium molten salt (FLiBe) as an up-and-coming product form
- Featured presentations from both fission and fusion companies and research organizations
- Offered a tour of the National Ignition Facility (NIF), a laser inertial fusion project at LLNL
- Included participation from vendors, who presented their products and services in the field

The technical portions of the meeting were comprised of 14 presentations, including industrial-scale use of beryllium molten salt (FLiBe) in new fission reactors, potential for use of FLiBe in future fusion reactors, sampling studies being conducted at two major fusion research organizations, an overview of beryllium product forms and their uses in fission and fusion applications, an update on beryllium disease prevention regulations, the latest in beryllium analytical techniques, and products and services offered by the vendors. All of these presentations called attention to the importance of beryllium health and safety to ensure the success of the research.

There was also a BHSC business meeting, at which the point was raised that there is still a vacancy on the Board for the position of Recording Secretary, hopefully soon to be filled. The other important highlight was the announcement of the BHSC 2023 Fall Meeting, which will be held from 6-8 November 2023 at DOE's Forrestal Building in Washington, DC.

The final BHSC 2023 Spring Meeting agenda is included near the beginning of these Meeting Minutes to introduce the abstracts and presentations that follow. A list of the registered participants may be found in the Appendices of this document. Thanks again to all who participated to make this a great meeting.

Josef SOBIERAJ

Chair, BHSC Meetings & Symposia Sub-Committee

May 2023

BHSC 2023 Spring Meeting Agenda

The meeting agenda was organized under the leadership of BHSC Meetings & Symposia Sub-Committee Chair, Josef SOBIERAJ, with help from Committee Members Chris DORN of Kyoto Fusioneering and Be4FUSION, Gary GRIFFIN of GEG Consulting, as well as BHSC Chair Roland CHRETIEN. Local support at LLNL was provided by Jack BENNETT, Juliana SAGERT, and Eric ARELLANO. This is the version of the agenda that was distributed to the participants at the meeting.

AGENDA – Beryllium Health and Safety Committee Meeting May 9-10, 2023 – Lawrence Livermore National Laboratory Also available virtually; links to be provided later

All times listed below are Pacific Daylight Time (PDT)

Day 1 – Tuesday, May 9, 2023

Time (EST)	Activity	Task Lead(s) or Speaker(s)
<i>Morning (PDT) - available via webinar</i>		
07:30	Coffee and Pastries	
08:00	Welcome and Overview	Chretien
08:30	<i>'Case Studies of FLiBe Handling to Inform Industrial Practices'</i>	Merwin <i>et al.</i>
09:00	<i>'Beryllium Worker Protection Model for the Production and Handling of FLiBe'</i>	Heldt, G.
09:30	<i>'Safety Considerations Associated with FLiBe as an Advanced Breeder-Coolant for Fusion Tritium Breeding Blankets'</i>	Dorn <i>et al.</i>
10:00	Break	
10:15	<i>'Standardized Methods for Molecular Fluorescence Measurement of Trace Beryllium'</i>	Ashley <i>et al.</i>
10:45	Badging / Lunch	
<i>Afternoon (PDT) – available via webinar except for Tours</i>		
13:00	<i>'National Ignition Facility (NIF) Fusion Shot, to include a Discussion on Beryllium Operations and Analysis'</i>	Beale, R.
13:30	Travel and Coordination to the National Ignition Facility (NIF) / Discovery Center	Bennett, J.
14:30	NIF Tours / Discovery Center	Bennett, J.
16:30	Adjourn Tours (End of Day)	
18:00	Evening Social – Location TBD	

Day 2 – Wednesday, May 10, 2023

Time (EDT)	Activity	Task Lead(s) or Speaker(s)
<i>Morning (PDT) – available via webinar</i>		
07:45	Coffee and Pastries	
08:00	Second-day agenda review	Chretien
08:15	<i>‘Analysis of Beryllium Surface Contamination Levels of In-Vessel Components for the ITER Project’</i>	Kurinskiy <i>et al.</i>
08:45	<i>‘Analysis of Surface Sampling Techniques: Discussion of Results from UKAEA Pilot Study and Follow-on Progress’</i>	McKeon <i>et al.</i>
09:15	Break	
09:30	<i>‘10 CFR 850 Chronic Beryllium Disease Prevention Program Updates’</i>	Brown, A.
10:00	<i>‘Reduction of Airborne Beryllium Exposure by Automated Refurbishment of Z Machine Surfaces’</i>	Pass <i>et al.</i>
10:30	Break	
10:45	BHSC Business Meeting	Board Members
11:30	Lunch	
<i>Afternoon (PDT) – available via webinar</i>		
12:30	Vendor Technical Presentations	Moderator: Gary Griffin
13:15	Break	
13:30	<i>‘Beryllium and its Compounds Including Be Metal, BeO, FLiBe and Other Compounds and Their Manufacture and Uses in Nuclear Reactors’</i>	Smith, K.
14:00	<i>‘Experimental Development of Tritium Breeding Tests with 14MeV Neutrons and FLiBe’</i>	Woller <i>et al.</i>
14:30	Field/Mobile Accreditation for Be	Griffin/Brisson
14:40	Break	
15:00	Subcommittee Breakout Sessions	Members
16:00	Reports from Subcommittee Breakouts	S/C Chairs
16:30	Wrap-up	
End of Day 2		

(BHSC Board meeting: Mon, May 8)
(JOWOG 30-21 meeting: Thu/Fri, May 11-12)

BHSC Meetings & Symposia Sub-Committee

Name	Position	Organization
Josef SOBIERAJ	Chair	National Nuclear Security Administration
Chris DORN	Logo Design, Communications, Meeting Minutes	Kyoto Fusioneering America Ltd. Be4FUSION LLC
Gary GRIFFIN	Vendor & Sponsor Liaison	GEG Consulting LLC

BHSC 2023 Spring Meeting Vendor Organizations

The organizers of the BHSC 2023 Spring Meeting would like to thank the following vendors for their support of the event:



ALS Testing Services Salt Lake City, Utah, U.S.A.	Bureau Veritas North America Novi, Michigan, U.S.A. Lake Zurich, Illinois, U.S.A.	Scientific Sales, Inc. Oak Ridge, Tennessee, U.S.A.
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Day 1: Beryllium H&S: FLiBe Molten Salt, Analysis & Uses in Fusion

Case Studies of FLiBe Handling to Inform Industrial Practices

A. MERWIN et al. (Kairos Power LLC, California, USA)

Case Studies of FLiBe Handling to Inform Industrial Practices

Augustus MERWIN¹, Terrence WILLIAMS¹, Karleen JAMES², and
Alan KRUIZENGA¹

¹*Kairos Power, Alameda, California, USA*

²*Kairos Power, Albuquerque, New Mexico, USA*

The Kairos Power fluoride-salt-cooled, high-temperature reactor (KP- FHR) can be deployed with robust safety, affordable costs, and flexible operation to accommodate the expansion of variable renewables. The KP-FHR utilizes a mixture of lithium fluoride (LiF) and beryllium fluoride (BeF₂), also called FLiBe, for its unique properties as a liquid coolant and heat transfer fluid. While FLiBe offers advantages as a reactor coolant, it requires working with the beryllium fluoride at the industrial scale, which has associated environmental considerations in addition to needing robust worker health and safety practices.

Kairos Power has been working extensively with FLiBe for more than 2.5 years in a laboratory designed and built for this purpose. Lab operations have varied from closed systems, such as gloveboxes or inert piping, to open handling with engineering controls, such as ventilation, in addition to administrative controls and worker PPE. During these operations Kairos Power has gathered a variety of data; beryllium air monitoring and surface contamination data, photos and descriptions of operations, interview experience with the operators, and inspections that are compiled to provide lessons learned for improved work practices. A series of case studies on these operations, and the efficacy of the associated hazard controls will be presented to summarize findings from these laboratory experiences.

As Kairos Power scales towards deploying commercial reactors these laboratory findings are being used to inform industrial practices. Kairos Power has produced several tons of FLiBe for the Engineering Test Unit (ETU). ETU is Kairos Power's non-nuclear demonstration unit which has been hot commissioned and will demonstrate pumping tons of molten FLiBe at prototypic operating conditions for the first time. Strategies for applying the learnings from the laboratory case studies to industrial operations will be presented.

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CASE STUDIES OF FLIBE HANDLING TO INFORM INDUSTRIAL PRACTICES

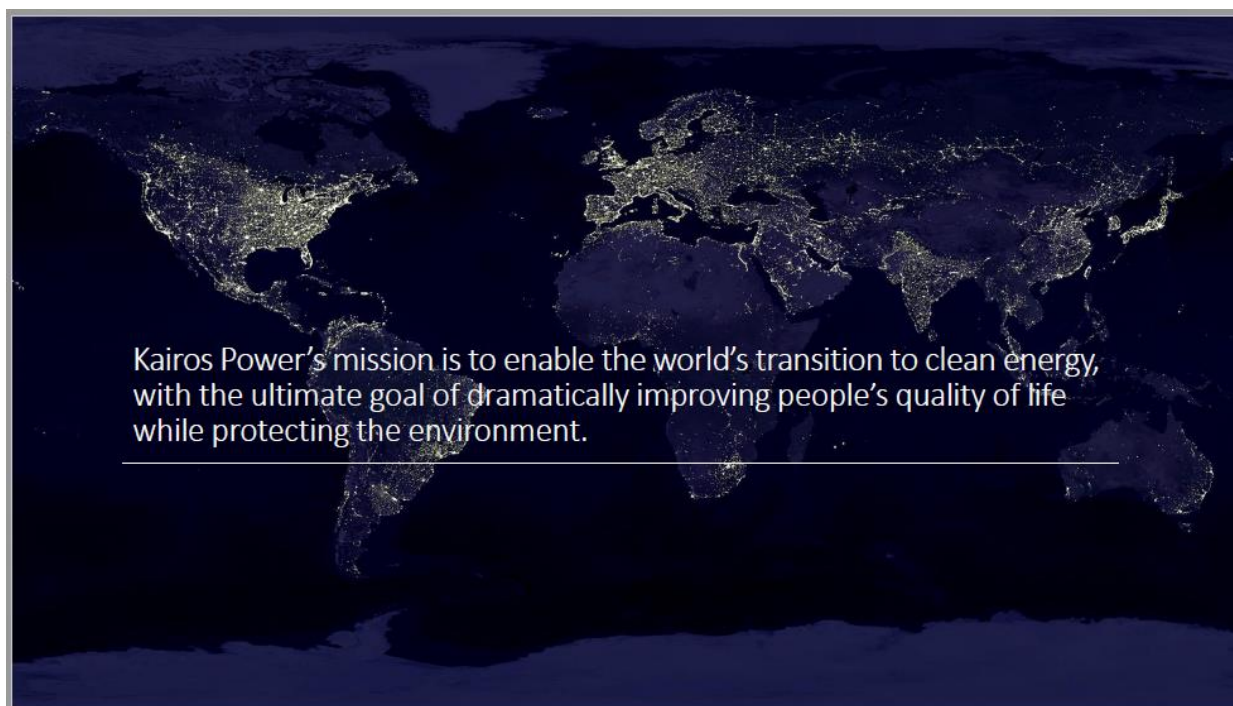
BERYLLIUM HEALTH & SAFETY COMMITTEE SPRING MEETING 2023

AUGUSTUS MERWIN, TERRENCE WILLIAMS, KARLEEN JAMES, ALAN KRUIZENGA

6 June 2023

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1



Kairos Power's mission is to enable the world's transition to clean energy,
with the ultimate goal of dramatically improving people's quality of life
while protecting the environment.

Overview of Kairos Power

- Nuclear energy engineering and design company focused on the commercialization of the fluoride salt-cooled high-temperature reactor (FHR)
 - Founded in 2016
 - Currently 300 Employees (*and growing*)
- Private funding commitment to engineering design and licensing program and physical demonstration through nuclear and non-nuclear technology development program.
- Schedule driven by US demonstration by 2030 (*or earlier*) and rapid deployment ramp in 2030s.

Kairos Power Headquarters

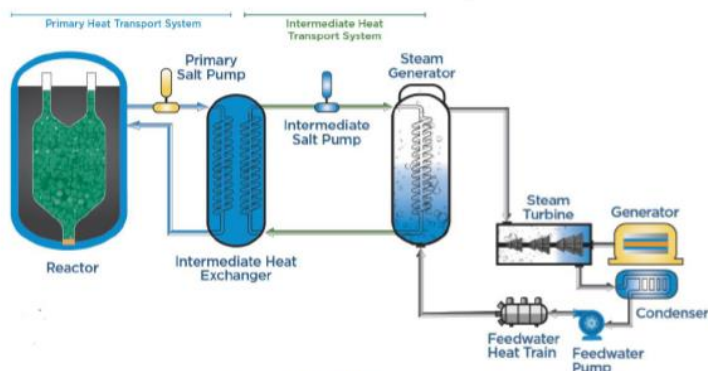


Kairos Power Locations



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Kairos Power Fluoride Salt-Cooled High-Temperature Reactor (KP-FHR)



- Reactor Power Level: 200-400 MWth
- Pebble Bed Core with Graphite Core Structures
- Core Inlet / Outlet Temperatures: 550 °C / 650 °C

Coated Particle Fuel - TRISO



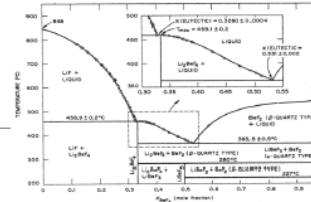
Liquid Fluoride Salt Coolant
Flibe (2LiF-BeF₂)



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Flibe as Reactor Coolant

- Chemistry
 - 2:1 molar mixture of LiF – BeF₂ salts
 - Thermodynamically compatible with structural alloys
 - Melting point at 460°C, boiling point >1400°C
 - Low vapor pressures and viscosity; good heat transfer properties
- Nuclear Properties
 - BeF₂ salts have excellent moderating ratios and ⁷Li enriched Flibe has negative temperature feedback
 - Pure salts have low short-term activation
- Industrial Hazards
 - BeF₂ is a dermal acting toxic sensitizer
 - Frozen Flibe is a sharps hazard
 - Potential for HF generation if impurities are present
 - High temperature fluid



Unpacking Beryllium Fluoride in S-lab

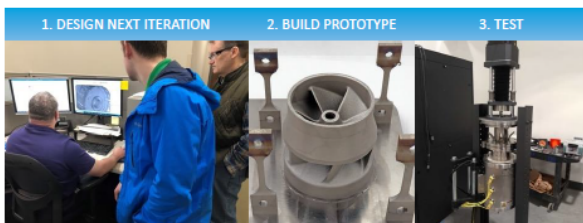


MSPP is located at the Materion Campus in Elmore, Ohio

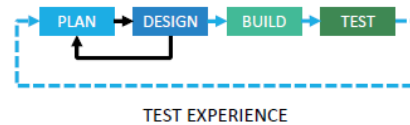
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K. A. Romberger, J. Branstetter, et al., J. Phys. Chem., vol. 76, (1972)

Kairos Power Nuclear Development Paradigm Shift



Conventional Nuclear Development Cycle

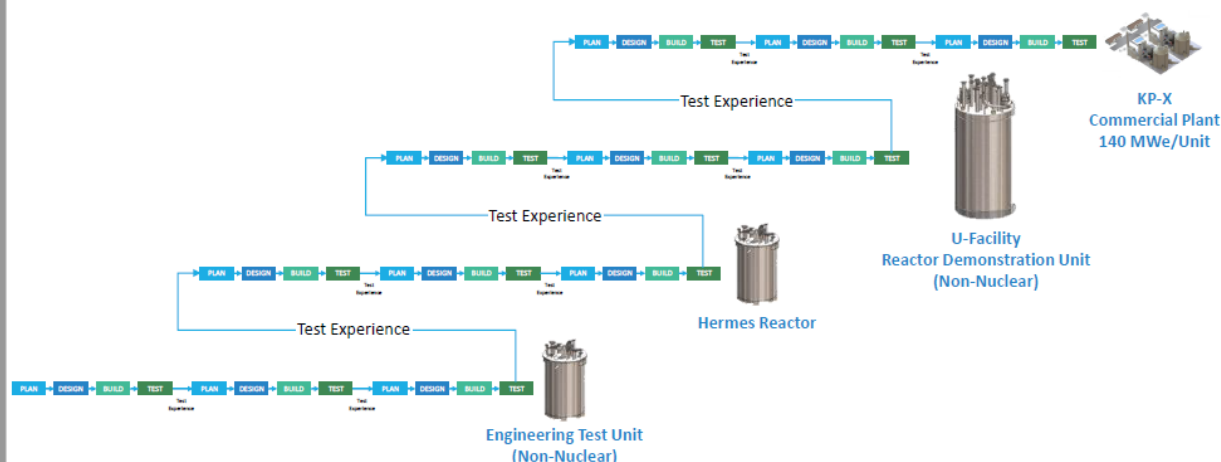


Kairos Power Accelerated Test Cycles for Innovation and Optimization



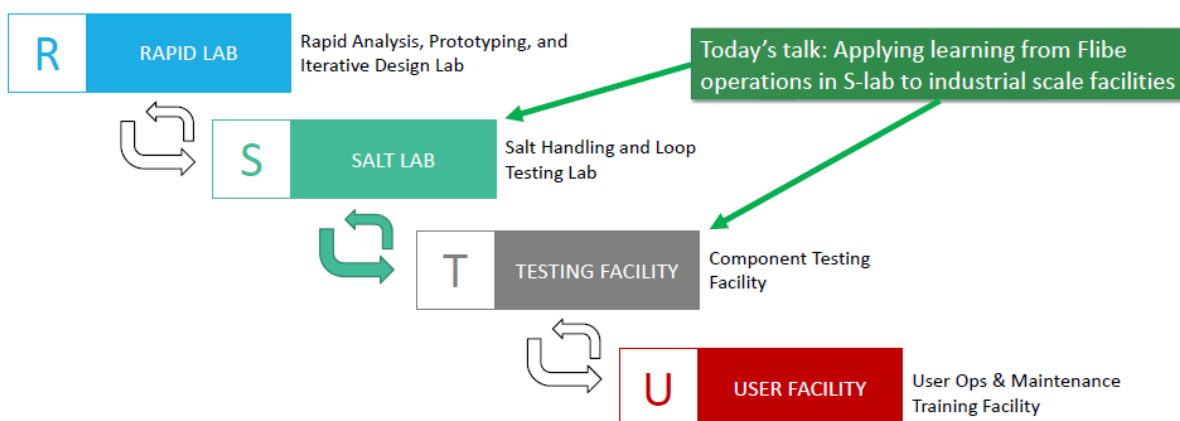
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Kairos Power Path to Commercialization: Successive Large-Scale Integrated Demonstrations



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Kairos Power Testing Program - Rapid Technology Demonstration Requires **Non-Nuclear** Development and Qualification Facilities



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Learning From S-lab to Inform ETU Operations



>2.5 years of operating experience with a verity of lab scale test systems



Construction complete / hot commissioning in progress
November 2022

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How Does Kairos Transition Knowledge Between Sites?

- S-lab employs fully redundant Engineering Controls and PPE to enable a rapid R&D environment
 - We want to move fast and break things in a controlled way
- Enables learning about migration of beryllium from Flibe under prototypic conditions
- Evaluate case studies to quantify efficacy of engineering controls
- Document learnings, train personnel on best practices, and apply controls to inform hazards assessments in a larger facility

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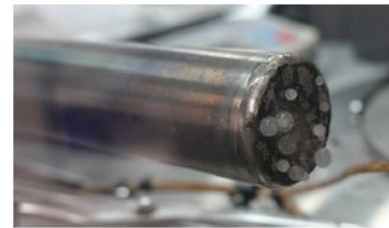
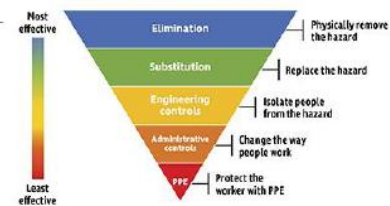
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General Notes on Flibe Controls

- Keep beryllium at the source
- How can beryllium migrate?
 - Light friable particulate travel by air currents
 - Solid heavy chunks travel by gravity
- When designing controls, we apply engineering controls for the form of contamination

NIOSH HIERARCHY OF CONTROLS



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Case Studies of Lab Engineering Controls

- Environmental Test (ET) – Opening flanged systems
 - Local ventilation and glovebags during maintenance
- In-Situ Mechanical (ISM) – Handling contaminated internals
 - An evolving series of controls as the machine and operations were optimized



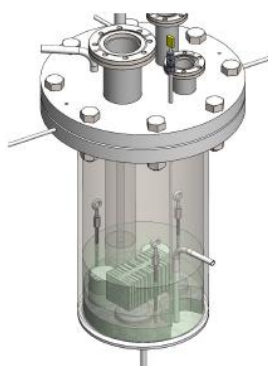
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Environmental Test

- Integrated effects test of controlling molten Flibe chemistry
- Accumulated >7 months of run time at 650°C
- Chemistry control operations often require procedures & controls for break of beryllium containment
- Operations and maintenance on ET are prototypic of what will be needed on ETU
 - ET was designed to practice ETU operations at a smaller scale to de-risk larger systems



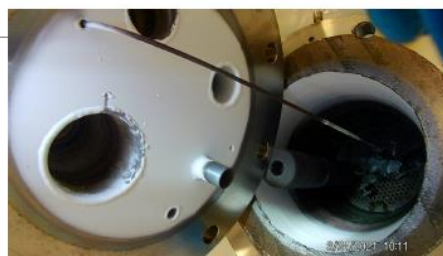
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ET Beryllium Hazards

- Vapor transport from molten Flibe forms friable "snow" on cold spots of system
- Filters in cover gas exhaust lines trap vapors/aerosols
- All system containment breaks require controls to prevent mobilization of snow that could spread contamination



Friable "snow" observed when breaking the main flange on ETU-ET



Flibe "snow" accumulated in off-gas lines

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ET Hazard Mitigation Strategies

- Engineering controls:
 - Local ventilation scaled to specific application
 - Glovebags used for larger tasks
 - Encapsulation/Containment when moving between containment areas
 - Down draft tables and gloveboxes for disassembling components
- Administrative Controls
 - Acceptance of local “dirty” zones that could not be practically cleaned
 - Regular swipes and monitoring for migration
 - Wet cleaning after all maintenance activities
 - “Dirty hand, clean hand”
- PPE:
 - Cut resistant gloves required for handling Flibe wetted materials



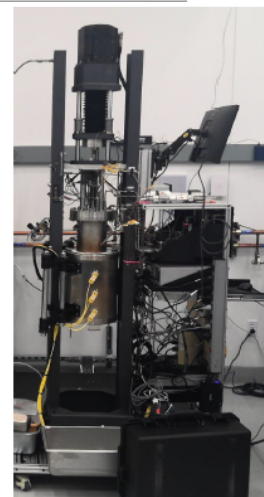
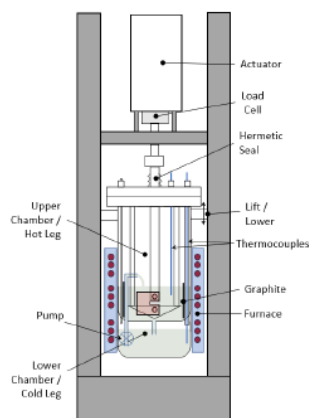
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In-situ Mechanical Test System – Flibe (ISM-F)

- ISM-F performs mechanical testing on reactor vessel materials immersed in Flibe
- Prototyping 1st of a kind systems required evolving the operational procedures which in turn evolved the methods of hazard control
- Several iterations of beryllium controls were implemented as we learned how and why beryllium behaved in the system



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ISM-F Hazard Mitigation Strategies v1

- Engineering controls:
 - Large local ventilation
- Administrative controls:
 - Mock system used for operator practice and dry runs outside of S-lab
- PPE:
 - Cut resistant gloves for all internal manipulations
 - Secondary Tyvek sleeves, treated like outer gloves
- Learning:
 - Mechanical manipulation of internals releases heavy particles that were not contained by ventilation



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ISM-F Hazard Mitigation Strategies v2

- Added engineering control:
 - Secondary containment (Ex. glove bags) during operations that required machinal manipulation of internals
- Added administrative control:
 - Task specific training and reviews to minimize migration of contamination
- Learning:
 - Adding on secondary containment systems slowed down operators and added hassle



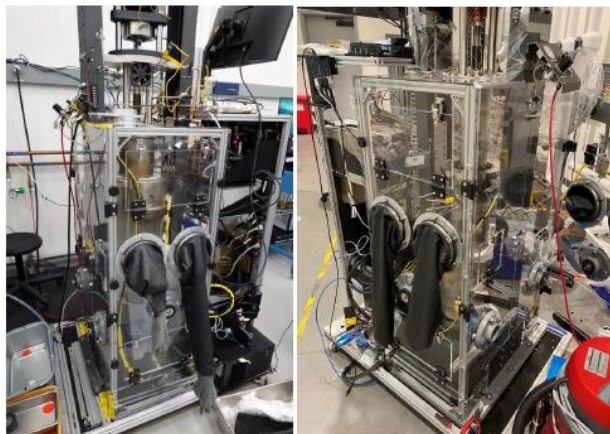
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ISM-F Hazard Mitigation Strategies v3

- Added engineering control:
 - Installed vented enclosure around test system
 - Designed to contain both heavy and aerosol particles
 - Removable doors facilitate low hazard tasks
 - Glove ports facilitate high hazard tasks
- Added administrative control:
 - Reduced the need for expert level operators
- Learning:
 - Designing custom-built containment systems saves time and energy



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Summary

- Kairos has been working hands on with Flibe in many test systems for several years
- Working with redundant layers of safety has enabled us to move quickly and learn about beryllium migration under various conditions
- Characterizing the migration of beryllium from a variety of hazard control schemes has informed how we work with Flibe and enabled us to design industrial controls to work with Flibe at reactor scales



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Beryllium Worker Protection Model for the Production and Handling of FLiBe
G. HELDT (Materion Brush Inc., Ohio, USA)

Beryllium Worker Protection Model for the Production and Handling of FLiBe

Gregory H. HELDT, MS MPH CIH

Materion Brush Inc., Mayfield Heights, Ohio, USA

Lithium beryllium fluoride (Li_2BeF_4), or FLiBe, is a molten salt made from a mixture of lithium fluoride (LiF) and beryllium fluoride (BeF_2) with potential applications as a coolant in molten salt-cooled nuclear reactors and as a liquid blanket for ARC fusion reactors. Beryllium, as either an insoluble or soluble compound, can cause beryllium sensitization (BeS) and chronic beryllium disease (CBD) in susceptible individuals.

Beryllium salts, such as BeF_2 and FLiBe, are soluble compounds. However, most beryllium worker protection efforts are concentrated around operations that process commercially available forms of insoluble beryllium such as beryllium metal, beryllium alloys, and beryllia ceramics. Recently renewed interest in the research and production of FLiBe resulted in the construction of a molten salt purification operation in at the Materion Brush Inc facility in Elmore, OH, where BeF_2 is readily available as a feedstock.

Industrial hygiene design considerations for the production and handling of FLiBe were required to address controls for both BeF_2 salt and molten FLiBe. These efforts included the utilization of existing beryllium worker protection controls used in the production of BeF_2 with the addition of an enclosed design, local exhaust ventilation, administrative procedures for process upsets, and personal protective equipment designed for working with soluble compounds. Initial industrial hygiene beryllium exposure assessments are currently underway.

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**Beryllium Worker Protection
Model for the Production and
Handling of FLiBe**

*Prepared by Gregory H. Heldt, MS MPH CIH
Materion Brush, Inc.*

9 May 2023

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Lawrence Livermore National Laboratory
**BHSC 2023
Spring Meeting**
Beryllium Health & Safety Committee
Livermore, California, USA
9-10 May 2023

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The slide features a dark blue background with a subtle pattern of concentric circles. On the right side, there is a graphic of a molecular structure with blue spheres and white connecting lines. In the center, there are three circular images: the first shows a globe with 'IOT' and various icons; the second shows a person working in a laboratory setting; the third shows a close-up of a mechanical component. The Materion logo is in the bottom right corner.



Brief Introduction

- Product Stewardship Manager – Materion Brush, Inc.
- 10+ years working with beryllium
- MPH Epidemiology
- MS Occupational Health / Industrial Hygiene
- Certified Industrial Hygienist

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The slide has a light blue background with a pattern of concentric circles. A thick blue diagonal line runs from the bottom left towards the top right. The text is in a clean, sans-serif font.

FLiBe

- Molten salt made from a mixture of lithium fluoride and beryllium fluoride
- Applications for both fission and fusion energy technologies

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Kairos Power and FLiBe

- The Kairos Power fluoride salt-cooled high-temperature reactor (KP-FHR) is a novel advanced reactor technology that leverages TRISO fuel in pebble form combined with a low-pressure fluoride salt coolant. The technology uses a steam cycle to convert heat from fission into electricity.
- Molten fluoride salts, such as FLiBe, have outstanding capability to transfer heat at high temperature, excellent chemical stability, and the ability to retain radioactive fission products that might be released from fuel.

 Kairos Power www.kairopower.com

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FLiBe Molten Salt Purification Pilot (MSPP)

- Materion Brush Inc and Kairos Power partnered to produce FLiBe as a coolant for the Kairos Power Fluoride salt-cooled High temperature Reactor (KP-FHR).
- The Molten Salt Purification Pilot (MSPP) facility was commissioned at Materion's Elmore, OH plant in July 2022.



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FLiBe Molten Salt Purification Pilot (MSPP)

- MSPP is the largest FLiBe production facility ever built and has the capacity to generate commercial quantities of material
- Materion operates the facility and provides beryllium fluoride and lithium fluoride as throughput material.



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Beryllium Worker Protection Model

- Composed of 8 Elements
- Developed specifically for the control of beryllium exposures at very low concentrations ($<1 \mu\text{g}/\text{m}^3$)
- Most industrial hygiene concepts are developed for the control of exposures in relatively high concentrations ($\sim\text{mg}/\text{m}^3$) and are less effective for controlling beryllium exposure

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Beryllium Worker Protection Model

1. Keep Beryllium
out of the Lungs

2. Keep Beryllium
off the Skin

3. Keep Beryllium
off Clothing

4. Keep Beryllium
at the Source

5. Keep Beryllium
in the Work Area

6. Keep Beryllium
on Plant Site

7. Keep Beryllium
Areas Clean

8. Keep Beryllium
Workers Prepared

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Beryllium Worker Protection Model

Most applications of the Beryllium Worker Protection Model concentrate around the processing of insoluble, commercially-available forms of beryllium:

- Beryllium Alloys (CuBe)
- Beryllia Ceramics (BeO)
- Beryllium Metal



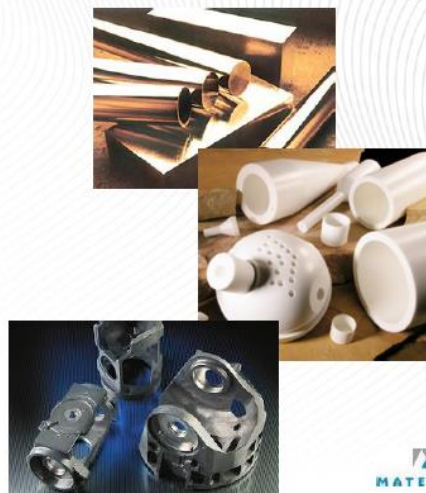
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Beryllium Worker Protection Model

Insoluble, commercial forms of beryllium are typically processed through casting, rolling, grinding, milling, polishing, and machining.

These activities do not cleanly translate to the processing and handling of FLiBe.



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Beryllium Worker Protection Model

Soluble forms of beryllium, including BeF₂ and FLiBe, are generally not commercially available.

Special considerations were required in the design and implementation of the BWPM for the production and handling of soluble molten salt.



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1. Keep Beryllium out of the Lungs

- Assigned Protection Factor of 1000
- Assumes a worst-case scenario involving the release of BeF₂ or FLiBe
- MSPP is a new process
 - IH beryllium exposure characterization is ongoing



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2. Keep Beryllium off Skin / 3. Keep Beryllium off Clothing

- All operators entering the MSPP are required to wear:
 - Hooded chemical coveralls
 - Chemical boot covers
 - Two pairs of nitrile gloves
 - Cut-resistant work gloves



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2. Keep Beryllium off Skin / 3. Keep Beryllium off Clothing

- The selection of chemical overalls is critical to worker protection and should include:
 - High permeation rate (>480 min)
 - Resistance to sweat penetration
 - Welded seams (not stitched)
 - Adhesive closures
- Nitrile gloves are taped at the wrists
- Tight-fitting PAPRs are taped to the hood



MICROCHEM 2000



MICROCHEM 2300+

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2. Keep Beryllium off Skin / 3. Keep Beryllium off Clothing

- Operators are provided visual cues designating the color of nitrile glove required to proceed through each part of the plant
- Ensures operators utilize a First On / Last Off glove system to safely doff respiratory protection in transition areas



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4. Keep Beryllium at the Source

- The MSPP is designed to isolate operators from directly handling salts
- LiF and BeF₂ drums are fitted with flanged cones and inverted for charging
- A HEPA vacuum is used to capture any fugitive material



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4. Keep Beryllium at the Source

- The MSPP is equipped with general exhaust ventilation on each floor of the skid
- Target is 10-12 air changes per hour (ACH)
- General exhaust ventilation is routed through a pollution control device



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5. Keep Beryllium in the Work Area

- Access to the MSPP is restricted by using one centralized transition room
- The transition room is HEPA filtered and equipped with downdraft tables for the donning and doffing of respiratory protection



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5. Keep Beryllium in the Work Area

- To control the migration of beryllium, operators use dedicated footwear when entering production areas



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5. Keep Beryllium in the Work Area

- To leave production areas, operators must pass through a HEPA-filtered air shower before doffing respiratory protection in the transition room



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Main Transition Area



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6. Keep Beryllium on Plant Site

- Materion utilizes a robust decontamination procedure to ensure transfer vessels are visibly clean and that beryllium remains on-site
- Transfer vessels are wipe sampled after decontamination prior to shipment to assess cleanliness

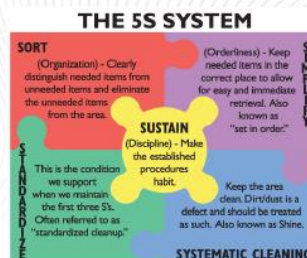


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7. Keep Beryllium Areas Clean

- The MSPP is held to the same 5S cleanliness standard as the rest of the manufacturing facility
- Checklists and housekeeping schedules are maintained to help keep the area visibly clean
- Stand-alone HEPA filtration units have been installed increase air changes and help remove fugitive particulate



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8. Keep Beryllium Workers Prepared

- Operators receive annual beryllium hazard awareness training, including the hazards of soluble beryllium
- Each operator must complete a PPE Donning/Doffing Competency Test demonstrating knowledge of PPE usage and removal

Beryllium Work Areas PPE Don/Doff Checklist for Competency		
Employee Name	Clock No.	
Department	Observer Name	
Date	Shift	
Part 1: Donning of PPE for entry into a contaminated work area		
Operator will be wearing prior to commencing this list (at a minimum) blues, a TFPAPR, FOLD gloves, and work boots.		
OBSERVERS MUST READ DONNING SEQUENCE TO THE OPERATOR IN A STEP-BY-STEP FASHION.		
Step 1	Hair length below shoulders must be tied back and secure, remove all jewelry, tools, or any item that may damage the PPE.	
Step 2	Inspect PPE prior to donning.	
Don PPE in the order that follows		
Step 3	Don outer layer of Nitrile gloves	
Step 4	Eye/hood is donned over head and respirator	
Step 4a	Hood completely covers ears and neck and is situated on the face piece of the TFPAPR	
Step 4b	Hood extends past the neck to the shoulders	
Step 5	Don booties	
Step 5a	Don first layer (grey) booties	
Step 5b	Don second layer (chemical) booties	
Step 6	Microchem 3000 suit donned	
Step 7	Both suit zippers are zipped completely. Care should be taken to ensure that the eye/hood is in place and no skin or hair is visible between the hood and the respirator	
Step 8	The following should be taped:	
	(1) Inner sleeve to outer Nitrile with 50/50 overlap	
	(2) TFPAPR to hood of Microchem 3000	
	(3) Outer zipper in neck area to prevent sliding of zipper.	
Step 8a	When conducting wet tasks a complete seal is required around the Microchem hood and TFPAPR, this should be done with yellow tape.	
Step 9	Work or chemical gloves should be underneath the outer sleeve of the Microchem 3000.	
Step 9a	When conducting wet tasks the outer sleeve for Microchem 3000 should be taped at the wrist to chemical gloves.	
Step 10	Swiffer is prepped for entry into the work area.	
Step 11	Integrity of PPE is verified by the observer and the lack of visible hair or skin is observed as well.	
Step 12	Place Swiffer in Hot Zone prior to beginning work.	

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Early Insights – IH Sampling Results

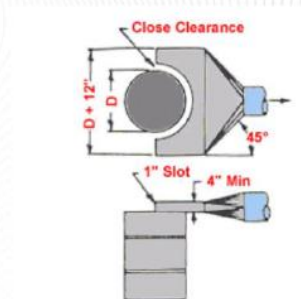
- IH exposure data results are limited due to process stability
 - (e.g., unexpected starts, stops)
- A full beryllium exposure characterization will be completed once the process is in control
- Some opportunities for improvement have been identified

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Early Insights – Local Exhaust Ventilation

- Operators currently use a central vacuum system to provide point ventilation for charging activities and maintenance line breaks
- There are opportunities to reduce worker exposure using permanent local exhaust ventilation collars at points where designated line breaks generate particulate
- Design is already underway



- $Q = 100 \text{ cfm/sq ft barrel top min}$
- Duct velocity = 3500 minimum
- Entry loss = $0.25 \text{ vp} + 1.78 \text{ slot vp}$
- Manual loading

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Early Insight – PPE and Housekeeping

- Efforts to implement a robust 5S cleaning schedule have been limited by short stay times dictated by PPE usage
- Even in ideal conditions stay times are limited to 90 minutes
- Stay times are likely to shorten during upcoming summer months
- There has been some success using standalone air conditioning units to cool the internal temperature of the skid
- Increased local and general exhaust ventilation may improve housekeeping

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Safety Considerations Associated with FLiBe as an Advanced Breeder-Coolant for Fusion Tritium Breeding Blankets

C.K. DORN (Kyoto Fusioneering America Ltd., Washington, USA) et al.

Safety Considerations Associated with FLiBe as an Advanced Breeder-Coolant for Fusion Tritium Breeding Blankets

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Kyoto Fusioneering (KF), a private fusion technology company based in Japan, is exploring the use of FLiBe (a lithium fluoride and beryllium fluoride eutectic mixture) molten salt as a promising breeder-coolant for tritium breeding in fusion reactors. FLiBe has many attractive features, such as: high neutron multiplication, excellent tritium breeding properties, low tritium solubility, limited interaction with the strong magnetic fields present in a magnetic fusion reactor, and the ability for operation at relatively low pressures. However, FLiBe and its associated technologies are at relatively low technology readiness levels and its use also raises several safety concerns that need to be addressed before it can be deployed in experimental - and, ultimately, commercial - fusion reactors. In collaboration with Kyoto University, KF is currently working with lab-scale quantities of FLiBe in a benchtop loop to develop our experience and capabilities, marking the start of the FLiBe-oriented arm of our overall tritium breeding research and development programme in the coming years (other breeder-coolants under exploration are lithium-lead and pure lithium). This work provides an overview of the identified safety issues associated with the use of FLiBe.

In a FLiBe breeding blanket, tritium will be produced by the interaction of neutrons with the lithium. This results in the production of tritium fluoride (TF), which is highly reactive and corrosive to the structural and functional materials, as well as components. The occurrence of corrosion comes with a risk of releasing materials to the environment, which could have serious safety consequences from both a conventional and radiological point of view. Additionally, a fusion reactor must breed its own fuel, so any tritium produced in the form of TF must also be separated out from the coolant to be injected back into the fusion reactor as fuel. TF is difficult to handle and transport due to its high reactivity and mobility, and thus specialized equipment and facilities are required for handling. It is thus desirable to remove TF, and strategies to remove TF using Be and Li in redox reactions are being investigated by KF.

The corrosion behavior of FLiBe is worsened by the presence of impurities contained with the mixture, which can be introduced either from the raw material of LiF and BeF₂ before mixing, or from corrosion during operation, meaning purification processes are desirable when operating a FLiBe coolant loop. These processes involve the use of H₂ and HF gas, both of which come with their own safety considerations.

Known FLiBe-compatible materials are limited, and nickel-based alloys known to have good compatibility produce large quantities of undesirable radioactive products under neutron irradiation. Finding suitable materials is thus also driven by safety considerations.

KF is exploring whether FLiBe has promise as a breeding blanket material, and is sharply focused on identifying and resolving safety concerns. Proper handling and containment measures should be incorporated into the design at the earliest stages, to mitigate risks associated with its use. Here, the challenges, as well as KF's programme to understand and find solutions, are presented.

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Beryllium Health & Safety Committee (BHSC) Spring Meeting
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9th May 2023

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the **FUTURE.**

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 - Tritium Generation & Extraction
 - Purification & Handling Processes
- Future R&D Directions with FLiBe
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- Broader Implications for Fusion Technology
- Summary of FLiBe Safety Concerns
- Conclusions

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Introduction (1)

- Presenter Personal Background
 - Education
 - Commercial Beryllium Industry
 - Fusion and Environmental, Health & Safety (EH&S)
 - BHSC Board & IEA Be Technology WG
- About Kyoto Fusioneering (KF)
 - Established Oct-2019
 - Venture Capital (VC) Funding: ¥2.1B (JPY) = \$17M (USD)
 - Locations: Japan, UK, and US
 - Company Size: 85+ (including part-time and contractors)
 - Currently Hiring in all Locations



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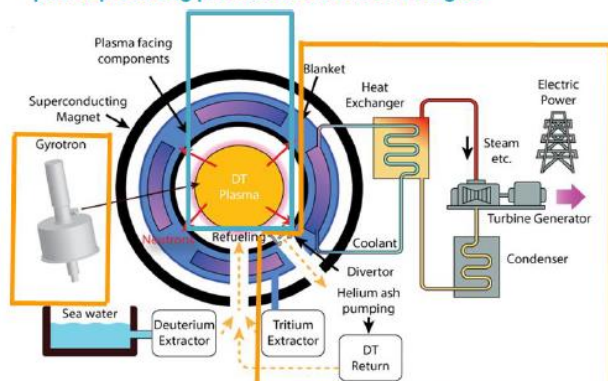
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Introduction (2)

- KF Business Model
 - Akin to the role of Levi Strauss in the California Gold Rush
 - Focused on *Critical Path* Reactor Technologies to enable overall success of the Fusion Industry
- KF Mission Statement
 - To accelerate the development of high performance, commercially viable reactor technologies associated with plasma heating, thermal cycle, and fuel cycle to support the rapid expansion of the budding fusion industry.

Fusion developers around the world are working on power-producing plasmas & related technologies



Kyoto Fusioneering is focused on reactor technologies and engineering

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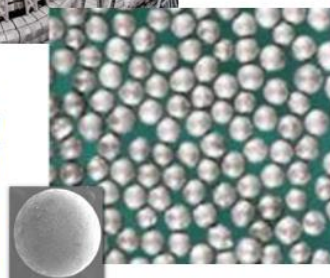
History: Beryllium in Fusion & FLiBe Molten Salt (1)

- Plasma-Facing Material
 - Joint European Torus (JET)
 - Beryllium as replacement for Graphite
 - First Large-Scale Use in JET in 1989
 - Belt Limiter Tiles
 - RF Antenna Tiles
 - ITER-Like Wall in JET in 2009-2010
 - Planned for ITER First Wall Panels (?)
- Neutron Multiplier
 - Originally Solid Breeder Concept
 - Various Material Forms
 - Small-Diameter Pebbles
 - Beryllide Intermetallic Compounds
 - Liquid Breeder Concept ==> FLiBe?



Interior of the JET Reactor with the ITER-Like Wall beryllium tiles installed

Beryllide Intermetallic (TiBe_{12}) 1mm-diameter pebbles made by KAKEN for QST in Rokkasho, Japan using an optimized Rotating Electrode Process in small quantities (Source: Nakamichi et al., 2019)



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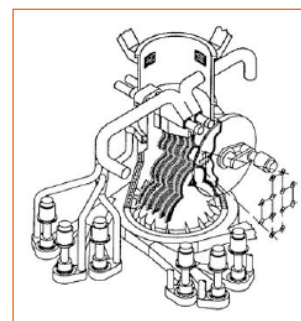
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History: Beryllium in Fusion & FLiBe Molten Salt (2)

- FLiBe Molten Salt (Fission)
 - Lithium Fluoride – Beryllium Fluoride Mix
 - Molten Salt Reactor Experiment (MSRE)
 - First Use of FLiBe
 - Oak Ridge National Lab (ORNL)
 - Ran from 1965-1969
 - Other Molten Salts at ORNL (1950s)
 - Today: Small Modular Reactors (SMRs)
 - Alternative to Lead-Bismuth (LBE)
- FLiBe for Fusion
 - Earliest Application in Design
 - HYLIFE Concept (Moir et al., 1993)
 - LLNL supported by US Dept of Energy
 - Advantage: Multi-Purpose Material
 - 3 Major Functions (see next slide)



Heat Transfer Reactor Experiment (HTRE-2 and HTRE-3) at Idaho Nat'l Lab. Photo Credit: Richard Pearson, taken Oct-2017.



HYLIFE-II Reactor Schematic Image. Source: Moir et al., 1993

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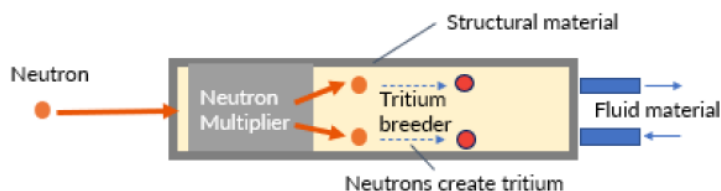
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Why FLiBe for a Fusion Blanket?

What is a Fusion Blanket?

- The blanket is the material surrounding the plasma inside the vacuum vessel. It has three functions: heat conversion, shielding, and fuel breeding [1].



A Fusion Blanket Needs 4 Key Functional Materials

- Tritium Breeder
- Neutron Multiplier
- Heat Extraction Fluid
- Blanket Structural Material

FLiBe

Compared to other Be-based materials for various fusion blanket design concepts, FLiBe has the advantage that it could fulfill 3 of the 4 key functions

[1] Source: Baus, C. [Fusion Reactor: Blanket: Colin | Fusion Energy | Medium](#)

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Current FLiBe R&D Program at Kyoto Fusioneering (1)

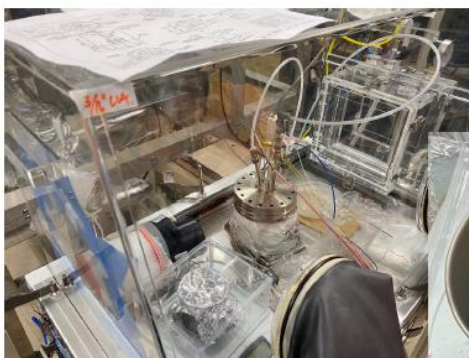
FLiBe Principal Research Area	Challenges/ Requirements	Current Activities at KF	Key Safety Considerations
Compatibility: Corrosion & Containment	Stability of materials in contact with FLiBe, neutrons, tritium, and heat	Seek out candidate materials based on known properties & other data	Worker exposure limits for beryllium and local environmental regulations
	Longevity and reliability under reactor conditions	Modeling & small-scale testing	Radiation safety, including radioactive waste
	Impact on structural materials and components	Modeling, testing, and design work	Worker & environmental protection programs
Tritium Generation & Extraction	Performance related to Tritium Breeding, Release & Extraction	Modeling & small-scale testing	Tritium safety
	Reactivity of tritium fluoride (TF) and hydrogen fluoride (HF)	Laboratory testing	Leaks resulting in release of Be or tritium to the environment
Purification Process & Handling	Specifications for and availability of feedstock materials	Supply chain investigation, including make/buy options	Supplier compliance responsibilities
	Impurities in FLiBe increase its reactivity/ corrosivity	Small batch trials conducted	Facilities/ equipment aligned to worker & environmental protection programs

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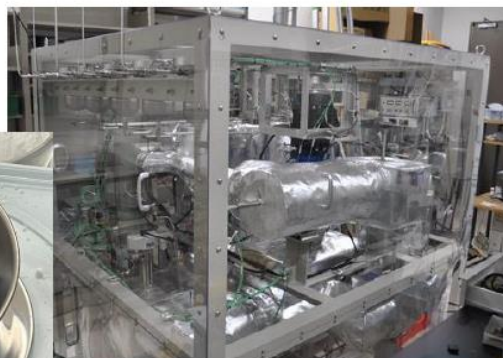
Current FLiBe R&D Program at Kyoto Fusioneering (2)



Glovebox set-up at Kyoto University, used for making and purifying laboratory quantities of FLiBe for testing.



Solid beryllium fluoride for making FLiBe in the lab.



FLiBe Test Loop bench-top experiment at Kyoto University, which will be used to investigate the dynamic performance of the liquid breeder/coolant.

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Future R&D Directions with FLiBe



- Investigate Alternative FLiBe-Compatible Blanket Materials
 - Testing under Reactor Conditions
 - Corrosion & Containment
 - Static vs. Dynamic for Liquids
- Advanced Purification & Tritium Extraction
 - Improve Yields of Current Methods
 - Breakthroughs in Tritium Handling
- Containment System Design
 - Minimize Risks
 - Use Innovative Concepts
 - Improve Monitoring & Control Systems



KF's planned state-of-the-art research test platform, UNITY (UNIQUE Integrated Testing facility), which will be the world's first such testing facility for fusion power plant equipment. Electricity generation with fusion-relevant technologies is planned by 2024.

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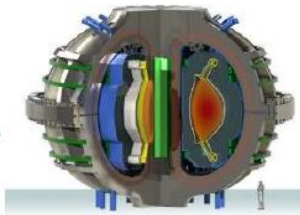
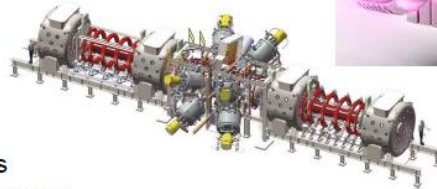
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Integration: Experimental & Commercial Fusion Reactors



- Safety as part of early Design Phase
 - Both Conventional & Radiological Safety
 - Proactive Approach to Addressing Risks
- Collaboration
 - Industry, Academia & Regulatory Bodies
 - Public-Private Partnerships
 - Exchange Knowledge & Share Resources
 - Coordinate Efforts to Advance Fusion Progress
- Potential FLiBe Use in Fusion
 - Establish Safety Guidelines
 - Develop Best Practices
 - Consider Scalability of Systems & Materials
 - Regulatory Framework for FLiBe
 - Learn from Fission Users (SMRs, FHRs)



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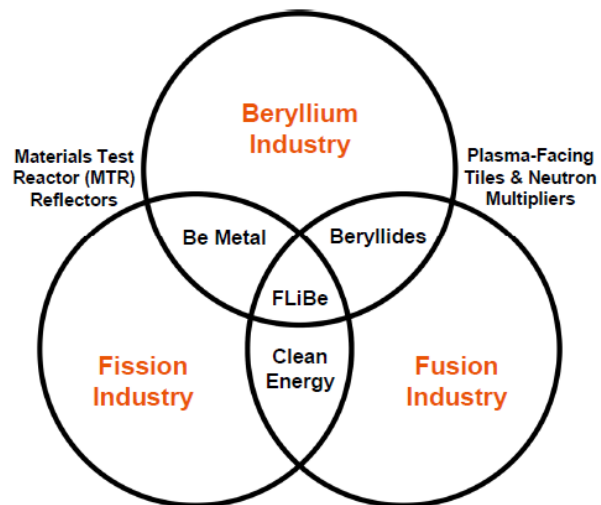
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Broader Implications for Fusion Technology



- Overall Impact of FLiBe Use
 - Potential Increased Efficiency
 - Tritium Breeding (Fuel)
 - Improved Thermal Management
 - Contribute to Global Energy Transition
 - Fusion: Clean with Abundant Fuel
 - Accelerate Use of Fusion Power Plants
- Focus on Safety
 - Building Public Trust in Fusion
 - Multiple Concerns with FLiBe
- Other Considerations
 - Economics/ Financial
 - Supply Chain
 - Potential Need for Recycling?



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Summary of FLiBe Safety Concerns

- Transmutation of Lithium (Li) into Tritium
 - Increase Fluorine (F) Potential in the System
 - Leads to Generation of HF and TF, both highly Corrosive Compounds in their own Right
 - Could Result in further Increasing FLiBe's Corrosivity to Structural Materials
- Nuclear Safety Aspects
 - Formation of Short-Lived Radionuclides of Fluorine
 - Potential Cause of Leaks of FLiBe to the Environment
- Worker & Environmental Protection
 - Consider Be, F, T, HF, TF and Perform Needed R&D
 - Must also include Radiation Protection
 - Impact of Scale-Up to Systems using 100s of Tons



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Conclusions

- FLiBe has Potential as Fusion Breeder Blanket Material
 - Some Advantages over Other Options
 - Key Challenges require R&D: Materials Compatibility, Tritium Extraction & Purification
 - More R&D Needed under Fusion-Relevant Conditions
 - Scalability for Fusion Power Plants
- Safety is on the Critical Path
 - Environmental, Health & Safety (EH&S) Programs are Integral to all R&D
 - Radiological Safety must also be a Key Element of the EH&S Program
 - Success of Fusion is Predicated on Ability to Operate Safely
- Collaboration & Partnerships
 - Public-Private Partnerships
 - Government Programs
 - Industry to Industry (Fission & Fusion Synergies?)

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Standardized Methods for Molecular Fluorescence Measurement of Trace Beryllium
K. ASHLEY (Ashley Analytical Associates LLC, Arizona, USA) et al.

Standardized Methods for Molecular Fluorescence Measurement of Trace Beryllium

Kevin ASHLEY¹, John P. CRONIN², Anoop AGRAWAL², and Lori ADAMS²

¹Ashley Analytical Associates LLC, Amado, Arizona, USA

²Berylliant Inc., Tucson, Arizona, USA

Standardized protocols have been developed based on a molecular fluorescence method for the determination of trace beryllium (Be) in samples collected in occupational and environmental settings. The methodology, which is field-portable, entails extraction of collected samples in dilute ammonium bifluoride (NH₄HF₂, aqueous), followed by fluorescence measurement of the complex formed between Be and hydroxybenzoquinoline sulfonate (HBQS). The technique has been optimized to achieve an estimated method detection limit (MDL) of ≤1ng Be/sample, with a dynamic range extending to >10µg Be/sample. Potentially interfering metals (in >400-fold excess concentration compared to that of Be) are negligible or minimal. The estimated MDL of the fluorescence method is the lowest attained by means of conventional laboratory techniques.

Besides beryllium salts and other Be compounds, the fluorescence procedure is effective for the dissolution and quantitative determination of Be extracted from refractory beryllium oxide (BeO) particles. The method has also been successfully modified for measuring Be content in soil samples. The performance of the procedure compares favorably with methods employing sample digestion in acid mixtures that include hydrofluoric acid (HF), followed by inductively coupled plasma-mass spectrometry (ICP-MS). ASTM International voluntary consensus standards and U.S. National Institute for Occupational Safety and Health (NIOSH) methods based on the methodology have been published. The sampling and analytical protocol has been thoroughly evaluated and validated through intra- and inter-laboratory testing. These methods are recognized by laboratory accrediting organizations in the USA and in Europe. Application to the measurement of trace Be in occupational and environmental samples has been successfully extended to:

- Workplace air samples
- Surface wipe samples (media: cellulosic and polyvinyl alcohol)
- Cellulosic inserts for air & micro-vacuum samples
- High-fired (calcined) BeO
- Beryllium salts (e.g., BeF₂, FLiBe)
- Cotton gloves
- Nanoparticles (airborne)
- Soil samples

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U.S.A.

STANDARDIZED METHODS FOR MOLECULAR FLUORESCENCE MEASUREMENT OF TRACE BERYLLIUM

Kevin Ashley, PhD, FASTM

Ashley Analytical Associates LLC, Amado, AZ (USA)

John P. Cronin, PhD

Anoop Agrawal, ScD

Lori Adams

Berylliant, Inc., Tucson, AZ (USA)

Beryllium Health & Safety Committee Meeting, LLNL, May 2023

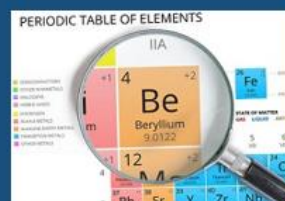
AIMS OF THIS PRESENTATION

- Give overview of method development, evaluation and validation of trace beryllium determination by means of molecular fluorescence
- Disseminate information on ASTM International consensus standards and CDC/NIOSH methods for trace beryllium
- Show performance data on ultra-trace beryllium measurement & applications to various sample media of concern

APPLICATIONS OF BERYLLIUM

Industries where beryllium is used:

- Aerospace
- Nuclear power & weapons
- Automotive industry
- Sports equipment
- Communications (cell phones)
- Foundries (e.g., Cu-Be alloys)
- Recycling of electronic components (e.g., computers)
- Aluminum (Be in bauxite)
- Coal (Be in ore; sandblasting)
(etc.)



BERYLLIUM – HEALTH RISKS

- Exposure pathways:
 - Inhalation (aerosols)
 - Dermal (surface contamination)
- Be health effects:
 - Immunological response (sensitization)
 - Chronic beryllium disease (CBD)
- ACGIH:
 - $0.05 \mu\text{g}/\text{m}^3$ (8-hr TWA)
- US DOE – surface Be:
 - $0.2 \mu\text{g}/100 \text{ cm}^2$

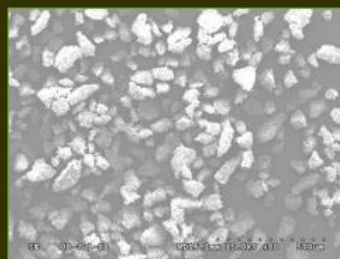


Be Regulatory OELVs GESTIS database, IFA, Germany (2023)		
Country	8-hr TWA, $\mu\text{g}/\text{m}^3$	STEL, $\mu\text{g}/\text{m}^3$
US	0.2	2
DE	0.14 (I); 0.06 (R)	0.14 (I); 0.06 (R)
AU, SG, UK	2	–
CA (PQ)	0.15	–
IE, PL, ES, LV, NZ, IL, IT, RO	0.2	–
JP, NO	1	–
FI	0.1	0.4
BE	0.05	10
AT	0.02	0.2
FR, CH, SE, HU	0.6	–
CA (ON), KR	2	10
ZA	0.1	–
CN	0.5	1
DK	0.02	2
EU (effective 2026)	0.02	–

ANALYTICAL CONSIDERATIONS

- Dissolution technique must solubilize Be from refractory materials, notably calcined BeO
- Detection method must quantitatively measure Be at sub-nanogram levels

High-fired
BeO particles →



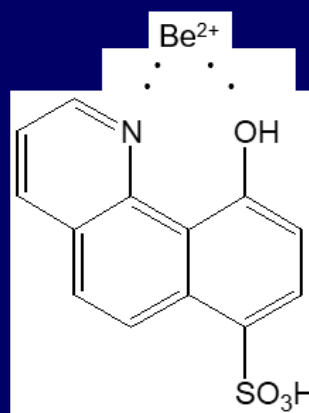
TRACE MEASUREMENT METHODS FOR BERYLLIUM IN AIR SAMPLES: ESTIMATED METHOD DETECTION LIMITS (MDLs)

Technique	Estimated MDL (ng/sample)
GFAAS (ETAAS)	5 (NIOSH Method 7102)
ICP-AES (ICP-OES)	9 (NIOSH Method 7300)
ICP-MS	<4.2 (Rousset et al., <i>J. Occup. Environ. Hyg.</i> 2016)
Molecular fluorescence	≈0.1 (Adams et al., <i>Int. J. Environ. Anal. Chem.</i> 2017)

→ Very low MDLs needed for lower limit values & short-term monitoring

BERYLLIUM FLUORESCENCE: HIGH QUANTUM-YIELD FLUOROPHORE FOR TRACE DETECTION

- Beryllium binds phenolate groups strongly
- Six-member chelate ring provides ideal Be-O / Be-N stereochemistry



Hydroxybenzoquinoline sulfonic acid (HBQS)

H. Matsumiya et al., *Analyst* (2002)

Beryllium fluorescence with HBQS (3× dilution; pH ≈ 13; λ_f = 480 nm)

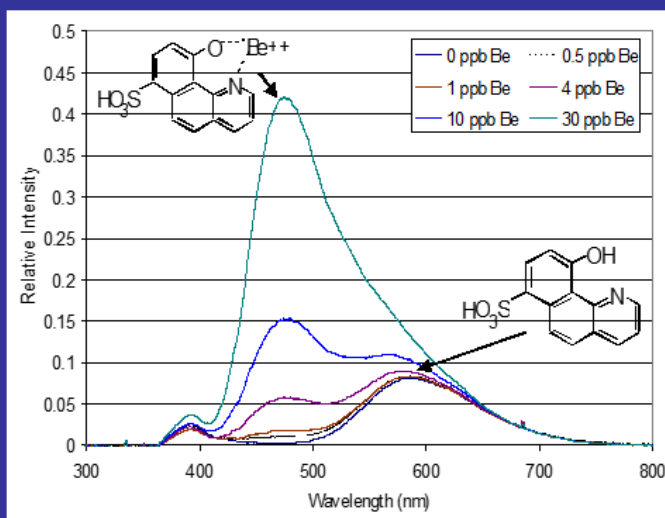
For λ_i = 384 nm:

MDL ≈ 0.06 ppb/0.1 ng

LOQ ≈ 0.2 ppb/0.3 ng

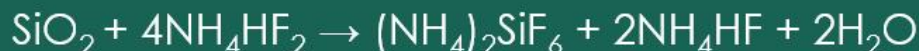
Linear response, wide
dynamic range (5x)

Lack of interference
from most metals in
high excess (except
Fe, Ti)



E. Minogue et al., *J. ASTM Int.* (2005)

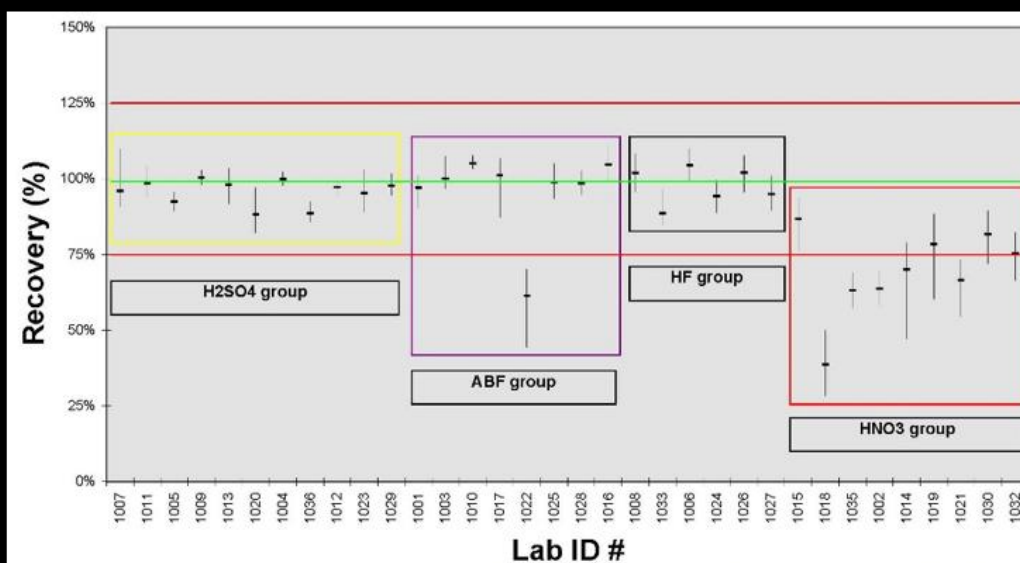
Alternative dissolution to HF, H₂SO₄: Dilute ammonium bifluoride (NH₄HF₂)



- Dissolution of silicate materials; apply to
refractories such as ceramic BeO:



MULTI-LAB BERYLLIUM OXIDE DISSOLUTION STUDY



T. J. Oatts et al., *J. Environ. Monit.* (2012)

NH₄HF₂ (1%) DISSOLUTION: BERYLLIUM METAL & BERYLLIUM OXIDE ON SAMPLING MEDIA

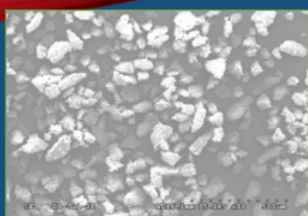
Sample / media	Extraction temp (°C)	Mean % recovery	RSD (%)
Be/MCE filter (n=3)	23°	93	7.3
Be/cellulosic wipe (n=3)	23°	95	4.2
BeO/MCE filter (n=15)	23°	86	5.9
BeO/MCE filter (n=6)	85°	99	7.7
BeO/cellulosic wipe (n=15)	23°	82	5.6
BeO/cellulosic wipe (n=6)	85°	96	6.2
BeO/PVA wipe (n=5)	90°	99	2.5

K. Ashley et al., *Anal. Chim. Acta* (2007)

Trace BeO measurement: $(\text{NH}_4)\text{HF}_2$ extraction – HBQS fluorescence method (cellulosic filters & wipes)

Spike level, $\mu\text{g Be}$ (as BeO; 4 labs)	Mean, $\mu\text{g Be}$ (MCE; Wipe)	RSD (%) (MCE; Wipe)
Blank media	0.0001; 0.0004	---
0.002 (<< PEL)	0.0023; 0.0025	13; 19
0.005 (< 15-min STEL)	0.0052; 0.0056	2.3; 6.3
0.020 ($\approx$ STEL)	0.0210; 0.0209	2.6; 2.3
0.050 (< 8-hr TWA)	0.0504; 0.0507	2.8; 2.6

K. Ashley et al., *Anal. Chim. Acta* (2007)

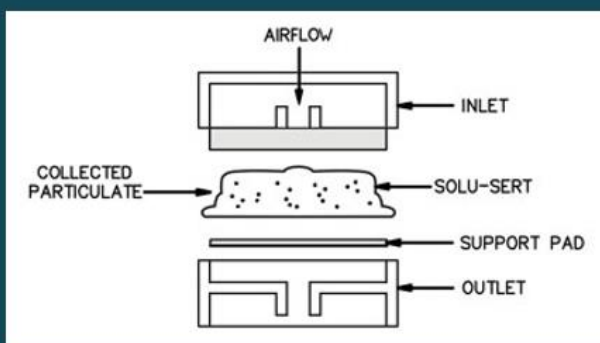


Dissolution of larger BeO particles: 3% $(\text{NH}_4)\text{HF}_2$ extraction (90°C , 4-5 h) HBQS fluorescence Be measurement

BeO particle size fraction (μm)	No sampling media (% Rec. $\pm$ SD)	MCE air filters (% Rec. $\pm$ SD)	Cellulosic wipes (% Rec. $\pm$ SD)	Cotton gloves (% Rec. $\pm$ SD)
<32	95 $\pm$ 5	92 $\pm$ 6	91 $\pm$ 5	111 $\pm$ 17
90-106	102 $\pm$ 12	100 $\pm$ 7	97 $\pm$ 4	98 $\pm$ 12
180-212	97 $\pm$ 5	92 $\pm$ 1	97 $\pm$ 4	90 $\pm$ 5

M. J. Goldcamp et al., *J. Occup. Environ. Hyg.* (2009)

CELLULOSIC CAPSULE INSERTS – “SOLU-SERTS™”



(Courtesy of Zefon International / Antylia)

Analysis of beryllium spiked cellulosic filter cassettes using 3x dilution

$\mu\text{g Be; ppb Be}$ (n=3)	$\mu\text{g Be measured}$ (RSD)	ppb Be measured ($\pm\text{Std Dev}$)	Avg % Recovery
0.0000; 0.000	-0.0001 (25)	-0.004 (± 0.0025)	---
0.0005; 0.033	0.0005 (7.2)	0.033 (± 0.0024)	100
0.001; 0.067	0.0009 (2.8)	0.061 (± 0.0017)	91.0
0.002; 0.133	0.0020 (5.4)	0.133 (± 0.0071)	100
0.005; 0.333	0.0045 (1.4)	0.301 (± 0.0042)	90.3
0.050; 3.334	0.0456 (2.2)	3.043 (± 0.0675)	91.3
0.480; 32.00	0.448 (0.87)	29.87 (± 0.26)	93.3

L. Adams et al., *Int. J. Environ. Anal. Chem.* (2017)

Addressing interference of Fe (10,000x excess) using filtration through hydrophilic polypropylene filters

% NH ₄ HF ₂ (aqueous, w/w):	1%		3%	
Dilution factor (HBQS dye):	20×	5×	20×	5×
Relative fluorescence intensity, no Fe	100.0	100.0	100.0	100.0
Relative fluorescence intensity (Fe present), filtered immediately	99.9	100.1	97.1	100.9
Relative fluorescence intensity (Fe present), filtered after 2 hr	99.9	102.2	100.7	99.8

L. Adams et al., *Int. J. Environ. Anal. Chem.* (2017)

DISPOSABLE INHALABLE SAMPLER (DIS)

- Based on IOM design, but incorporates many improvements
- ENTIRE UNIT disposable
- Pre-weighed PVC filter + PVC capsule for gravimetric analysis,
OR
- Digestible MCE filter + cellulose capsule for metals analysis
- Also, modification available for within-cassette dissolution
- And foams for multi-fraction (Respirable & Inhalable) sampling

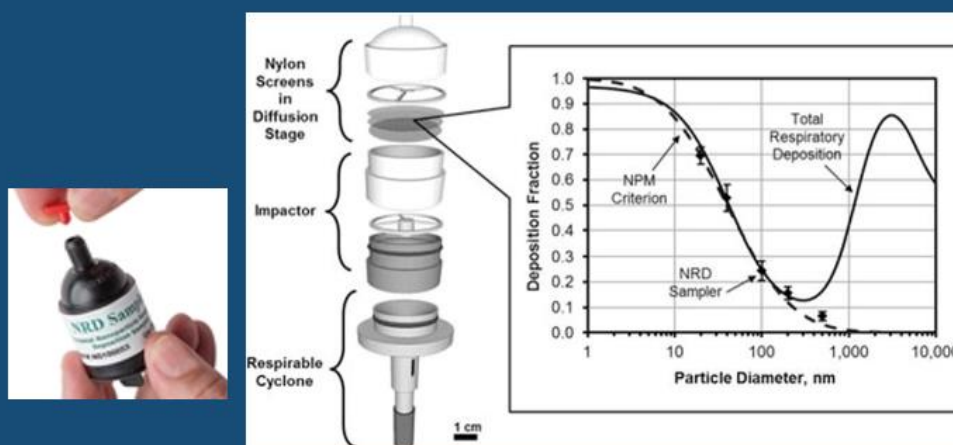


[Courtesy of Antylia / Zefon Int'l]

DISPOSABLE INHALABLE SAMPLER [DIS] (U. UTAH / ZEFON STUDY: D. SLEETH / M. HARPER)



ASTM D8208: STANDARD PRACTICE FOR COLLECTION OF NON-FIBROUS NANOPARTICLES USING A NANOPARTICLE RESPIRATORY DEPOSITION (NRD) SAMPLER

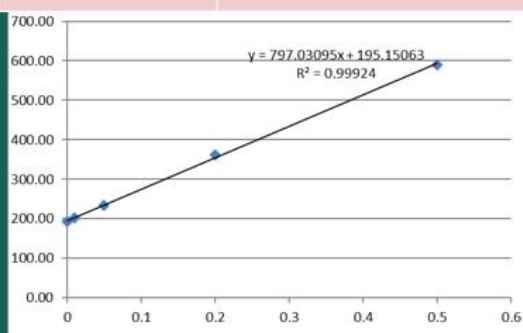


L. G. Cena et al., *J. Occup. Environ. Hyg.* (2014)

TRACE BERYLLIUM BY $(\text{NH}_4)\text{HF}_2$ EXTRACTION & HBQS FLUORESCENCE MEASUREMENT: NANOPARTICLE SAMPLER (NYLON FILTERS)

Be mass, μg	[Be], ppb	Mean recovery ($\pm$ Std dev; n=3)
0.001	0.01	97.3 ($\pm$ 0.4)
0.002	0.02	99.4 ($\pm$ 0.3)
0.005	0.05	99.3 ($\pm$ 0.3)
0.02	0.2	99.8 ($\pm$ 0.2)
0.05	0.5	100.2 ($\pm$ 0.1)

Raw fluorescence signal vs. [Be], ppb



FLUORESCENCE MEASUREMENT OF BERYLLIUM IN GEOLOGIC MEDIA

Reference material / source country	Reference [Be], $\mu\text{g/g}$	Measured [Be], $\mu\text{g/g}$
Basalt (Japan)	0.27 ($\pm$ 0.04)	0.31 ($\pm$ 0.02)
Sediment (USA)	1.6 ($\pm$ 0.3)	2.37 ($\pm$ 0.05)
Andesite (Japan)	2.05 ($\pm$ 0.44)	2.11 ($\pm$ 0.02)
Soil (Canada)	2.4	2.53 ($\pm$ 0.03)
Soil (USA)	2.5 ($\pm$ 0.07)	3.35 ($\pm$ 0.10)
Sediment (USA)	3	3.50 ($\pm$ 0.06)
Rhyolite (Japan)	7.6 ($\pm$ 0.83)	7.1 ($\pm$ 0.18)
Coal fly ash (USA)	12.1	12.85 ($\pm$ 0.36)
Syenite (Canada)	22	21.35 ($\pm$ 0.60)

A. Agrawal et al., *Environ. Sci. Technol.* (2008)

FLUORESCENCE MEASUREMENT OF BERYLLIUM IN SOIL – INTERLAB STUDY (N=6)

[Be] ref. value, $\mu\text{g/g}$	Mean reported [Be] ($\pm\text{SD}$), $\mu\text{g/g}$	Interlaboratory RSD (%)	Estimated bias
2.4 (unspiked)	2.43 (± 0.22)	8.9	+0.01
4.36*	5.13 (± 0.53)	10	+0.18
11.5*	12.4 (± 0.6)	4.8	+0.08
124*	126 (± 9)	7.1	+0.02
246*	234 (± 16)	6.9	-0.05

*Canadian CRM soil spiked with high-fired BeO

J. C. Cronin et al., *J. Environ. Monit.* (2008)

NIOSH methods for determining ultra-trace beryllium in air & wipes

NIOSH Manual of Analytical Methods 5th ed.:
www.cdc.gov/niosh/nmam

- Method No. 7704, Be in Workplace Air by Fluorescence
- Method No. 9110, Be in Surface Wipes by Fluorescence
- ▶ NH_4HF_2 extraction / HBQS fluorescence detection



International consensus standards – Be ultra-trace fluorescence analysis

ASTM International (www.astm.org)

ASTM D7202: Beryllium in workplace samples by NH_4HF_2 extraction and fluorescence detection

→ Covers both air & surface wipe samples



Also:

ASTM D7458: Beryllium in soil samples by NH_4HF_2 extraction & fluorescence detection

→ Investigate anthropogenic Be in soils

ASTM BERYLLIUM WIPE SPECIFICATION

ASTM D7707: Standard Specification
for Wipe Sampling Materials for
Beryllium in Surface Dust

→ Covers requirements for premoistened wipe materials used to collect settled dusts on surfaces for the subsequent determination of beryllium

→ Cellulosic and polyvinyl alcohol (PVA) wipe materials are both suitable



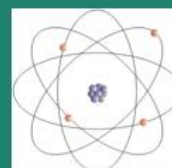
Summary: Trace Be fluorescence analysis with HBQS after ammonium bifluoride extraction – Sample types

Occupational air filter samples
Cellulosic inserts for air sampling
Wipe samples
Microvacuum samples
Cotton gloves
Soil samples
High-fired BeO
Nanoparticle sampler



COMMERCIAL USE OF BE-HBQS FLUORESCENCE METHOD

DOE Laboratories: CA; IA; ID; NM; NV; SC; TN; WA
US Army Corp of Engineers: OH; PA
Materion: OH; AZ
INRS, France
UKAEA, United Kingdom
HELCZA, Czech Republic
EPS, Spain



► Recognized by AIHA-LAP as an accredited method

ACKNOWLEDGMENTS

ASTM International

ASTM Committee D22 on Air Quality

ASTM Interlaboratory Studies program

High-Purity Standards – Charleston, SC (USA)

Materion – Tucson, AZ (USA) (formerly Brush Wellman Ceramics)

Dr Martin Harper – *University of Florida* (formerly with Antylia / Zefon)

Prof Darrah Sleeth – *University of Utah*

Gary Griffin, Mike Brisson – *Beryllium Health & Safety Committee (BHSC)*

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National Ignition Facility (NIF) Fusion Shot, to include a Discussion on Beryllium Operations and Analysis

R. BEALE (Lawrence Livermore National Laboratory, California, USA)

National Ignition Facility (NIF) Fusion Shot, to include a Discussion on Beryllium Operations and Analysis

Richard BEALE

Lawrence Livermore National Laboratory, Livermore, California, U.S.A.

The National Ignition Facility (NIF) is the world's most energetic laser system, enabling the study of high energy density conditions to support:

- Stockpile Stewardship
- Inertial Confinement Fusion (ICF)
- Discovery Science

NIF is the size of a sports stadium—three football fields could fit inside. NIF's unique energy and power enable cutting-edge research to help keep the U.S. safe and secure, explore new frontiers of science, and lay the groundwork for a clean, sustainable source of energy.

NIF is also the world's most precise and reproducible laser system. It precisely guides, amplifies, reflects, and focuses 192 powerful laser beams into a target about the size of a pencil eraser in a few billionths of a second, delivering more than 2 million joules of ultraviolet energy and 500 trillion watts of peak power.

NIF generates temperatures in the target of more than 180 million degrees Fahrenheit and pressures of more than 100 billion Earth atmospheres. Those extreme conditions cause hydrogen atoms in the target to fuse and release energy in a controlled thermonuclear reaction. Ignition provides fresh impetus and the scientific foundation for inertial fusion energy.

- Inertial Fusion Energy (IFE) is the next grand challenge
- Realizing the potential of IFE will require developing new technologies
- The scale of investment needed will be comparable or more to the investment required to obtain ignition

In partnership with the community and in a manner synergistic with our stewardship mission, LLNL seeks to enable an ecosystem to accelerate IFE in support of DOE's decadal vision for accelerating the commercialization of fusion energy.

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Livermore, California 94550
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The slides shown here are similar to those presented in the meeting. They are offered here as they have been previously approved for public distribution.



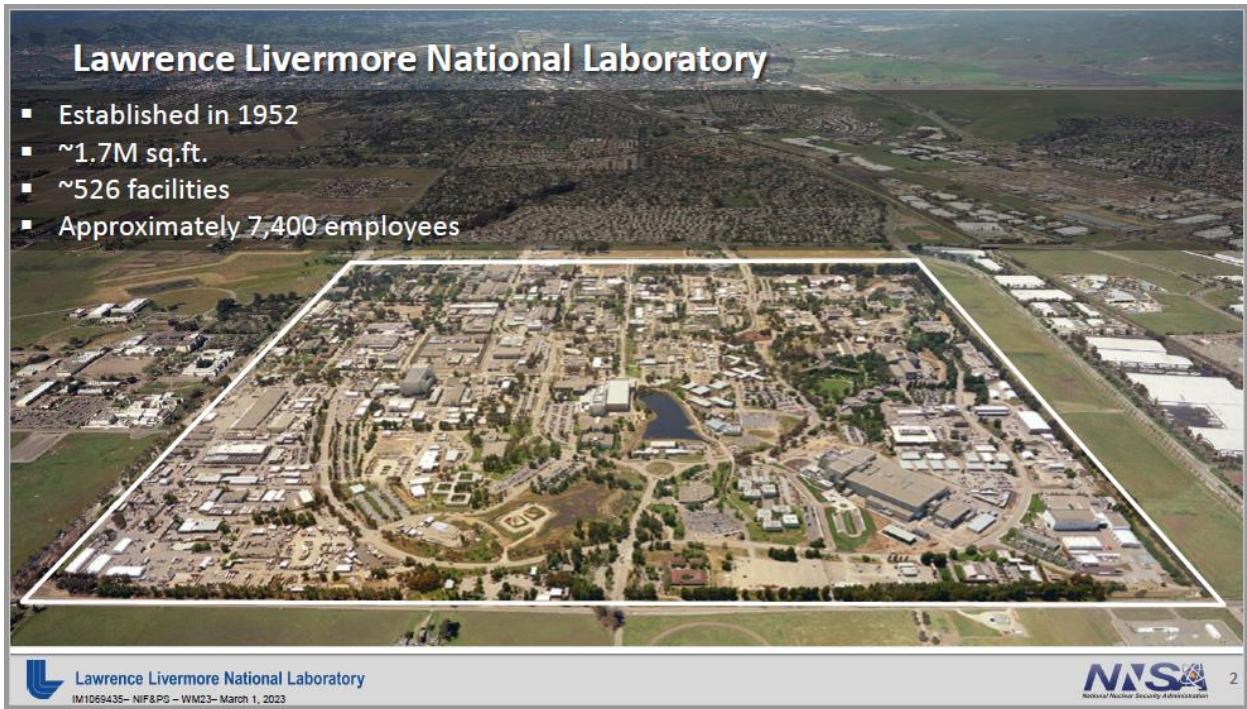
First Demonstration of Fusion Ignition by Inertial Confinement Fusion at the National Ignition Facility

Ken Kasper, CHP, CIH
National Ignition Facility
Radiological Operations Manager

WM23
March 1, 2023

LLNL-PRES-1069435
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

 Lawrence Livermore
National Laboratory

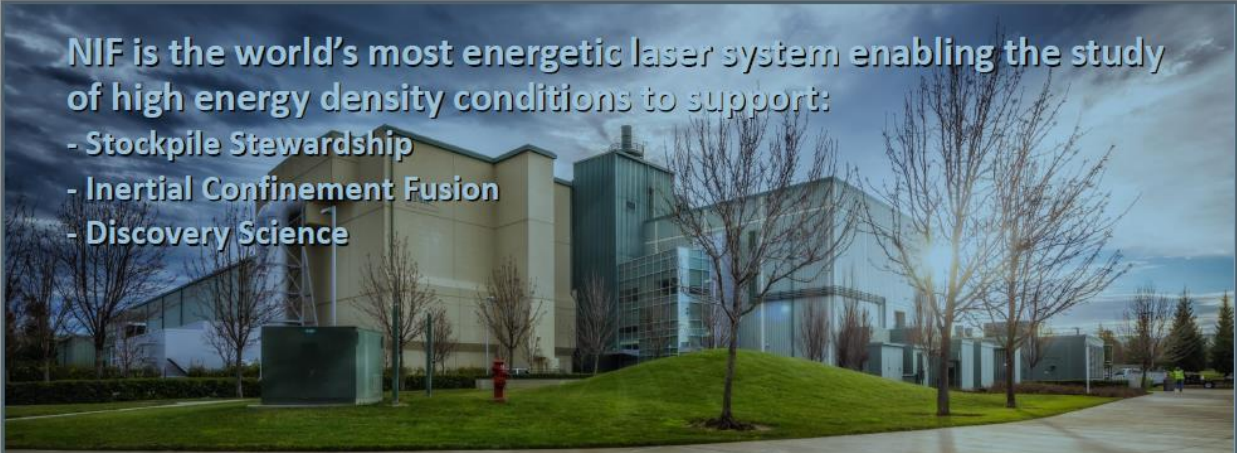


Lawrence Livermore National Laboratory

- Established in 1952
- ~1.7M sq.ft.
- ~526 facilities
- Approximately 7,400 employees

 Lawrence Livermore National Laboratory
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 2
National Nuclear Security Administration



NIF is the world's most energetic laser system enabling the study of high energy density conditions to support:

- Stockpile Stewardship
- Inertial Confinement Fusion
- Discovery Science

▪ 192 Beams, 1.9 MJ Energy, 500 TW Power	▪ Densities	$>10^2 \text{ g/cm}^3$
▪ Matter temperature $>10^8 \text{ K}$	▪ Pressures	$>10^{11} \text{ atm}$
▪ Radiation temperature $>3.5 \times 10^6 \text{ K}$	▪ Number of Diagnostics	>120

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NISA
National Nuclear Security Administration

4



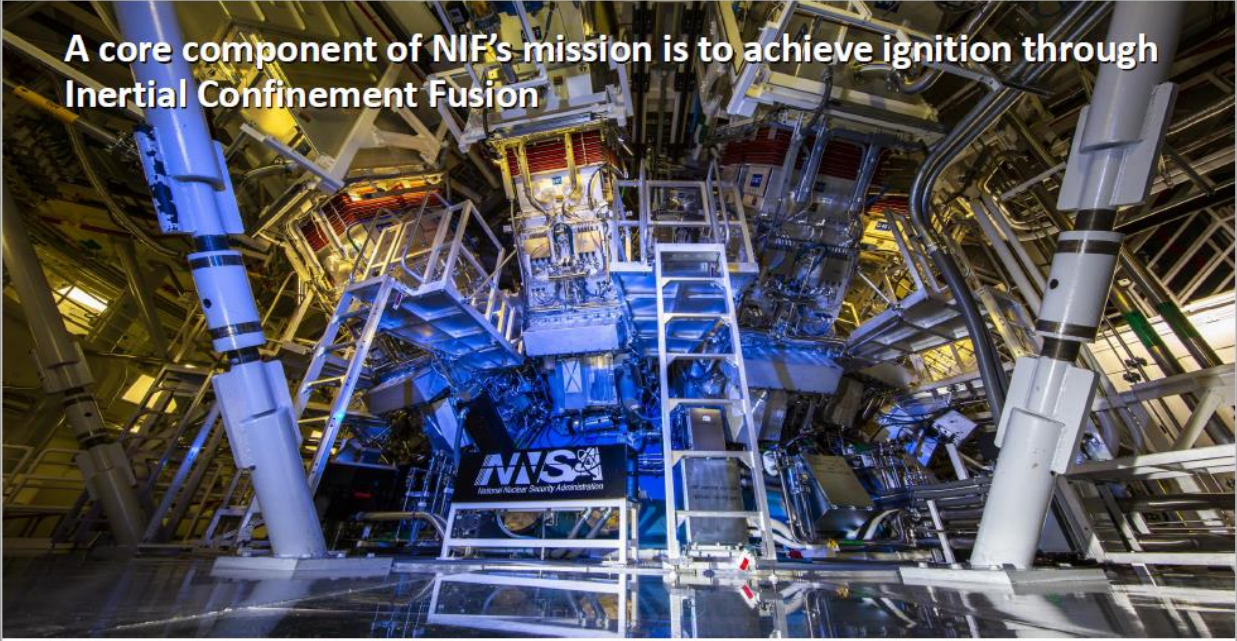
NIF is a core part of ensuring a safe and reliable deterrent without returning to underground nuclear testing

NIF provides a laboratory to test our understanding of diverse and extreme physical regimes — the same regimes experienced by stars and our nuclear deterrent, and required for fusion energy

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5



A core component of NIF's mission is to achieve ignition through Inertial Confinement Fusion

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6

In building NIF, many challenges were addressed, relying on decades of advances on optical material, pulsed power, laser physics and architectures, target fabrication, and diagnostics

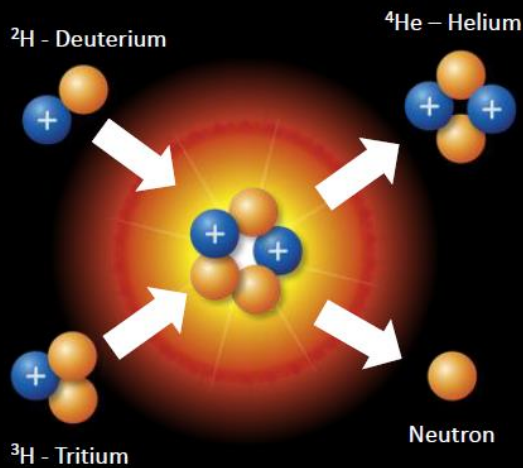


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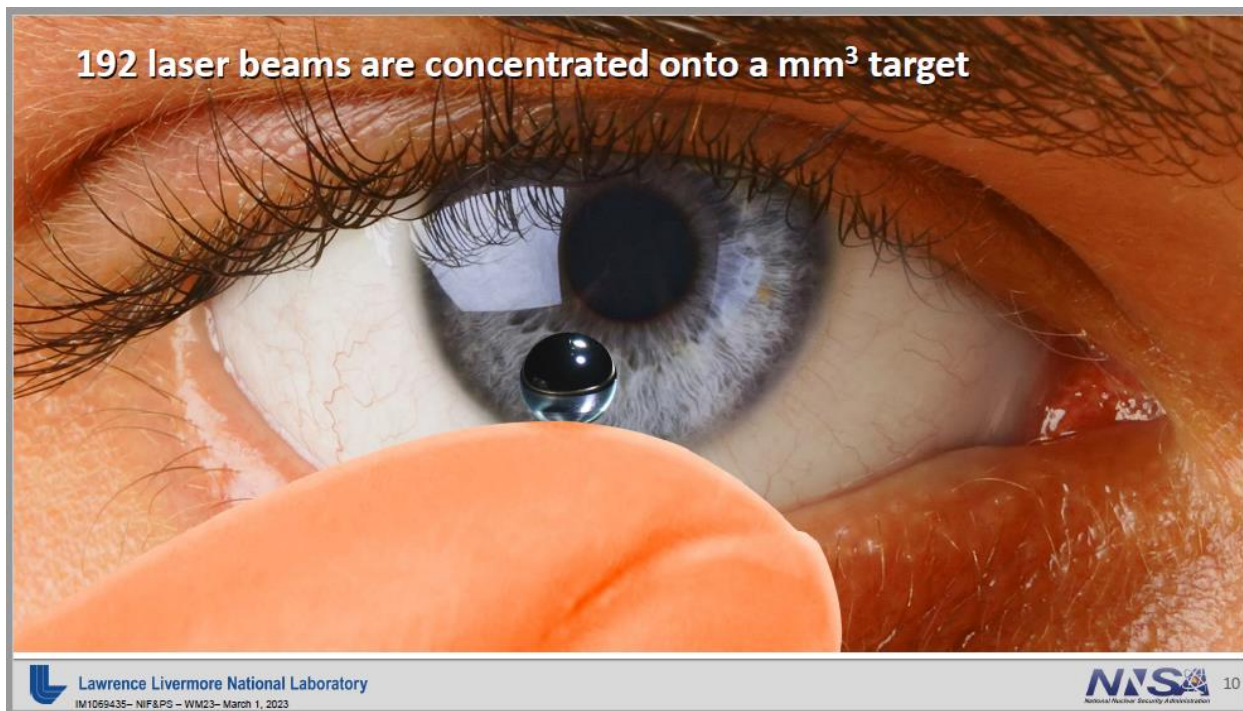
The sun and the stars are powered by fusion



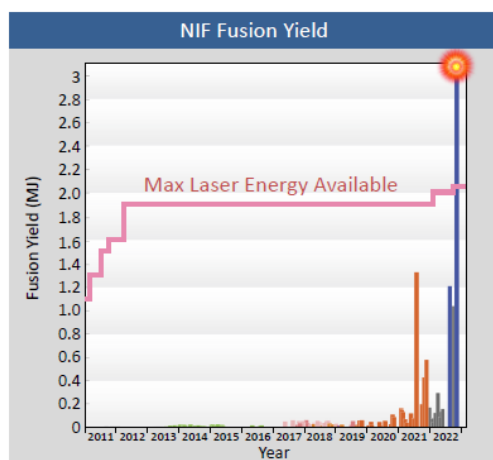
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On December 5, 2022, NIF exceeded the threshold* for ignition, with 3.15 MJ of fusion output for 2.05 MJ laser delivered



- This shot used a new increased energy laser drive capability (2.05 MJ on target) and a slightly thicker shell, and resulted in a target gain of 1.5 and a capsule gain of ~12
- This shot follows a series of alpha dominated burning plasma experiments which achieved 100's kJ – 1.35 MJ^{1,2,3} and built understanding in the ignition regime.
- Achieving such yields required a concerted long-term effort to improve our:
 - Target quality
 - Laser accuracy and increased energy delivery
 - Diagnostic capabilities
 - Physics Design
- Improved understanding has led to design refinements enabling 3 shots that have exceed a MJ since Fall 2022

Ignition enables a new era of applications for stockpile stewardship and the foundation for inertial fusion energy

Next Steps: exploit ignition for stewardship application with routine MJ-yield operations and ignition

NIF has
not yet
reached its
full potential

Few
MJ

Yield

10s
of MJ

2023

Routine
MJ-yield
operations
and
ignition



Long-term
Stewardship



Ignition for
Fusion

2.2 MJ

Laser Energy

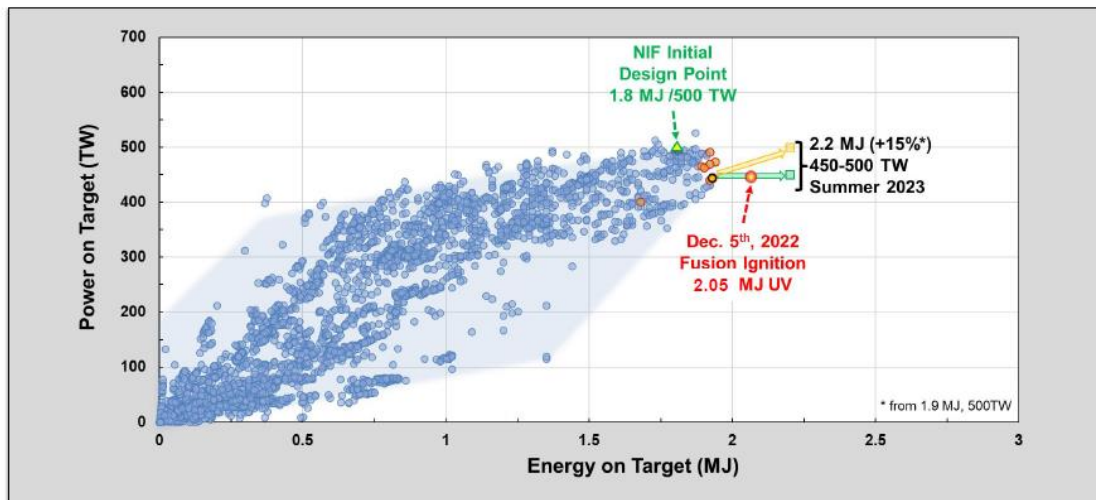


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For the summer 2023, the NIF laser will deliver 8% more energy compared to Dec. 5th, providing more margins and allowing routine MJ yields



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Di Nicola et al. *Nucl. Fusion*, 59, (2019)



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Next Steps: Perform long-term sustainment, increase energy and power

NIF has not yet reached its full potential

2009–2019
Yield
Explore high-yield, high-gain regime

2020–2028
Laser Energy
Increase Energy and Power

2023
Long-term Sustainment
Routine MJ-yield operations and ignition

2023–2028
Long-term Sustainment
Increase Energy and Power

2009
Few MJ
10s of MJ

2023
2.2 MJ

2028
10s of MJ
2.6–3 MJ

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The current NIF design, with modest modifications, can support much higher performance

A scatter plot titled "The current NIF design, with modest modifications, can support much higher performance". The y-axis is labeled "Power on Target (TW)" and ranges from 0 to 700. The x-axis is labeled "Energy on Target (MJ)" and ranges from 0 to 3. A large cloud of blue dots represents historical data points, mostly concentrated below 400 TW and 1.5 MJ. Several colored arrows point towards higher energy and power targets:

- A red arrow points from approximately (1.8, 450) to (2.6, 650).
- A yellow arrow points from approximately (1.9, 450) to (2.6, 550).
- A green arrow points from approximately (1.9, 450) to (2.2, 450).

A blue box in the upper left corner contains the following text:

- 2.2 MJ (+15%), 450-500 TW (FY23)
- 2.6 MJ (+40%), 500 TW
- 3.0 MJ (+60%), 450 TW
- 2.6 MJ, 600-650 TW (+25%*)

On the right side of the plot, there are labels for specific target points:

- 2.6 MJ, 600-650 TW (near the end of the red arrow)
- 2.6 MJ, 500 TW (near the end of the yellow arrow)
- 3 MJ, 450 TW (at the end of the green arrow)

Potential options for more performance increase

* from 1.9 MJ, 500TW

Next Steps: Explore high-yield, high-gain regime



Ignition provides fresh impetus and the scientific foundation for inertial fusion energy

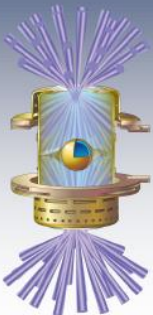
- Inertial Fusion Energy (IFE) is the next grand challenge
- Realizing the potential of IFE will require developing new technologies
- The scale of investment needed will be comparable or more to the investment required to obtain ignition

In partnership with the community and in a manner synergistic with our stewardship mission, LLNL seeks to enable an ecosystem to accelerate IFE in support of DOE's decadal vision for accelerating the commercialization of fusion energy



The NIF uses a laser driven hohlraum to compress a fuel capsule to achieve the conditions for ignition

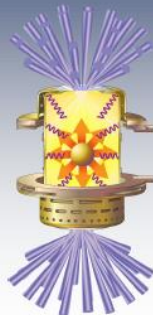
Each of the 192 laser beams are focused onto the inner wall of the hohlraum



Laser beams rapidly heat the inside surface of the hohlraum creating x-rays



The x-rays blow off the fuel capsule wall, accelerating the fuel inward to ~500 km/s



The fuel core reaches 100 times the density of lead and ignites at 100,000,000°C



Fusion burn spreads rapidly through the compressed fuel, yielding many times the input energy



Achieving ignition in the laboratory is a Scientific Grand Challenge nearly 60 years in the making



Lawrence Livermore National Laboratory

IM1069435- NIF&PO - WM23- March 1, 2023

J. Lindl, *PoP*, 1995; S. Haan, *et al.*, *PoP*, 2011
J. Nuckolls *et al.*, *Nature*, 1972



20

Day 2: Beryllium H&S: Air & Surface Sampling in Fusion, FLiBe Molten Salt Use, and Disease Prevention Update

Analysis of Beryllium Surface Contamination Levels of In-Vessel Components for the ITER Project

P. KURINSKIY (ITER Organization, France) et al.

Analysis of Beryllium Surface Contamination Levels of In-Vessel Components for the ITER Project

Petr KURINSKIY¹, Russell EATON¹, Paul EDWARDS¹, Liman BAO¹, Jiming CHEN²,
Pinghuai WANG², Jialin LI², Kun WANG³, D. GLAZUNOV⁴, and S. BOBROV⁴

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⁴*D.N. Efremov Institute of Electrophysical Apparatus, Saint-Petersburg, Russia*

Beryllium-bearing First Wall (FW) panels provided by suppliers in China, Europe, and Russia are specified for use in the ITER project. These FW panels will be transported to France and stored in the Tokamak Assembly Preparation Building (TAPB) on the ITER site. The ITER site is an Installation Nucléaire de Base (INB), making the FW panels subject to key safety requirements for working with and storage of beryllium-containing parts. One such requirement specifies the degree of control and monitoring of beryllium dust associated with these components. Associated with this scope, we have undertaken beryllium surface sampling campaigns on beryllium-clad panels in each of the three FW-supplying countries to better understand expected surface contamination quantities and the relation to certain processes during the panel lifecycle.

In this work, we adapted the sampling method based on NIOSH (National Institute for Occupational Safety and Health) procedure to collect beryllium dust (loose particles) by surface wiping. Following sampling, we analyzed smear filters using fluorometric or ICP-MS/AES (Inductively Coupled Plasma Mass Spectrometry/Atomic Emission Spectroscopy) methods to obtain surface contamination levels (expressed in $\mu\text{g}/\text{m}^2$).

We collected data to investigate the effect on surface contamination of beryllium components in different conditions, including:

- As-received (as-manufactured) state
- After cleaning
- After High-Heat Flux (HHF) testing
- After repeatable cleaning/surface sampling

Finally, based on performed data analysis, conclusions related to cleaning efficiency and influence of HHF testing on the amount of collected beryllium dust will be presented.

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FRANCE

Analysis of Beryllium Surface Contamination Levels of In-Vessel Components for the ITER Project

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Disclaimer: The views and opinions expressed herein do not necessarily reflect those of the ITER Organization



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OUTLINE

- Introduction
- Work objectives
- Surface sampling method
- Suppliers and investigated beryllium-containing components/parts
- Measured beryllium surface contamination levels provided by:
 - China ITER Domestic Agency (CN DA)
 - Russian Federation ITER Domestic Agency (RF DA)
 - European Union ITER Domestic Agency (EU DA)
- Repeatable surface sampling/ultrasonic cleaning and its effect on beryllium dust removal
- Conclusions



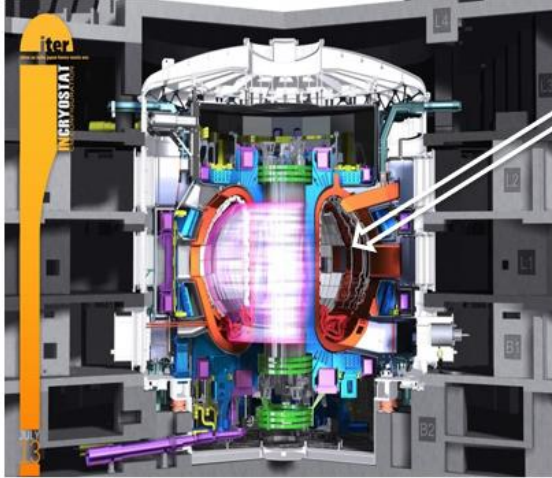
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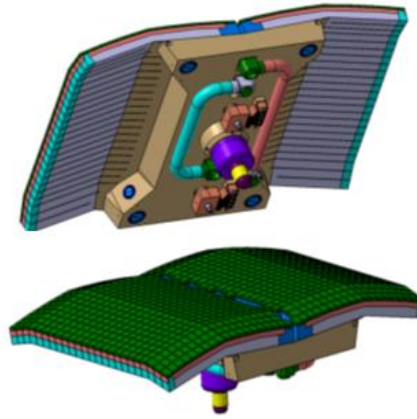
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INTRODUCTION



Beryllium is considered as one of candidates for the plasma-facing cladding in the blanket system consisting of First Wall Panels (FWPs)



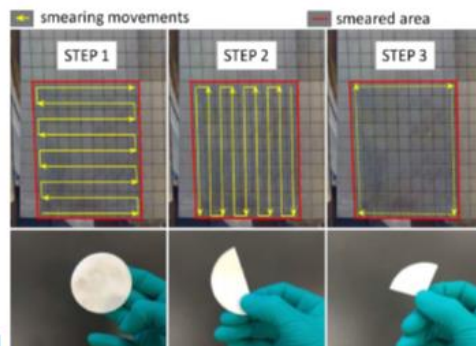
Typical view of First Wall Panel

WORK OBJECTIVES

- ❖ Evaluate of Beryllium surface contamination levels from the point of view IO FW panels deliverable conditions
- ❖ Evaluate of Beryllium surface contamination at different stages of manufacturing/assembly process
- ❖ Provide of data to IO Safety Team
- ❖ Study of efficiency of different methods of FWP cleaning

SURFACE SAMPLING METHOD

- ❑ Surface sampling based on wet wiping (distilled water) was used
- ❑ Sampling method was developed by NIOSH (National Institute for Occupational Safety and Health) a few decades ago
- ❑ Be surface contamination (in $\mu\text{g}/\text{m}^2$) was measured using fluorometric or ICP-AES/MS methods



Surface sampling procedure/consequent filter folding



Whatman541 filter paper used by surface sampling

Method advantages

- Full coverage of the sampled surface
- Applied liquid binds loose Be particles by performing of sampling procedure
- Relatively easy sampling procedure for operators

Method disadvantages

- Amount of collected Beryllium particles (dust) depends on the applied individual force of technician. Thus, final results on surface contamination depend on subjective factor



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SUPPLIERS AND BERYLLIUM-CONTAINING COMPONENTS/PARTS

Some features of performed activity on surface sampling:

- Several hundreds of data points were received
- Proper statistical representation of results was needed
- Only representative part of the results is shown at this Meeting

Percentage of overall First Wall Panel Supply

EU DA (50%)	RF DA (40%)	CN DA (10%)
High-heat flux tested Full-Scale Prototype panels (FSP1, FSP2, FSP3)	Individual First Wall panel fingers in different states:	Individual First Wall panel fingers in different states:
Advanced design mock-up (ADMU)	i. High heat flux tested,	i. after manufacturing,
	ii. after manufacturing,	ii. after ultrasonic cleaning,
	iii. after ultrasonic cleaning,	iii. after repeatable ultrasonic cleaning and sampling
	iv. after repeatable ultrasonic cleaning and sampling	
	Surface sampling of the assembled Full-scale Prototype (results are expected in the 2 nd half of Year 2023)	Full-scale Prototype after assembly (results are expected by Oct. 2023)



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Beryllium surface contamination levels provided by CN DA

Data from 29 individual fingers are shown below:

- 25 fingers in “After HIP/before final machining, cleaned” state
- 4 fingers in “After final machining, not cleaned” state

Average Be surface contamination values, $\mu\text{g}/\text{m}^2$

Condition: “After HIP/before final machining”, cleaned		Condition: “After final machining”, not cleaned	
Flat surfaces of Be tiles/amount of analyzed samples	Two “long” slots/amount of analyzed samples	Flat surfaces of Be tiles/amount of analyzed samples	Two “long” slots/amount of analyzed samples
112.8/25	1452/25	99.3/4	3946/4

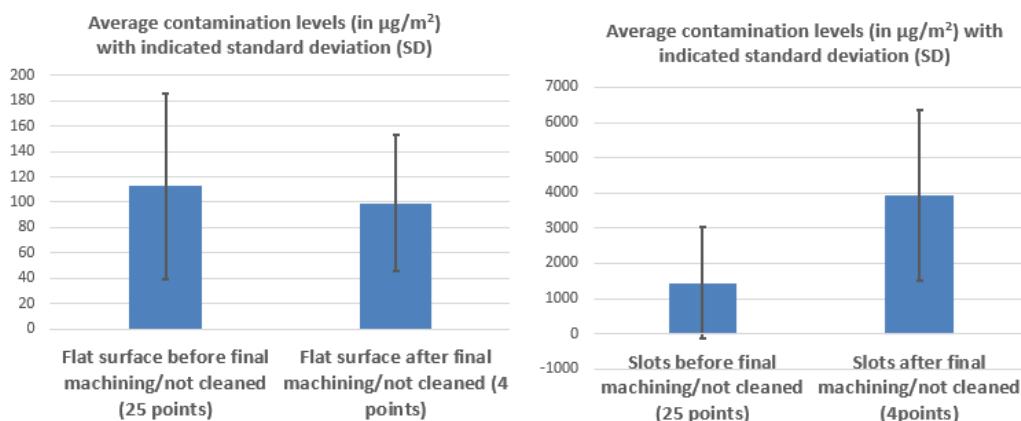
- Several technicians performed smearing activities what might result in bigger data scatter
- Contamination in slots has increased while the amount of Be dust on the flat surfaces remained on the same level

Beryllium surface contamination levels provided by CN DA

$$SD = \sqrt{\frac{\sum |x - \bar{x}|^2}{n}}$$



Standard deviation – degree of dispersion of a set of the values



- Big scatter of obtained data

Beryllium surface contamination levels provided by RF DA

- Data from 32 FWP Fingers in conditions “before” and “after ultrasonic (US) cleaning”

Average Be surface contamination values, $\mu\text{g}/\text{m}^2$

Before US cleaning		After US cleaning	
Flat surfaces of Be tiles/amount of analyzed samples	Two “long” slots/amount of analyzed samples	Flat surfaces of Be tiles/amount of analyzed samples	Two “long” slots/amount of analyzed samples
102.4/28	250.4/28	116.6/31	286.1/32



Flat surface of Be tiles covered by surface sampling (full finger surface)



Two “long” horizontal slots between Be tiles wiped by sampling (one smear filter for both slots was used)



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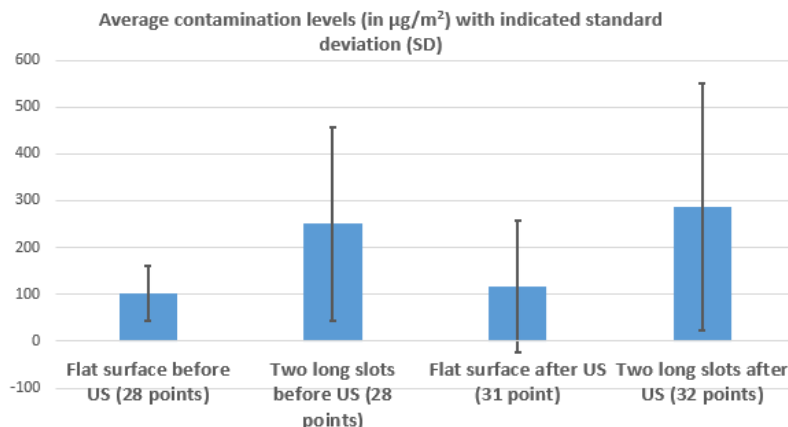
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Beryllium surface contamination levels provided by RF DA

Statistical analysis of obtained data



- Big scatter of obtained data
- Ultrasonic cleaning did not lead to decrease of Be surface contamination



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Beryllium surface contamination levels provided by EU DA

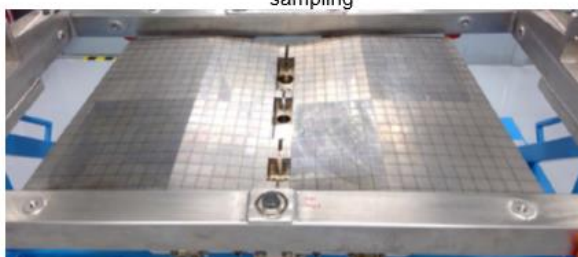
Parameters of High Heat Flux (HHF) testing:

- Applied power - 2MW/m²
- Cycle duration: 30s power on, 30s dwell time
- Atmosphere: high vacuum



Wiped Be-containing component	Surface condition of wiped Be components	Amount of samples
Full-scale prototype (FSP1) FW panel	After high-heat flux testing at 0, 1000 and 7500 cycles	87
Full-scale prototype (FSP2) FW panel	After high-heat flux testing at 0 and 7500 cycles	117

NOTE: HHF tested FSPs were manually cleaned (decontaminated) using ethanol and "heavy-duty" paper prior to performing of surface sampling



FSP2 before performing of sampling procedure



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Beryllium surface contamination levels provided by EU DA

FSP1 (Full-Scale Prototype 1)

Number of cycles	Amount of samples (flat surface/slot)	Average Be surface contamination value for flat surfaces, in $\mu\text{g}/\text{m}^2$	Average Be surface contamination value for slots, in $\mu\text{g}/\text{m}^2$
0	4/13	35.2	180
1000	2/6	42.2	384
7500	7/25	47.3	175

FSP2 (Full-Scale Prototype 2)

Number of cycles	Amount of samples (flat surface/vertical slot/horizontal slot)	Average Be surface contamination value for flat surfaces, in $\mu\text{g}/\text{m}^2$	Average Be surface contamination value in vertical/horizontal slots, in $\mu\text{g}/\text{m}^2$
0	13/29/17	6.3	443/326
7500	12/28/18	3.4	284/170

❖ Average Be contamination levels are about **few hundreds $\mu\text{g}/\text{m}^2$ for Be slots and few tens $\mu\text{g}/\text{m}^2$ for Be flat surfaces**

❖ HHF testing did not lead to significant increase of beryllium surface contamination



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Repeatable surface sampling/ultrasonic cleaning and its effect on beryllium dust removal

□ EU DA

Some data on beryllium surface contamination sampled from high heat flux tested FSP3 panel

High Heat Flux Testing (if any)		Repeatable smearing				Surface area, m ²	Flat surface/Slots, F/S
Number of heat cycles	Applied power (MW/m ²)	Number of smearing cycles	Initial Beryllium contamination value, µg/m ²	Final Beryllium contamination value, µg/m ²	Average Beryllium contamination value, µg/m ²		
0	n/a	3	66.2	73.2	70.6	0.0162	F
0	n/a	3	64.9	85.4	83.3	0.0184	F
0	n/a	4	55.7	57.3	66.7	0.0127	F
0	n/a	3	86.3	83.9	89.6	0.0184	F
0	n/a	3	58.4	30.7	47.4	0.02	F
7500	2	5	46	50.6	50.1	0.0138	F
7500	2	3	34	48.8	40.6	0.0231	F
7500	2	4	41	42	39.2	0.0231	F
7500	2	3	79	73.9	79.4	0.0231	F
7500	2	4	83.8	72.9	84.6	0.0231	F
7500	2	3	95.5	74.3	83.8	0.0216	F
7500	2	4	84.4	71.3	73.3	0.0231	F
7500	2	3	58.4	54.5	56.8	0.0185	F
0	n/a	3	1570	363	1024.3	0.0089	S
0	n/a	5	2890	867	1509.4	0.0089	S
0	n/a	5	419	270	328.6	0.0074	S
7500	2	3	1190	1160	1071	0.0089	S
7500	2	3	839	903	885.3	0.0089	S
7500	2	5	1860	897	1375.4	0.0084	S

NOTE:

Manual wet cleaning (decontamination) using heavy duty paper and ethanol was sufficient enough for removal of Be dust (especially, from flat be surfaces). Results on repeatable smearing confirm this observation.



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Repeatable surface sampling/ultrasonic cleaning and its effect on beryllium dust removal

□ Data suppliers: CN DA and RF DA

Sampled beryllium surfaces

CN DA

Finger 10C-10

- Repeatable wiping of flat surfaces (same surface area), x5 times
- Repeatable wiping of slots (same surface area), x5 times

Finger 07C-13

- Repeatable wiping of flat surfaces **after ultrasonic cleaning** (same surface area), x4 times
- Repeatable wiping of slots **after ultrasonic cleaning** (same surface area), x4 times

RF DA

Finger FR 1299

- Repeatable wiping of flat surfaces (same surface area), x5 times
- Repeatable wiping of slots (same surface area), x5 times

Finger 205-NF-1R (HHF tested)

- Repeatable wiping of flat surfaces **after ultrasonic cleaning** (same surface area), x4 times
- Repeatable wiping of slots **after ultrasonic cleaning** (same surface area), x4 times



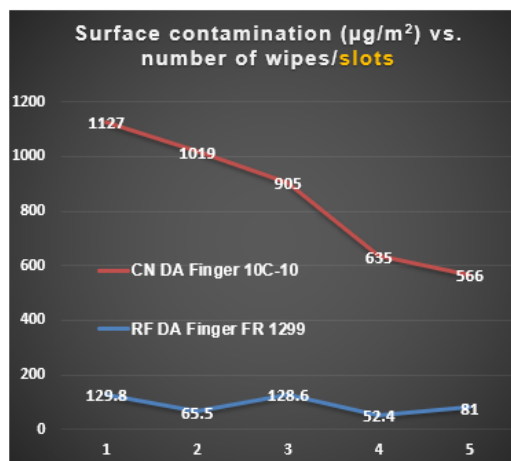
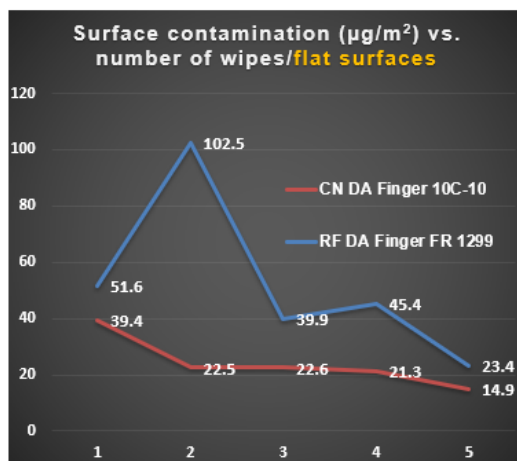
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Repeatable surface sampling/ultrasonic cleaning and its effect on beryllium dust removal



- ❖ **CN DA Finger:** Be contamination decreased gradually by applying of consequent wiping of both, slots and flat surface
- ❖ **RF DA Finger:** no distinct correlation between the amount of collected Be dust and the number of applied wipes was observed



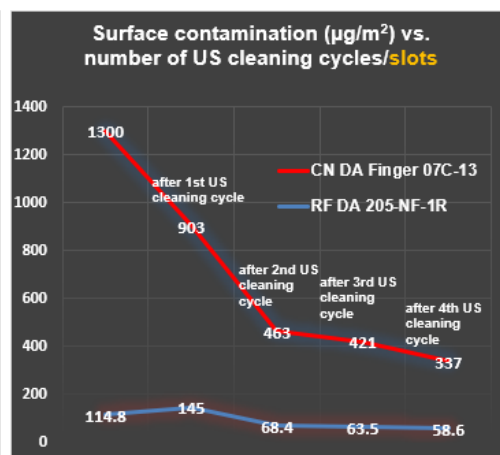
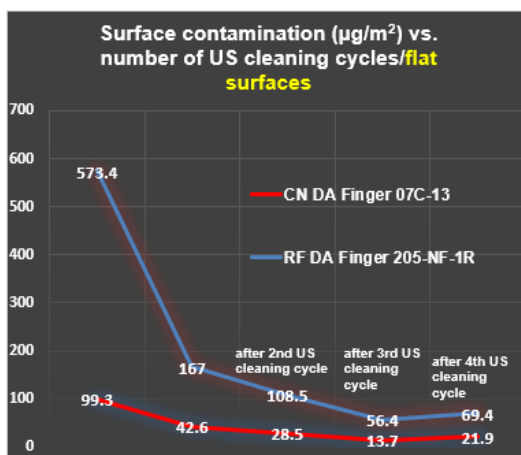
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Repeatable surface sampling/ultrasonic cleaning and its effect on beryllium dust removal



- ❖ Combination of US cleaning and wiping led, **with high probability**, to **synergetic effect**: observed decrease of Be surface contamination is higher compared to one where only repeatable wiping was used



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Conclusions

- Generally, obtained data are characterized by a big scatter what might refer to “subjective” human factor by performing of the surface sampling procedure
- Average Be contamination levels up to few thousands $\mu\text{g}/\text{m}^2$ for Be slots and few tens $\mu\text{g}/\text{m}^2$ for Be flat surfaces were measured in the performed works
- Thermal cycling (HHF testing) in high vacuum atmosphere did not lead to significant increase of beryllium surface contamination
- Ordinary manual cleaning (e.g., using “heavy duty” paper and ethanol) could be an effective tool to remove beryllium dust from the surface
- 2-3 cycles of Be surface cleaning **can be** sufficient to reach a horizontal saturation area on Be contamination curve

THANK YOU VERY MUCH FOR YOUR ATTENTION!

Analysis of Surface Sampling Techniques: Discussion of Results from UKAEA Pilot Study and Follow-On Progress

E. McKEON et al. (UK Atomic Energy Authority, UK)

Analysis of Surface Sampling Techniques: Discussion of Results from UKAEA Pilot Study and Follow-on Progress

Eilish MCKEON, Amy BLEASDALE, and Lia AU YEUNG

UK Atomic Energy Authority, Culham Centre for Fusion Energy, Abingdon, UK

At the UK Atomic Energy Authority (UKAEA), surface sampling for beryllium is performed by Health Physics technicians trained in standard processes. Given the manual nature of the task, natural variations occur from person to person. Current UKAEA research aims to aid in the development of robotic sampling methods by determining the typical performance of operators.

A pilot study was initially performed to determine the feasibility of studying sampling variability between technicians, investigating the effect of pressure exerted on beryllium recovery. Technicians used both Whatman filters (dry) and Ghost Wipes (wet), and despite the small sample sizes used, results indicated a significant relationship between pressure and beryllium recovery when using Ghost Wipes. During the pilot study it was noted that Whatman filters are routinely used at UKAEA. Ghost Wipes are used less frequently. It was concluded that one of the potential reasons that average pressure was not significant for Whatman filters might be because the technicians are more familiar with this sampling medium and rely on their own techniques to get better results, rather relying on pressure alone. Alternatively, no significant relationship may have been picked up by the model due to the granularity of the study which resulted in small subsets of data.

The second study phase aims to further the understanding of surface sampling variables, pertaining to operator input, including force application, surface types, and sampling protocol. Determining the effect of these factors on sampling results is expected to inform the development of remote sampling techniques through the development of complex swabbing motions for more efficacious and repeatable swabbing using a robotic arm, comparing robotic and manual sampling efficiency using qualitative measures.

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UNITED KINGDOM



UKAEA

**Analysis of Surface Sampling Techniques:
Results from UKAEA Pilot Study and Follow-on
Progress**

E. McKEON, A. BLEASDALE, L. AU YEUNG
Beryllium Health and Safety Committee Meeting
Lawrence Livermore National Laboratory • 10 May 2023

**BHSC 2023
Spring Meeting**
Beryllium Health &
Safety Committee
Livermore, California, USA
9-10 May 2023

Presentation Plan

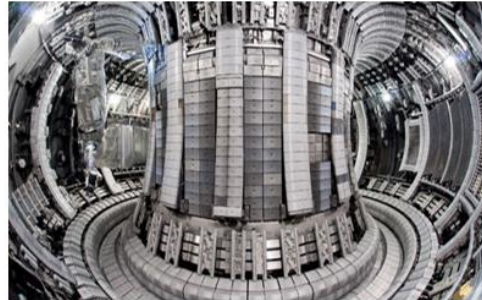
- ❖ Background
- ❖ Prior Work
- ❖ Pilot Study
- ❖ Phase 2



Culham Centre for Fusion Energy, Abingdon, Oxfordshire, UK

Background

- Beryllium has been in operational use at UKAEA since 1989
- Despite the lack of surface contamination limits, UKAEA foresaw the need to monitor for beryllium surface particulate
- As a result, and based on their experience in radiological protection, UKAEA developed a surface sampling method for beryllium, in conjunction with Sandia National Lab (USA)
 - Dry wiping using Whatman Grade 1 filter papers
 - Analysis of collected samples done on site
- Manual task with natural variation:
 - Person to person
 - Technique to technique
 - Surface to surface

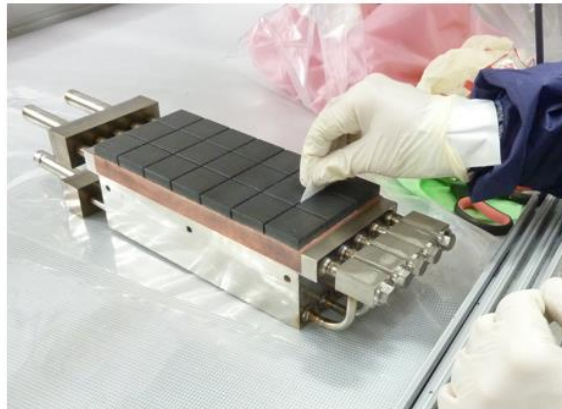


JET Reactor c.2010-11 with Beryllium ITER-Like Wall Installed [1]

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Project Aims

- To aid in the development of robotic sampling methods by determining the typical performance of operators, by:
- Determining the effects of swabbing force on the removal of contamination.
- Determining the effects of sampling efficiency on different surface types.
- Using the physical and chemical data gathered from the previous deliverables to inform robotic smearing techniques, comparing robotic sampling efficiency with human efficiency using qualitative measures.



Wipe sampling with dry Whatman filter paper of beryllium tile surfaces

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Prior Work



- **Mirjana Damjanovic, CEA at UKAEA**
 - "Comparison of Collection Efficiencies of Whatman No.1 Filter Paper and Ghost Wipes for Beryllium Sampling" (presented at BeWS-14) [2]
 - Study performed with UKAEA's Health Physics technicians and analysis lab.
 - Looked at sampling glass plates and vinyl material.
 - Concluded sampling technique, including pressure exerted, may be an important variable



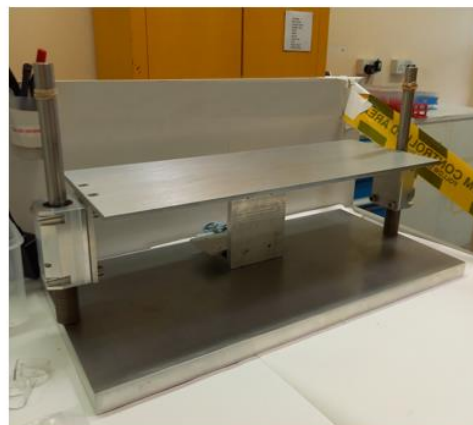
Glass plates spiked with beryllium-containing solution in known amounts were used in the previous study [6]

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Pilot Study – Technician Variability



- **Background**
 - Internally funded by Innovation Dept
 - Pressure rig designed by Materion
 - 4 technicians with experiencing ranging from <2 years to 10+ years
- **Scope of Work**
 - Determining if the results are correlated and if relationship exists between pressure exerted (N/s) and beryllium recovered (%)
 - Assessing the feasibility of pursuing further research into this relationship in a low-risk manner.



Pressure rig (test fixture) built at UKAEA and used in the study (the force gauge is not installed in this view).
Design credit: Materion Corp., Ohio, USA
Shown here with kind permission [3]

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Method

- Spike a defined surface with a range of known concentrations of beryllium on a plastic surface
- 1ml and 2ml of Beryllium standards at concentrations of:
 - 0PPB (control), 40PPB, 80PPB, 200PPB
- 4x Technicians: HPT A-D
- 2x sample media: Whatman Filters (dry), Ghost Wipes (Wet)
- Measure pressure ranges exerted
- Measure the amount of beryllium detected



Technicians prepare standardised beryllium samples in a temporary controlled area set up in the Analytical Laboratory at UKAEA expressly for the purposes of this study

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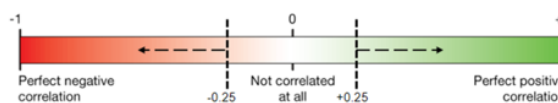
Results

- Despite the small sample sizes results indicated a fairly correlated (+0.33) relationship between average pressure (N/s) and beryllium recovery (%) overall.
- A chi-squared test for independence was used to further check the relationship and found a statistically significant relationship between the variables at 5% significance
 - i.e., the null hypothesis that *"there is no effect of pressure on the percentage of beryllium recovered during sampling"*, was rejected
- For subsets of the different combination of technician and sample media (e.g., HPT C and Whatman), no relationship was found between pressure and beryllium recovered.
 - Possibly due to granularity around Be concentrations and small sample sizes.

Min/Mean/Max pressures of technician and sample medium

Technician	Sample Media	Minimum Pressure (N/s)	Mean Pressure (N/s)	Maximum Pressure (N/s)	Mean Be Recovery (%)
Overall	Overall	1.9	5.9	14.4	76.8
A	Dry Whatman	4.2	6.1	7.4	87.6
	Ghost Wipe	5.2	6.2	8.5	67.7
B	Dry Whatman	2.8	3.3	4.0	79.3
	Ghost Wipe	1.9	2.9	3.9	51.0
C	Dry Whatman	2.3	3.2	4.2	94.3
	Ghost Wipe	2.2	3.0	3.6	62.6
D	Dry Whatman	8.1	10.2	12.6	93.9
	Ghost Wipe	9.9	12.3	14.4	81.8

Interpretation of the correlation coefficient



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Results (continued)

- Linear regression of all Beryllium Recovery (%) vs Average Pressure (N/s) data found significance at 10%, 5%, but not 1%.
 - Prob (F-statistic) <0.05
- For subsets of individual technician data, again no significance found
 - Prob (F-statistic) >0.1

Relationship w/ 'Beryllium Recovery (%)' column:		Intercept Coefficient	Column Coefficient	Prob(F-statistic)	Significant at 5%
Column	Technician				
Average Pressure (Newton/Seconds)	A	73.440	0.648	0.891	No
	B	14.038	16.714	0.240	No
	C	86.923	-2.815	0.800	No
	D	109.962	-1.867	0.246	No

Results table for regressions performed for the individual technicians

OLS Regression Results					
Dep. Variable:	Beryllium_Recovery	R-squared:	0.112		
Model:	OLS	Adj. R-squared:	0.092		
Method:	Least Squares	F-statistic:	5.785		
Date:	Fri, 26 Aug 2022	Prob (F-statistic):	0.0202		
Time:	16:21:02	Log-Likelihood:	-206.24		
No. Observations:	48	AIC:	416.5		
Df Residuals:	46	BIC:	420.2		
Df Model:	1				
Covariance Type:	nonrobust				
	coef	std err	t	P> t	[0.025 0.975]
Intercept	66.9690	5.019	13.342	0.000	56.866 77.072
Average_Pressure	1.6845	0.700	2.405	0.020	0.275 3.094
Omnibus:	3.032	Durbin-Watson:	1.018		
Prob(Omnibus):	0.220	Jarque-Bera (JB):	2.234		
Skew:	-0.518	Prob(JB):	0.327		
Kurtosis:	3.210	Cond. No.	13.9		

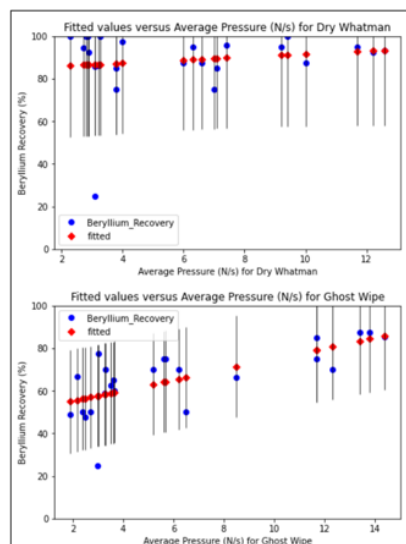
Regression Results Table

Results (continued)

- Average pressure and the two sample media types:
 - Not significant for Whatman filters
 - Significant at 1%, 5%, 10% for Ghost Wipes
- Model suggests there is a relationship between average pressure and beryllium recovered for Ghost Wipes, but not Whatman filters.
 - Possibly due to experience in knowing the best ways to manoeuvre the filter on the surface.

Relationship w/ 'Beryllium Recovery (%)' column:		Intercept Coefficient	Column Coefficient	Prob(F-statistic)	Significant at 5%
Column	Sample Media				
Average Pressure (Newton/Seconds)	Dry Whatman	84.524	0.707	0.473	No
	Ghost Wipe	50.283	2.479	0.000	Yes

Results table for regressions performed for the individual technicians



Fitted vs True values of Beryllium recovery for the separate sample media

Results (continued)



- Possible impact of technician experience indicated by the difference seen between Technician C and D
 - Experience of approx. 2 years:
 - D was more likely to have conformed to the taught method to a large extent and achieved 87.5% beryllium recovery
 - Experience of up to 10 years:
 - C used less pressure and achieved 100% recovery.

Tech: C, Avg. P: 2.9 N/s; Be Recovered: 100.0%

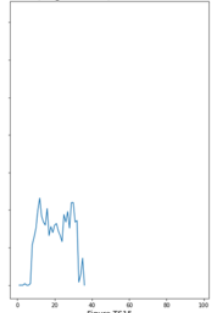


Figure TS15

Tech: D, Avg. P: 10.0 N/s; Be Recovered: 87.5%

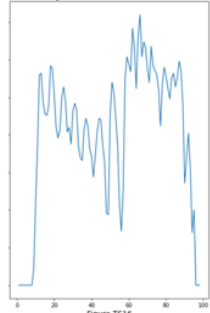


Figure TS16

Tech: C, Avg. P: 3.5 N/s; Be Recovered: 62.5%

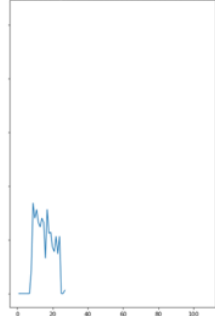


Figure TS47

Tech: D, Avg. P: 13.4 N/s; Be Recovered: 87.5%

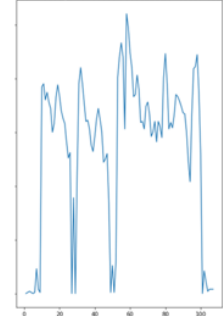


Figure TS48

Sampling force consistency over time: Tech C&D with Whatman Filters

Sampling force consistency over time: Tech C&D with Ghost Wipes

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Phase 2 – Next Steps



- Continuing with the same sample media: Whatman filters and Ghost Wipes and a range of technicians. Expanding to:
 - take more repeats per technician
 - look at 2 types of surface (plastic and metallic)
 - explore UKAEA methods versus 2x NIOSH techniques (9110 and 9102)
- Sampling Methods:
 - Each method alternates horizontal and vertical S-patterns of wiping
 - UKAEA and NIOSH methods differentiated by folding requirements:
 - UKAEA – sample media folded at end of process and is the same process followed for beryllium and tritium sampling on site.
 - NIOSH – sample media folded between overlapping S-patterns. Also slight differences between the NIOSH methods:
 - We're testing NIOSH 9102 with Ghost Wipes:
 - 3x S-pattern on the surface area alternating horizontal and vertical.
 - And NIOSH 9110 with Whatman filters:
 - Substitutes 3rd S-pattern with a final wipe along the perimeter of the area.
- Expecting to present results at the Beryllium Industrial Workshop in October.

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References & Credits

- [1] European Fusion Development Agreement (EFDA) and Joint European Torus (JET). ITER-Like Wall Project, Original URL: <http://www.efda.org/jet/>, 2009.
- [2] Damjanovic, M. "Comparison of Collection Efficiencies of Whatman No. 1 Filter Paper and Ghost Wipes for Loose Beryllium Surface Contamination". *Proceedings of the 14th International Workshop on Beryllium Technology (BeWS-14)*, held in Long Beach, California, U.S.A., 2019, pp. 324-346. Lemmens Medien GmbH, 2021.
- [3] Materion Corp., Mayfield Heights, Ohio, USA, 2021.

Questions?



10 CFR 850 Chronic Beryllium Disease Prevention Program Updates

A. BROWN (US Department of Energy, Maryland, USA)

10 CFR 850 Chronic Beryllium Disease Prevention Program Updates

April BROWN, CIH

US Department of Energy, Office of Health & Safety, Germantown, Maryland, USA

EHSS-11 is amending the Chronic Beryllium Disease Prevention Program (10 CFR 850) regulation. To make these amendments to the final rule, we are revising the economic assessment for the Office of Management and Budget (OMB). An economic assessment ensures OMB that decisions to update rules are based on the most accurate information available and provides the Department with the data necessary to compare the action with acceptable alternatives. The data required to update the costs, benefits, and administrative burden statistics support an economic assessment for modifications to 10 CFR 850 comes from the sites with beryllium operations.

Corresponding Author:

Ms. April Brown, CIH

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U.S. Department of Energy

Worker Safety and Health Policy

Office of Environment, Health, Safety, and Security

Office of Health and Safety (EHSS-11)

19901 Germantown Road

Germantown, Maryland 20874

U.S.A.



10 CFR Part 850 Chronic Beryllium Disease Prevention Program

Department of Energy
Beryllium Health and Safety Committee Meeting
May 10, 2023

Presented by:
April Brown, CIH, EHSS-11

Office of Environment, Health, Safety and Security
U.S. Department Of Energy



Agenda

- **Updates**
 - 10 CFR Part 851 Proposed Amendment
 - 10 CFR Part 850
 - Economic Assessment Questionnaire

Office of Environment, Health, Safety and Security



Proposed 10 CFR Part 851 Amendment

Correction:

- Requirements related to beryllium and beryllium compounds
- Consistency with 10 CFR part 850, Chronic Beryllium Disease Prevention Program

Clarifies:

- DOE did not intend to adopt the 2016 American Conference of Governmental Industrial Hygienists threshold limit value for beryllium and beryllium compounds

Office of Environment, Health, Safety and Security



Proposed 10 CFR Part 851 Amendment

NOPR:

- Published in the Federal Register on September 3, 2022
- Comment period closed on October 3, 2022

- Currently: Reconciling comments and drafting Final Rule

Office of Environment, Health, Safety and Security



10 CFR Part 850

Promulgated: December 8, 1999 **Expanded standard**

- Effective date: January 7, 2000
- Compliance date: January 7, 2002
- Established – chronic beryllium disease prevention program
- Adopted OSHA's 8-hour time weighted average – $0.2 \mu\text{g}/\text{m}^3$
- action level, exposure monitoring, hazard assessment, respiratory protection, regulated area, hygiene facilities and practices, housekeeping, medical surveillance, medical removal, medical consent, protective clothing and equipment, training and counseling, warning signs and labels, waste disposal, release criteria, recordkeeping, performance feedback

Office of Environment, Health, Safety and Security



10 CFR Part 850 Amendment Process

Notice of Proposed Rulemaking

- Published June 7, 2016
- 90-day Comment period - September 6, 2016
- Four public hearings: Richland, WA; Oak Ridge, TN; Las Vegas, NV; and Washington, DC

50 sets of comments

- DOE contractors, private industry, trade associations, worker advocates, public health and medical professionals, safety and health professionals, state government and other interested individuals.

Office of Environment, Health, Safety and Security



10 CFR Part 850 Amendment Process

Supplemental Notice of Proposed Rulemaking (SNPR)

- 30-day public comment period
- Alternative action level
- Short-term exposure limit

Update Final Economic Assessment

- Economic Assessment
Questionnaire to Beryllium-
affected Program
Offices: EM, NA, NE, and SC
- Responses due:
 - April 30, 2023

Office of Environment, Health, Safety and Security



10 CFR Part 850 Amendment Process

Update Final Economic Assessment

- EHSS received responses:
 - EM, NA, NE, and SC
- **EHSS and Economists**
 - Reviewing responses
 - Potential questions
 - Drafting final document

Office of Environment, Health, Safety and Security



10 CFR Part 850 Amendment Process

Develop draft Final Rule

- Based on comments from the NOPR and SNPR's public comments

Based on comments from the NOPR and SNPR's public comments

- Review and concur
 - Comments
 - Comment resolution – EHSS and Program Offices

Office of the General Counsel

- Review and concur
 - GC Comments
 - Comment resolution – EHSS and GC

Office of Environment, Health, Safety and Security



10 CFR Part 850 Amendment Process

Secretary of Energy

- Review and concur

Office of Management and Budget Review

- Approves draft final rule and economic assessment
- Publication in the Federal Register

Secretary of Energy

- Approves and signs the final rule

Congressional Notification

- GC and EHSS

Federal Register

- Review and comment
- EHSS and GC resolve comments
- Publish in the Federal Register

Office of Environment, Health, Safety and Security



Proposed 10 CFR Part 850 Final Rule

Effective Date: 30 days after publication date

- Compliance Date: One year after the effective date
- Engineering controls – 2 years after the effective date

Strengthen existing provisions

- Incorporates lessons learned
- Clear distinction between Beryllium worker and Beryllium-associated workers

Office of Environment, Health, Safety and Security



Proposed 10 CFR Part 850 Final Rule

Action level

Permissible exposure limit

Clarifies:

- Medical surveillance program
- Medical removal and removal benefits
- Role of the Site Occupational Medical Director
- Medical restriction
- Conditionally-hired individuals

- Release of beryllium equipment and real property
- Use of direct reading/portable testing equipment

Office of Environment, Health, Safety and Security



Questions



Office of Environment, Health, Safety and Security

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Contacts

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 - james.dillard@hq.doe.gov
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Office of Environment, Health, Safety and Security

14

Automated Refurbishment of MITL Surfaces (ARMS)

K.D. PASS et al. (Sandia National Laboratories, New Mexico, USA)

Automated Refurbishment of MITL Surfaces (ARMS)

Diego LUCERO and K.D. PASS

Sandia National Laboratories, Albuquerque, New Mexico, USA

Sandia's "Z Machine" is the world's most powerful and efficient laboratory radiation source. It uses high magnetic fields associated with high electrical currents to produce high temperatures, high pressures, and powerful X-rays for research in high energy density physics. **The Z Machine creates conditions found nowhere else on Earth.**

<https://www.sandia.gov/z-machine/>

The Z Machine Beryllium Minimization Program's primary goal is to reduce worker exposure to airborne beryllium during our Magnetically Insulated Transmission Lines (MITLs) Refurbishment process. Currently this is a hands-on activity and has the highest potential to exceed the US Department of Energy (DOE) Action Limit of $0.2\mu\text{g}/\text{m}^3$. The goal is to realize a fully functional automated MITL cleaning system.

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Environment, Health & Safety

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Albuquerque, New Mexico

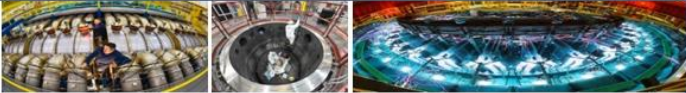
U.S.A.



Sandia
National
Laboratories

Automated Refurbishment of MITL Surfaces (ARMS)

Beryllium Health & Safety Committee Briefing



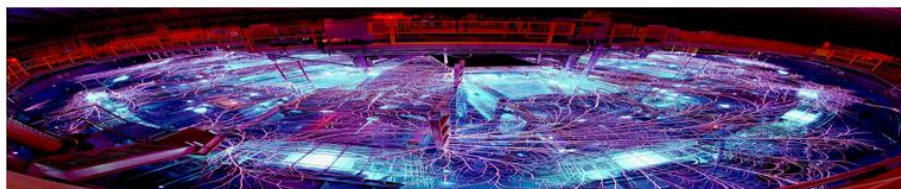
PRESENTED BY
Diego Lucero, KD Pass





Sandia National Laboratories is a multidisciplinary laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

What is Z Machine?



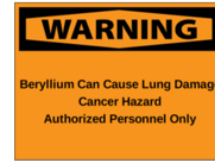
Sandia's Z machine is the world's most powerful and efficient laboratory radiation source. It uses high magnetic fields associated with high electrical currents to produce high temperatures, high pressures, and powerful X-rays for research in high energy density physics. The **Z machine creates conditions found nowhere else on Earth.**

<https://www.sandia.gov/z-machine/>

Z Machine Beryllium Operational Area

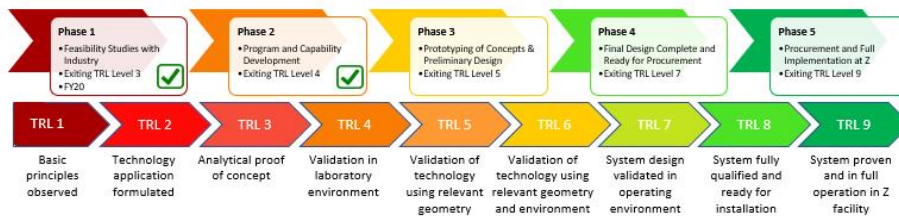
- Broken into 3 Primary Areas

- **General Work Area:** Surface Contamination is kept below 0.2 ug/100 cm² the DOE Release to the General Public
- **Beryllium Contamination Control Area:** Surface Contamination is kept below 3.0 ug/100 cm² DOE's housekeeping limit as a requirement and a goal to be below 0.2 ug/100cm². Activities do NOT create airborne beryllium above the 8-hour TWA of 0.2 ug/m³ DOE Action Level
- **Beryllium Regulated Area:** Surface Contamination is kept below 3.0 ug/100 cm² DOE's housekeeping limit as a requirement and a goal to be below 0.2 ug/100cm². Activities MAY create airborne beryllium above the 8-hour TWA of 0.2 ug/m³ DOE Action Level
 - MITL Enclosure
 - Center Section



3

Beryllium Minimization Program Goal



Reduce worker exposure to airborne beryllium

Refurbishment of the Z Magnetically Insulated Transmission Lines (MITLs) has been identified as the activity with the highest potential for beryllium inhalation exposure to the workforce.

Center 1600 has commenced on a 5 year, phased approach to implement an automated MITL refurbishment process which would reduce worker exposure to airborne beryllium hazards to below the DOE Action Level of 0.2 ug/m³.



4

Project Overview

During Z experiments material is vaporized and produces molten debris that deposits on the machine's MITLs. These MITLs (of which there are 5) are the final component in the electrical circuit of Z and are connected to the target.

Following each experiment, the debris is removed from the MITLs using grinders and different grinding media. Although manual removal of the debris has been done for many years, the work has become physically taxing on personnel as higher safety standards are being invoked.



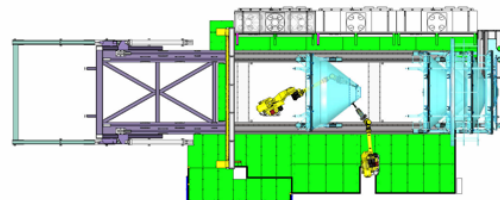
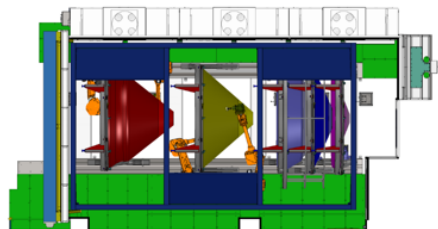
5

Phase 1 Results

Phase 1 was conducted to **determine the feasibility of a commercial solution for MITL refurbishment**

Phase 1 resulted in:

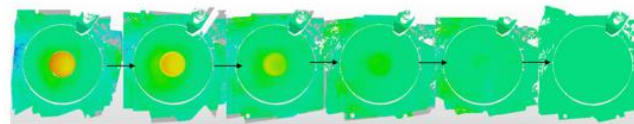
1. The determination that a credible solution(s) to the problem could be achieved by multiple vendors
2. Establishment of ROM-level estimates for cost and schedule for design and implementation of the proposed solution at the Z facility
3. Information on the key risks or shortfalls, in technologies, design, integration for a fully automated solution
4. Feasibility of an integrated system within Z given the limited space and facility infrastructure



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Phase 2 Results

- Phase 2 was conducted to establish program and capability development with laboratory validation (TRL 4).
- Successful demonstration of grinding operations on test coupons
 - 304 Stainless Steel like MITLs
 - 2" Diameter x .010" tall protrusion
 - Conservative vs. MITL Slag
- Iterative scanning after each polishing cycle. Immense amounts of data
 - 1 scan = 8-10 Gb
 - Color scale is approximately 0.000" (green) to 0.012" (orange)



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Phase 3 Expectations

- Program and Capability Development
- Objectives:
 - Demonstrate the sanding process on conical parts.
 - Would like to conduct grinding operations at SNL in the MITL refurbishment tent on used convolutes
 - Determine how sanding process changes depending on material (beryllium vs stainless for example).
 - Estimate percentage of material that can be removed.
 - Continue work on layout and operation. Key items:
 - Algorithm Development
 - Footprint
 - Cycle time
 - Part holding with the existing part fixtures
 - End Effectors and Abrasives



8

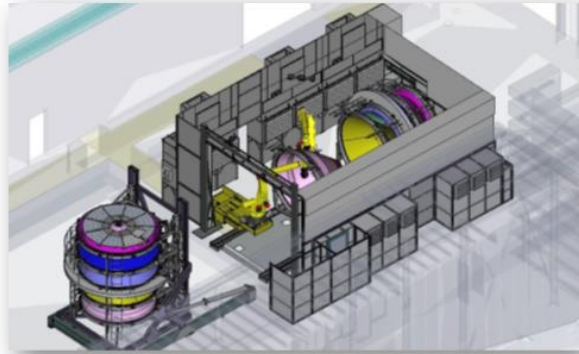
Phase 4/5 (Future Steps)

Phase 4 – Final System Design

- Final engineering designs (modeling, drawings for procurement, design reviews, approvals)
- Will require more extensive procurement process due to higher dollar values and additional onsite Activity Level Work
- Budgetary estimates have been provided but total cost likely to be higher once PaR Systems has the opportunity to conduct initial grinding operations on various debris fields present on used convolutes
- Schedule TBD based on Phase 3 findings

Phase 5 – Full Implementation

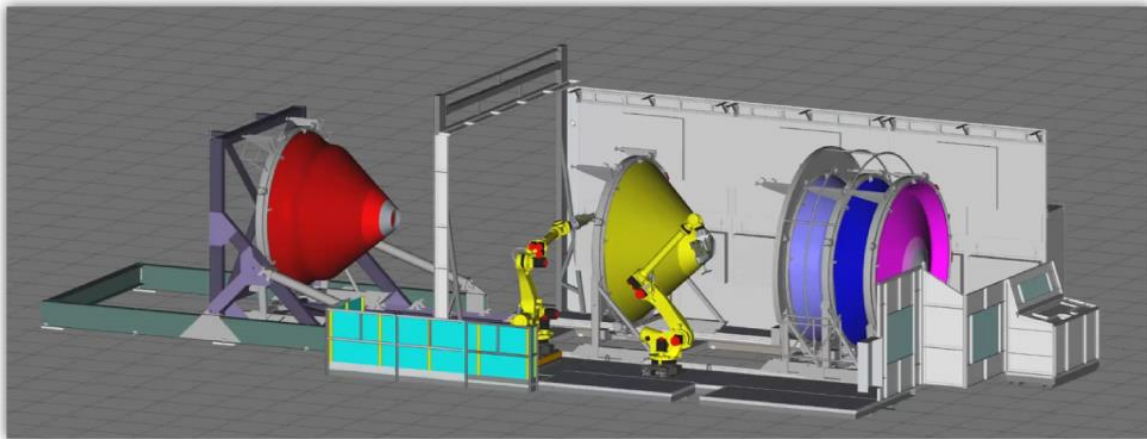
- Integration and testing at PaR's facility
- Factory Acceptance Test at PaR's facility
- Full installation and commissioning of system and supporting facility infrastructure in the Z MITL Refurbishment tent
- Robots, EOATs, Scanning Systems, Laser trackers
- Fixture for holding the full stack of parts, with the capability to rotate parts for accessibility by the robots.
- Installation Supervision
- 4 weeks of on site training/support
- Site Acceptance Test



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Cost and Budgetary Estimates

- ~\$20,000,000 Investment by Z to fully implement



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Questions?



11

Experimental Development of Tritium-Breeding Tests with 14MeV Neutrons and FLiBe
K. WOLLER (Massachusetts Institute of Technology, Massachusetts, USA) et al.

Experimental Development of Tritium-Breeding Tests with 14MeV Neutrons and FLiBe

Kevin B. WOLLER, C. CUMMINGS, R. DELAPORTE-MATHURIN, C.S. DUNN,
E. EDWARDS, S.E. FERRY, N. GOLEŠ, A.T. LANZRATH, R. LECCACORVI,
E.E. PETERSON, S. SEGANTIN, R. VIEIRA, D.G. WHYTE, L. ZHOU, and W. ZHOU

Massachusetts Institute of Technology, Cambridge, Massachusetts, USA

M.D EKLUND, T.F. FUERST, H. GIETL, A.A. RIET, and C.N. TAYLOR

Idaho National Laboratory, Idaho Falls, Idaho, USA

Experimental development of liquid FLiBe tritium breeder technology is underway at the Massachusetts Institute of Technology Plasma Science and Fusion Center (PSFC) with modeling and design support from Idaho National Laboratory (INL) Safety and Tritium Applied Research (STAR) Facility. The project goal is to investigate tritium breeding and release from molten FLiBe at up to 700°C with a source of D-T fusion neutrons. This environment ensures relevant conditions for comparison to Fusion Power Plants (FPP). In order to reach prototypical neutron energy spectrum conditions throughout the breeding blanket, path lengths greater than 30cm of FLiBe are required. Neutronics modeling of a prototype blanket of this scale indicates tritium-breeding ratios (TBR) approaching unity.

Safe handling and management of FLiBe, taking into account the hazards of corrosive fluoride compounds and beryllium toxicity, are paramount. Efforts to document and share safe practices in addition to scientific results are treated just as importantly. Working directly with high-energy D-T fusion neutrons forces experiments not only to account for optimizing tritium breeding, just as would need to be done by FPP developers, but also pushes experimental design to take into account tradeoffs in shielding material versus breeding material.

Corresponding Author:

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Experimental Development of Tritium Breeding Tests with 14 MeV Neutrons and FLiBe

Kevin B. Woller, kbwoller@mit.edu
on behalf of the MIT/INL LIBRA team

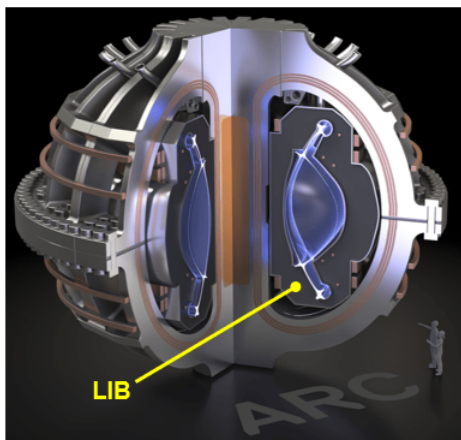
Beryllium Health and Safety Committee Meeting
Wednesday, May 10, 2023

This work is sponsored by an ARPA-E OPEN21 award DE-AR0001542

Outline

- LIBRA project overview - Develop experimental capabilities to test tritium breeding in molten salts from exposure to a D-T neutron source
- Primary breeding salt of interest is FLiBe ($2\text{LiF}:\text{BeF}_2$), so additional capabilities for safe handling practices and beryllium surveillance are being used for personnel safety and environmental stewardship
 - Hazards covered: Tritium, Hydrogen Fluoride, and Beryllium

LIBRA: Liquid Immersion Blanket Robust Accountancy



Magnetic Fusion Energy
Power Plant Concept

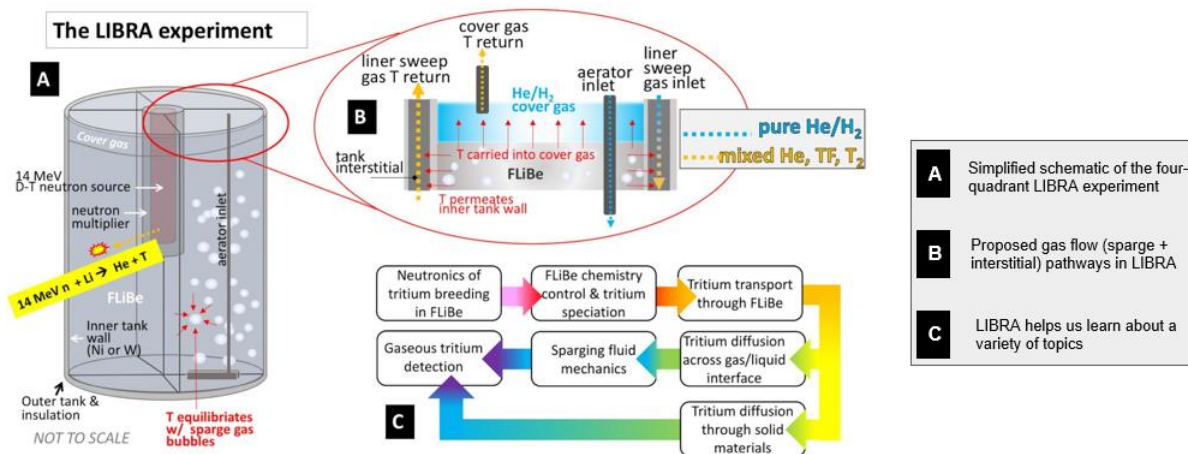
Project Overview:

Investigate viability of the Liquid Immersion Blanket (LIB) at fusion power plant (FPP) relevant conditions:

- ★ ~550-700 °C operation for increased heat extraction efficiency
- ★ 14.1 MeV D-T neutrons
- ★ Significant volumes of breeder (100s of liters) to have tritium fuel self-sufficiency, Tritium Breeding Ratio (TBR) >1
- Moderate and absorb D-T neutrons (14.1 MeV) with FLiBe (proposed breeder material for ARC concept)
 - Requires near-4π coverage of blanket around D-T source
- Demonstrate tritium accountancy while achieving TBR ~ 1
 - Requires >40 cm FLiBe thickness
- Explore mitigation strategies for corrosion and activation
 - Compatibility between structural materials and liquid breeder
 - Impact of materials choices on tritium speciation and transport

LIBRA: Liquid Immersion Blanket Robust Accountancy

Project Experimental Plan:

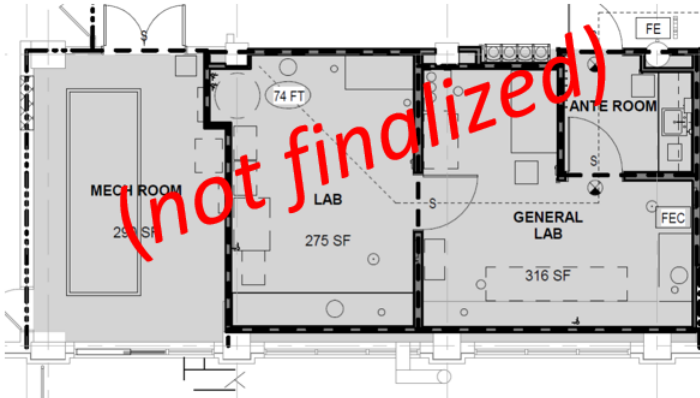


Design and Construction of FLiBe lab at MIT

MIT Nuclear Reactor Lab: FLiBe for molten salt reactors

MIT Plasma Science and Fusion Center: FLiBe for tritium breeding blankets

Co-develop a lab capable of handling FLiBe & carrying out neutron irradiations



Current FLiBe handling capabilities exist in 3+ gloveboxes:

1. Salt loading/mixing
2. Static Corrosion
3. Gas permeation
4. Additional glovebox being refurbished for electrochemical testing

-> Support small volume tests (<1 L)

MIT FLiBe Lab will support large volume handling for:

1. Pumped loop testing (~20-30 L)
2. LIBRA full-scale tritium breeding (500 L)

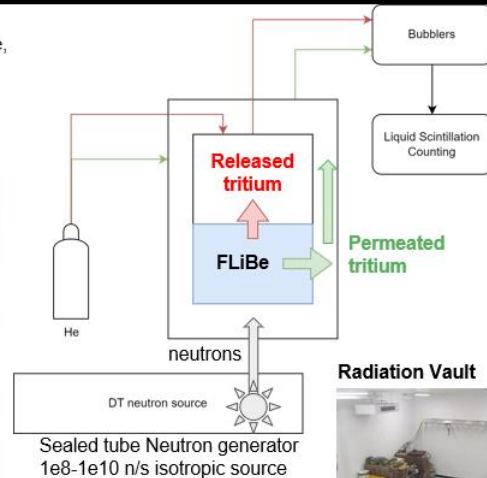
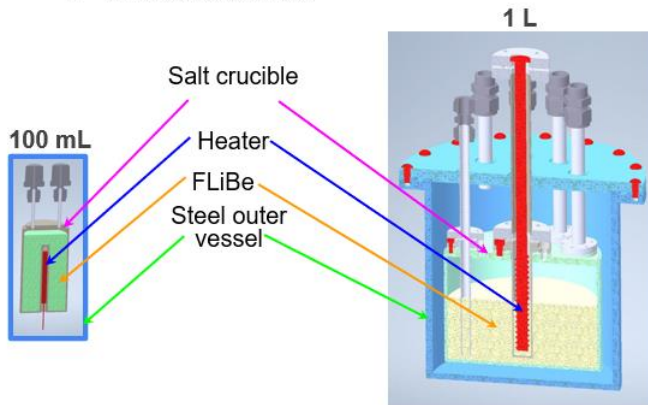
->Dedicated/engineered ventilated rooms to contain beryllium hazards

MIT PSFC LIBRA Team BHSC meeting LIBRA
May 10, 2023

5

First Iteration: Begin tritium breeding tests at benchtop scale

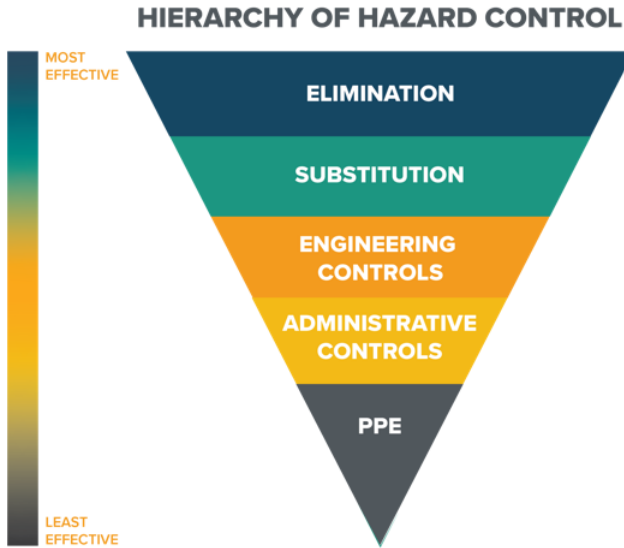
- Dress rehearsal for large-scale LIBRA experiments: neutrons, FLiBe, materials, tritium
- Breeder Volume: **0.1 to 1 L** of FLiBe
- Minimal tritium production
- Housed in radiation vault



MIT PSFC LIBRA Team BHSC meeting LIBRA
May 10, 2023

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Hazard Management



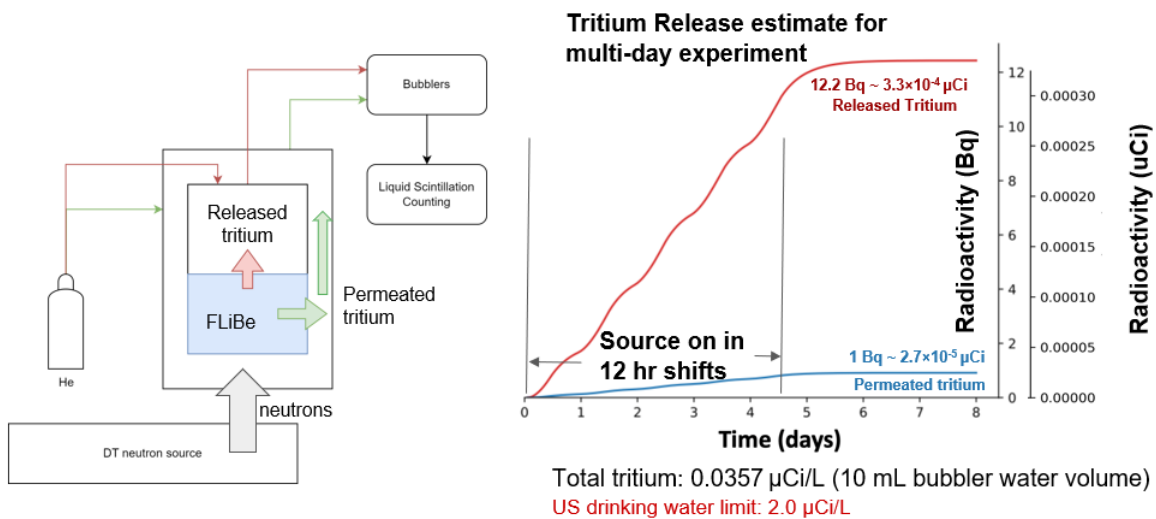
Specific Hazards to consider:

- Tritium
- Hydrogen Fluoride
- Beryllium

MIT PSFC LIBRA Team BHSC meeting LIBRA
May 10, 2023

7

Tritium hazard estimate

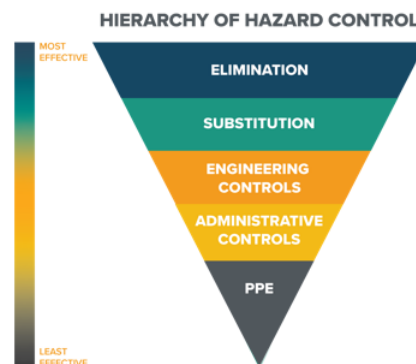


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Tritium hazard

- **Elimination:** Low tritium production
- **Substitution:** Against project goal
- **Engineering control:**
 - Barriers (crucible, gas flow system)
 - Tritium is collected in water bubbler
 - Swipes before and after runs
- **Administrative control:**
 - Organising training on the bubbler equipment (+ SOPs)
 - Radiological postings around the experiment
- **PPE:**
 - Gloves for handling the bubbler vials



MIT PSFC LIBRA Team

BHSC meeting LIBRA
May 10, 2023

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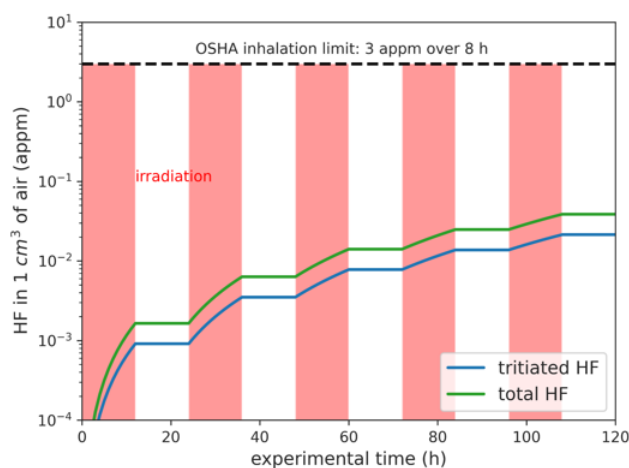
Hydrogen Fluoride hazard estimate

Conservative assumptions:

- Heavy irradiation schedule (3×10^8 n/s, 12h/day)
- All H from transmutations forms HF
- All T produced forms TF
- All HF/TF built up gets released in 1 cm^3 of air

Then:

- HF concentration would be 2-3 orders of magnitude lower than the OSHA inhalation limits
- Further analysis required for radiolysis or other release mechanisms for fluorine



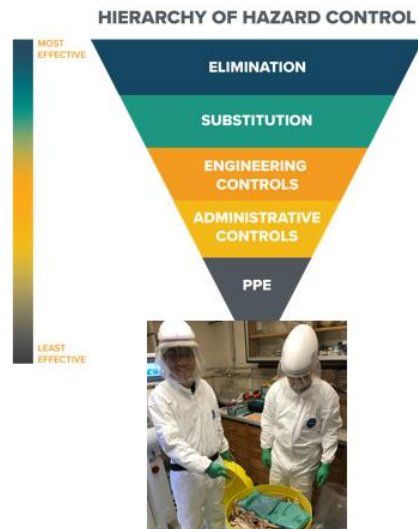
MIT PSFC LIBRA Team

BHSC meeting LIBRA
May 10, 2023

10

Beryllium hazard

- **Elimination:** Low FLiBe volume 0.1 - 1 L
- **Substitution:** Experimental development with surrogate salt
- **Engineering control:**
 - Barriers (crucible, outer vessel, ventilated enclosure)
 - Regular Be swipes
 - HEPA filter
- **Administrative control:**
 - Postings around the experiment
 - Health monitoring of Be workers: BeLPT, PFT, screening
- **PPE:**
 - PAPR respirators, suits, booties, gloves whenever testing new procedure
 - Only when levels are proven to be low/non-existent, then PPE requirements are relaxed



MIT PSFC LIBRA Team

BHSC meeting LIBRA
May 10, 2023

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Reduce/minimize exposure and release

Glovebox for capsule preparation and FLiBe loading



Monitor for Be release with Be Fluorescence swipe testing with Berylliant BeFinder



Personal Protective equipment for Standard Operating Procedure development



HEPA filter fumehood for irradiation tests in radiation vault



Questions or Comments?
kbwoller@mit.edu

MIT PSFC LIBRA Team

BHSC meeting LIBRA
May 10, 2023

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End of Presentation

Beryllium and its Compounds Including Be Metal, BeO, FLiBe, and Other Compounds and their Manufacture and Uses in Nuclear Reactors

K. SMITH et al. (Materion Brush Inc., Ohio, USA)

Beryllium and its Compounds Including Be Metal, BeO, FLiBe and Other Compounds and their Manufacture and Uses in Nuclear Reactors

Keith J. SMITH¹, Ron W. TOWNSEND², and Gregory H. HELDT³

¹*Materion Brush, Inc., Elmore, Ohio, USA*

²*Materion Brush, Inc., El Segundo, California, USA*

³*Materion Brush, Inc., Mayfield Heights, Ohio, USA*

Beryllium has a unique combination of properties desirable for nuclear applications. These include high neutron flux, low neutron absorption, high neutron scattering, high thermal conductivity, transparency to most forms of radiation, and the ability to maintain its characteristics at elevated temperatures.

These characteristics make beryllium an excellent candidate for nuclear reactors. Historical uses have generally been limited to nuclear test reactors and particle accelerators. Today, advanced next generation nuclear reactor design for both fission and fusion reactors may use pure beryllium metal, beryllium oxide, FLiBe, a molten salt containing lithium fluoride and beryllium fluoride, and beryllium intermetallic compounds.

This presentation will include an overview of the manufacture of Be, BeO, FLiBe, and other compounds by Materion in the United States. In addition, the general nuclear reactor uses for these materials will be presented.

Corresponding Author:

Mr. Keith J. SMITH

keith.smith@materion.com

Materion Brush Inc.

14710 West Portage River South Road

Elmore, Ohio 43416

U.S.A.

Beryllium and its Compounds Including Be Metal, BeO, FLiBe, and Other Compounds Their Manufacture and Uses in Nuclear Reactors

*Keith J Smith, Ron W Townsend, and Gregory H Heldt
Materion – Brush, Inc.*

10 MAY 2023

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Lawrence Livermore National Laboratory
BHSC 2023 Spring Meeting
Beryllium Health & Safety Committee
Livermore, California, USA
9-10 May 2023

MATERION

Meet Materion

- A global high-tech solutions provider of electronic materials, performance materials and precision optics
- 100+ years of material sciences knowledge
- Publicly traded since 1972 – NYSE (MTRN)
- In excess of \$1.7 billion in sales
- Based in Cleveland, Ohio
- 32 worldwide locations
- 3,700 employees
- 66 countries served

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MATERION

Materion's Advanced Materials – We cover the table

PERIODIC TABLE OF THE ELEMENTS

The periodic table shows elements from Hydrogen (1) to Oganesson (118). Beryllium (Be) is highlighted with a red box. The table is organized into groups (IA to VIIA) and periods (1 to 7). The lanthanide and actinide series are shown at the bottom.



The only fully integrated manufacturer of Beryllium in the world

- Mining & Extraction – Delta, UT
- Conventional Metal Processing - CuBe/ CuNiSn/NiBe
- Ceramic processing (BeO, Al₂O₃, others)
- Powder metallurgy (Be, Al-Be, others)
- Metal Matrix Composites (Al-B₄C, Al-SiC, others)
- Clad and Plated Metal Strip
- Machining - Fabrication



Beryllium has very unique nuclear properties.

- It has a **low thermal neutron absorption** cross section.
- It functions as a **neutron reflector and neutron moderator**.
- Bombard a Be target with alpha particles and you get neutrons, thus its use as a **neutron source** – increases neutron flux.
- Be is **transparent** to most forms of radiation.
- Be resists cracking under high heat flux thermal cycling.
- Maintains characteristics at elevated temperatures.

5



Material Requirements for a Nuclear Reactor

The primary function of a nuclear reflector within the reactor is to reflect leaking neutrons back into the core.

Nuclear reflector materials should have: ³

- Low atomic weight
- Low neutron absorption
- High neutron scattering
- High moderating efficiency

For solid reflectors, desirable characteristics should include: ³

- Structural strength
- Corrosion resistance
- Fabricability
- High thermal conductivity
- Good thermal and radiation stability

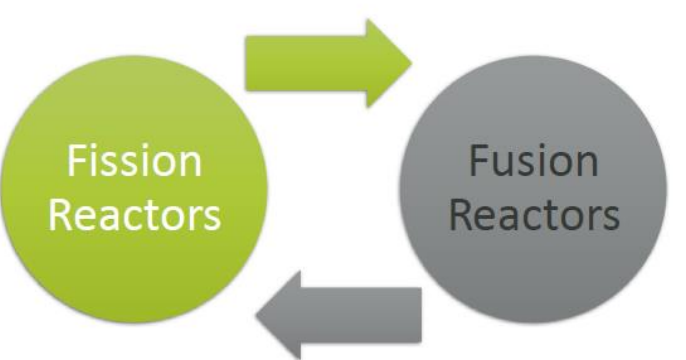
³ – Materials in Nuclear Energy Applications, Volume 1, by C.K. Gupta



TABLE OF ELEMENTS



What is the Commercial Nuclear Market for Beryllium?



7

Nuclear Market Segmentation

Traditional Nuclear

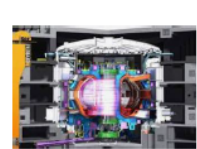
Test Reactors / Science

Be
BeO



Fusion

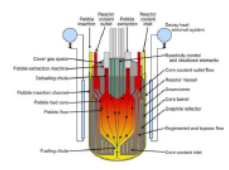
Be
FLiBe



New Nuclear

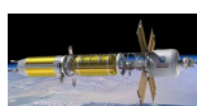
Molten Salt Reactors

FLiBe



Micro Reactors

Be
BeO



8

Nuclear Markets – Fission

• Fission Traditional:

➤ **Test Reactors** – Material Research and Radioisotope production

- KJRR – Doosan/KAERI: Current Order
- HFR- NRG Netherlands
- PALLAS – Netherlands
- ATR – Idaho National Lab
- HFIR – Oak Ridge National Lab
- BR-2 Belgium
- SAFARI – South Africa
- SOREQ - Israel



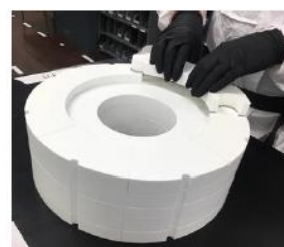
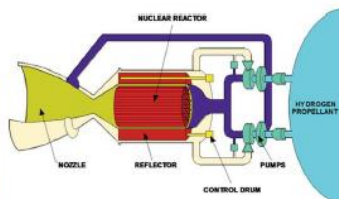
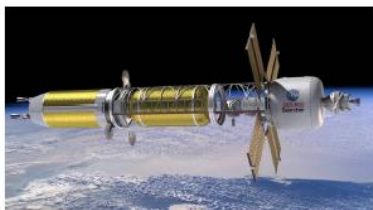
BR-2 SCK-CEN

ATR - INL

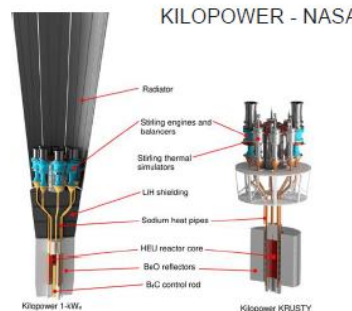


Nuclear Market – Fission

- **Micro Reactors:** <20MW, small, transportable
- **Space Power - NASA:** Kilopower (NASA-Glenn, LANL)
- **Nuclear Thermal Propulsion** (Mars, Cislunar)



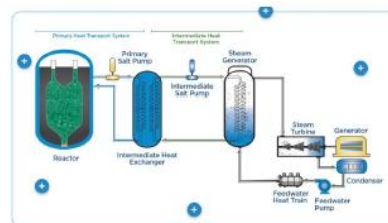
KILOPOWER - NASA



Nuclear Market – Fission

Molten Salt Reactors (MSR):

- **FLiBe (Li_2BeF_4)** – the ideal molten salt
 - Excellent chemical stability
 - High heat capacity
 - Heritage - MSRE Program (ORNL)
- Molten salt used as a coolant
- Some designs include thorium – Liquid Fluoride Thorium Reactor (LTFR)



Kairos Power KP-FHR (kairopower.com)



MSRE - ORNL



Nuclear Markets – Fusion

ITER - International Thermonuclear Experimental Reactor

- **First Wall Panels:**
 - Be Tile procurement has started
 - Fusion For Energy (F4E) - Europe
 - SWIP – China
 - ITER Russia – Eframov
- **Breeder Blanket:**
 - Development of materials:
 - Be “mini-spheres”
 - Beryllium intermetallics – “beryllides”
 - Ti and V



ITER Vacuum Vessel @ Cadarache, FR January 2023



First Wall Panel with Be Tiles



Nuclear Markets – Fusion

Inertial Confined Fusion:

- National Ignition Facility (NIF) - LLNL
 - December 5, 2022:



NIF @ LLNL, CA



Beryllium Manufacturing



Materion's Three Business

We operate in three reportable business segments.



Performance Materials

One of the world's leading suppliers of high-performance alloys, beryllium products, clad metals, metal matrix composites, and technical ceramics.



Electronic Materials

Specialty materials for thin film deposition, microelectronic packaging products and inorganic chemicals.



Precision Optics

One of the world's largest manufacturers of customized optical thin-film coatings and components

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Performance Materials

A leading global supplier of specialty metals, alloys and other advanced materials that enable design innovation and next-generation technologies.

Diverse product portfolio meets the most challenging needs of the Aerospace, Automotive, Consumer Electronics, Defense, Energy, Industrial and Telecom markets:

- Beryllium & beryllium-containing materials
- Clad metals
- High performance alloys
- Metal matrix composites
- Technical ceramics

Major end-use application groups:

- Avionics electronics, space and satellite structures, defense systems, X-ray equipment and acoustic beryllium
- EV battery connections and chargers
- Automotive connectors, electronic springs and connectors, cell phone voice coil motor springs, mining equipment and aerospace bushings and bearings, downhole drilling equipment components
- Commercial and defense aerospace structural components, space and defense optical systems, and on-highway automotive components
- Semiconductors, microwave equipment, laser systems and tubing, heatsinks and ceramic substrates



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Performance Materials Locations

Performance Materials

- Delta, Utah
- Elmore, Ohio
- Farnborough, England
- Lincoln, Rhode Island
- Lorain, Ohio
- Newton, Massachusetts
- Reading, Pennsylvania
- Singapore
- Tucson, Arizona
- Elmhurst, Illinois
- Shanghai, China
- Stuttgart, Germany
- Tokyo Japan



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Beryllium industry flow diagram

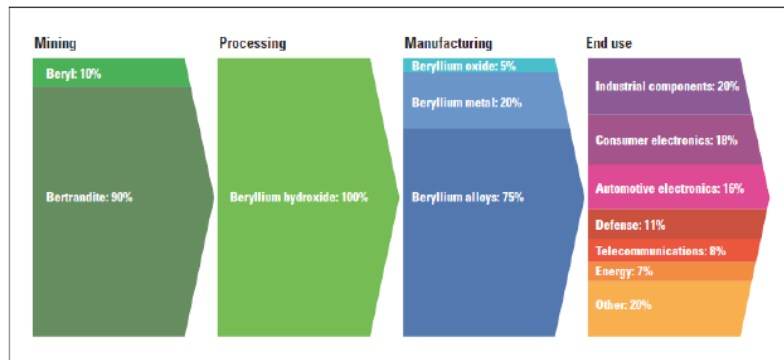


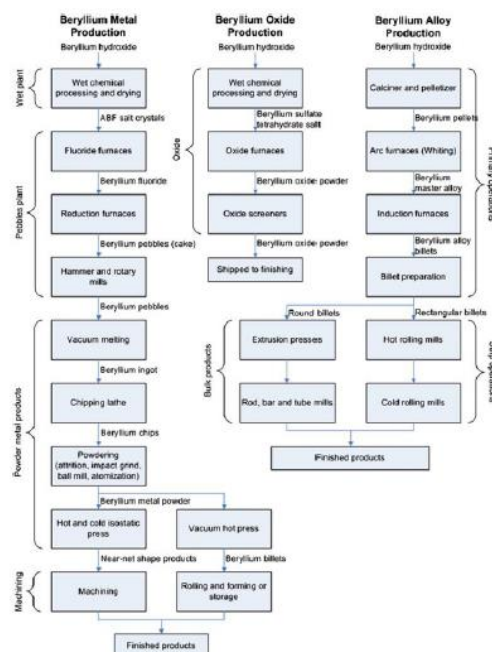
Figure 2. Simplified flow diagram of the beryllium industry. Percentages are relative to the total beryllium flow at each stage; flows between stages do not account for losses, changes in stocks, or recycling. End use category labelled "Other" includes 2 percent used in medical applications (Materion Corporation, 2016).

Beryllium – A Critical Mineral Commodity – Resources, Production, and Supply Chain,
US Geological Survey, October 2016

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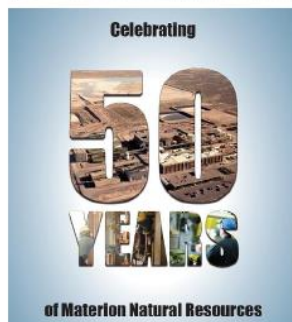


Be Process Flow



Beryllium Supply

- Materion operates a beryllium mine in the **Topaz-Spor Mountain** area of western Utah.
- The mineral is identified as **bertrandite**, a hydrous beryllium silicate ($\text{Be}_4\text{Si}_2\text{O}_7(\text{OH})_2$)
- Materion holds **estimated ore reserves for 70 years of production.**
- USGS estimates 21,000tons of Be reserves @ Utah.



Vertically Integrated Supply



Topaz-Spor Mountain, UT



Delta, UT



Elmore, OH

Delta, UT

Ore is calcined and concentrated
Aqueous extraction and conversion to beryllium hydroxide $\text{Be}(\text{OH})_2$

Elmore, OH

Conversion of hydroxide to a halide
Reduction of the halide to beryllium metal



Be Metal Processing

• Beryllium Pebble Plant - final stage Extraction

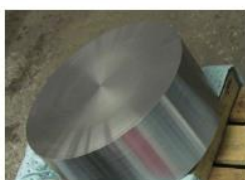
- Conversion of $\text{Be}(\text{OH})_2$ to Beryllium metal
 - Highly automated chemical plant
 - Dissolves $\text{Be}(\text{OH})_2$ in ABF Solution – ABF Salt
 - Decompose the salt to BeF_2
 - Reduction of BeF_2 to Be Metal – “Pebble”



Be Metal Processing

- **Final Be processing:**

- Vacuum melting
- Metal powder production
- Powder consolidation to generate parts
- Machining



FLIBE Molten Salt Production

- **Materion and Kairos Power** are collaborating to produce **FLIBE**, a molten fluoride salt, as a coolant for the Kairos Power Fluoride salt-cooled High temperature Reactor (KP-FHR).
- The facility has been constructed at Materion's Elmore, Ohio plant.
- Materion operates the facility and provides both BeF_2 and LiF .



Molten Salt Purification Plant

- **FLiBe Purification Facility** – Elmore, OH



FLiBe transfer vessel (2 Tons)



BeO Ceramic Production

- **BeO Powder Production:**
 - $\text{Be}(\text{OH})_2$ dissolved in $\text{H}_2\text{SO}_4 \rightarrow \text{BeSO}_4 \cdot 4\text{H}_2\text{O}$
 - Beryllium sulfate is calcined at high temperature to produce BeO powder
 - Powder consolidation and fabrication occurs at Materion's Tucson, AZ facility



US Be Containing Materials Manufacturing Facilities

- Materion, Customers, and Competitors
- Materials processed:
 - Be
 - AlBeMet
 - BeO
 - Cu-Be



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Materion enables what's next™

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Materion – Newton, MA Recent acquisition

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Newton Acquisition Overview



OUR TEAM: 140 Employees



OUR EXPERIENCE: 70+ Years



OUR SITE: Located in Massachusetts, USA
ISO 9001 certified
20,300 m²



OUR METALS: Tantalum
Niobium



OUR MARKETS: Electronics
Chemicals & Superconductors
Aerospace & Defense



30

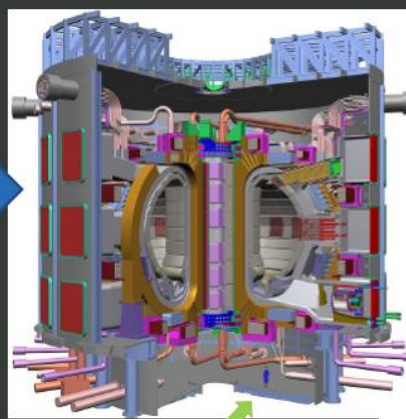
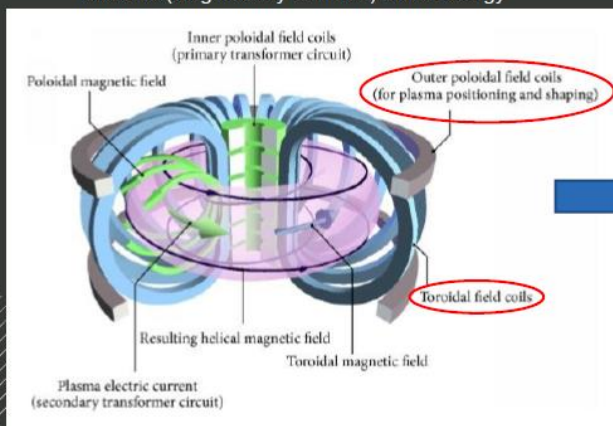
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Next Gen Nuclear Energy

- Niobium rod preforms are critical superconductor components of high strength magnets required for Tokamak (magnetically confined) fusion energy

- **Niobium and Tantalum** play a key role in fusion energy as the global scientific community drives to demonstrate its viability, sustainability, and ultimately commercialization



Superconductor Industry

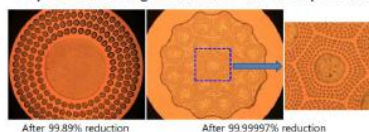
Applications

- MRI and NMR
- Mass spectroscopy
- **Nuclear fusion energy**
- Magnetic levitation
- Particle accelerators

Niobium and Tantalum Products

- Sheet
- Rod
- Wire

Superconducting Filaments – Nb rod preforms



Day 2: BHSC Business Meeting

Led by Roland CHRETIEN, BHSC Chair

Business Meeting Minutes compiled by Josef SOBIERAJ

BHSC Business Meeting Original Agenda (Black Font) Minutes Added (Red Font)

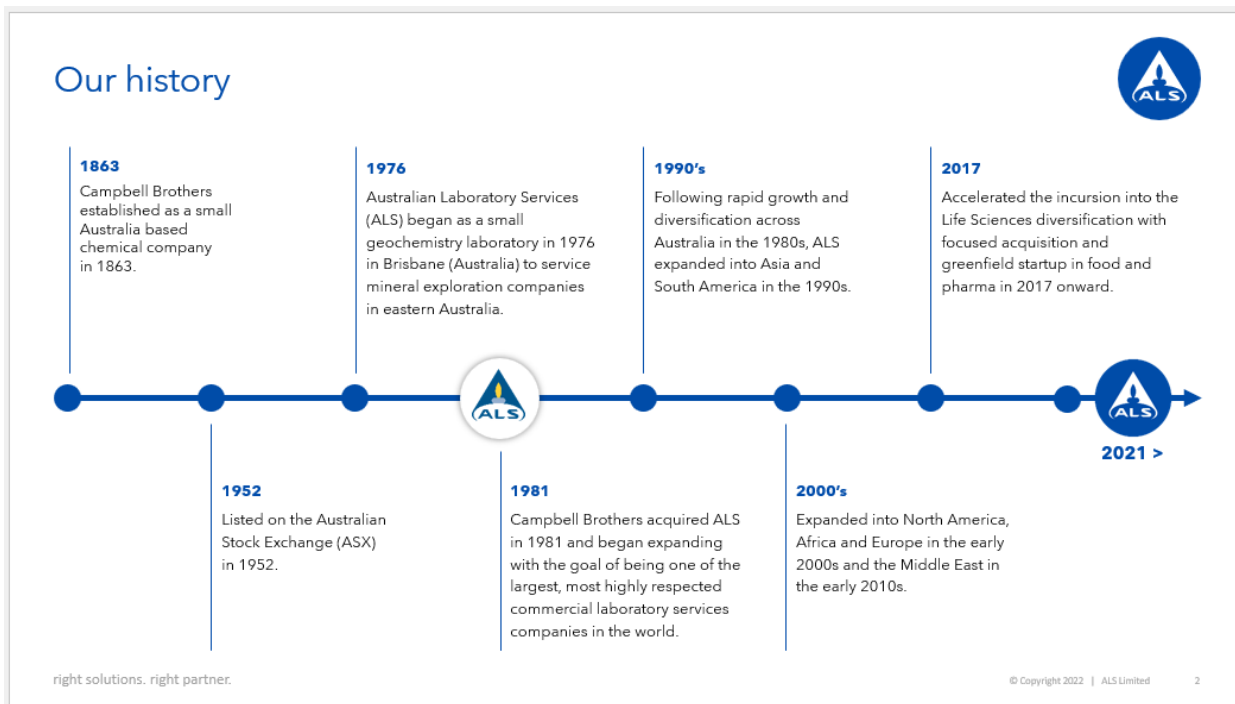
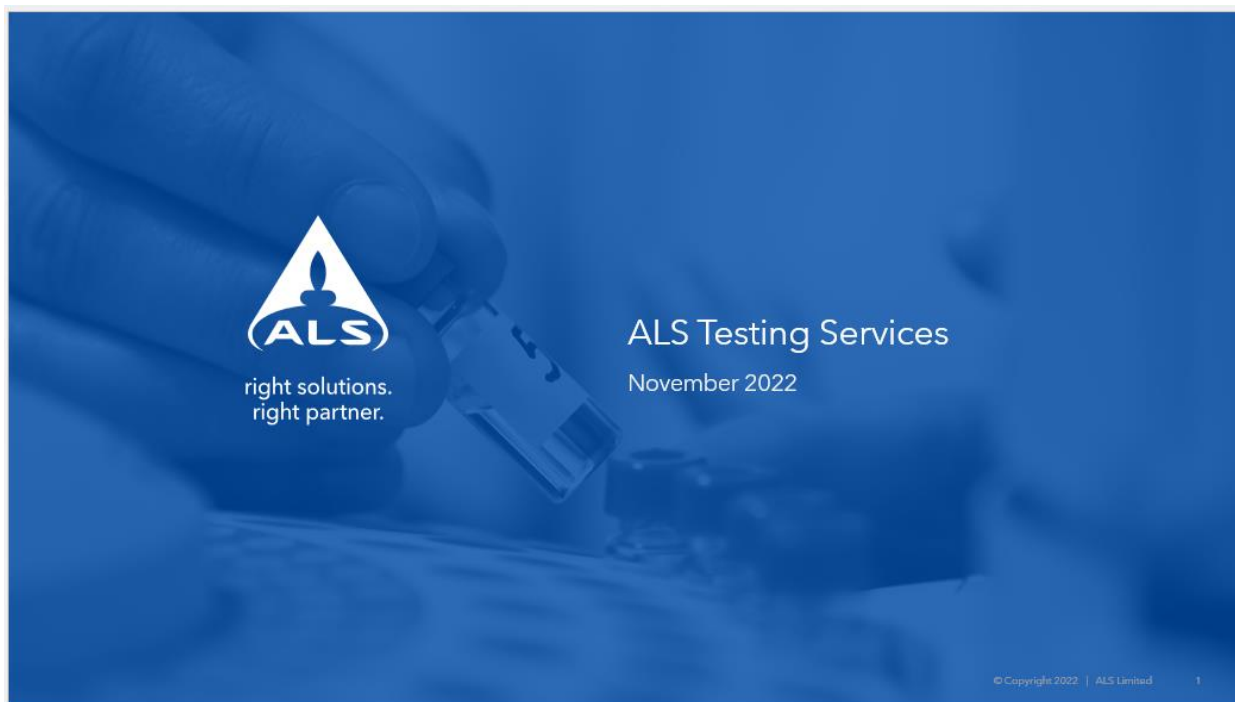
Wednesday, 10 May 2023 – At BHSC Spring Meeting & MS Teams Online
13:45 (1:45pm) - Eastern Daylight Time

1. Review and Approval of meeting agenda – Chair Roland presented the agenda. Motion to Approve as written – Chris Dorn. Second – Mike Brisson
2. Roll-Call – Recording Secretary (Chair or designee) Julie Fowler took roll call for all members including in-person and virtual attendees. The meeting had a quorum.
3. Election of Officers Danny Field stated there is a Recording Secretary vacancy. As part of succession planning, BHSC has opportunities to serve as Chair for subcommittees and overall Chair of BHSC. Beth Walker stated that she would like to volunteer as needed.
4. Other New Business Items No new business items.
5. Chairman's Report Roland reviewed activities since 11/22. Roland also spoke on the need for succession planning.
6. Status of Funds Roland paid Jackie Rogers \$50 for renewal of business license.
 - i. PayPal Dan Jensen stated this account has \$4,253.70.
 - ii. Wells Fargo Dan Jensen stated this account has \$7,710.64.
 - iii. Total balance of \$11,964.34.
7. Membership Report Julie stated that BHSC currently has 31 paid members and 203 contacts and subscribers.
8. Website Report Julie stated that BHSC is updating its website with many enhancements forthcoming.
9. Plans for Fall BHSC Meeting Josef summarized the planning details for the 11/6-8/23 Fall BHSC Meeting to be held at Forrestal Building in Washington DC. A Meetings and Symposia Subcommittee planning meeting will be held later this day with additional details presented to the entire group.
10. Subcommittee Chairs
 - Risk Communication – Nothing to report
 - Research Needs – Nothing to report
 - Technical Standards/Practitioners Guide/Measures – Seuri stated that this group is waiting for the 10 CFR 850 Rule changes, which will drive changes to the Practitioners Guide
 - Med/Epi Lisa stated that this group has been meeting every other month with 15 active members. This group is taking a deep dive in evaluating the BAWR to improve data quality in sections so that it can be better utilized to inform health and safety data and trends for sites and the DOE.
 - Meetings and Symposia Josef presented on the updated details from the Fall BHSC planning meeting. Separate meeting minutes were prepared and disseminated.
11. New Business None
12. Adjournment Motion to Adjourn at 1434 EDT – Chris Dorn. Second – Josef

Day 2: Vendor Technical Presentations

ALS Testing Services, Salt Lake City, Utah, USA

Bevan MEADE and Lisa REID



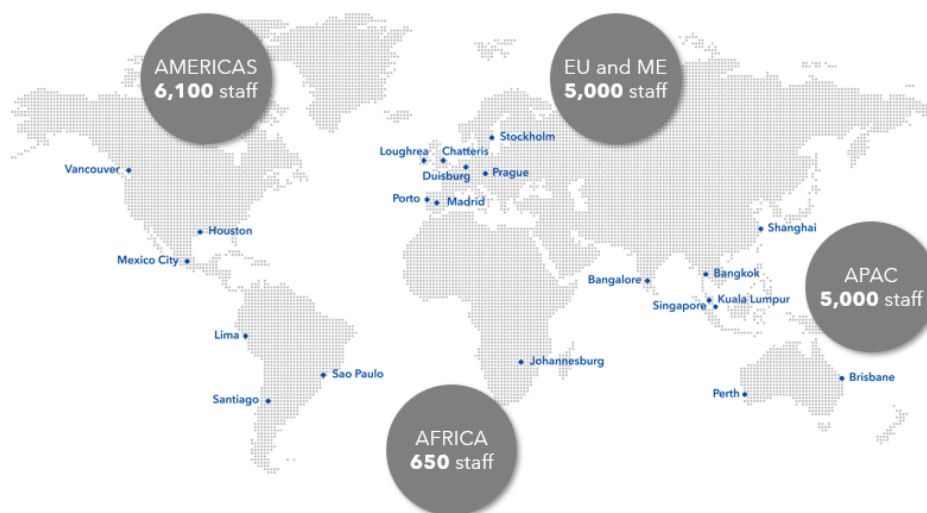


ALS is a global leader in providing laboratory testing,
inspection, certification and verification solutions

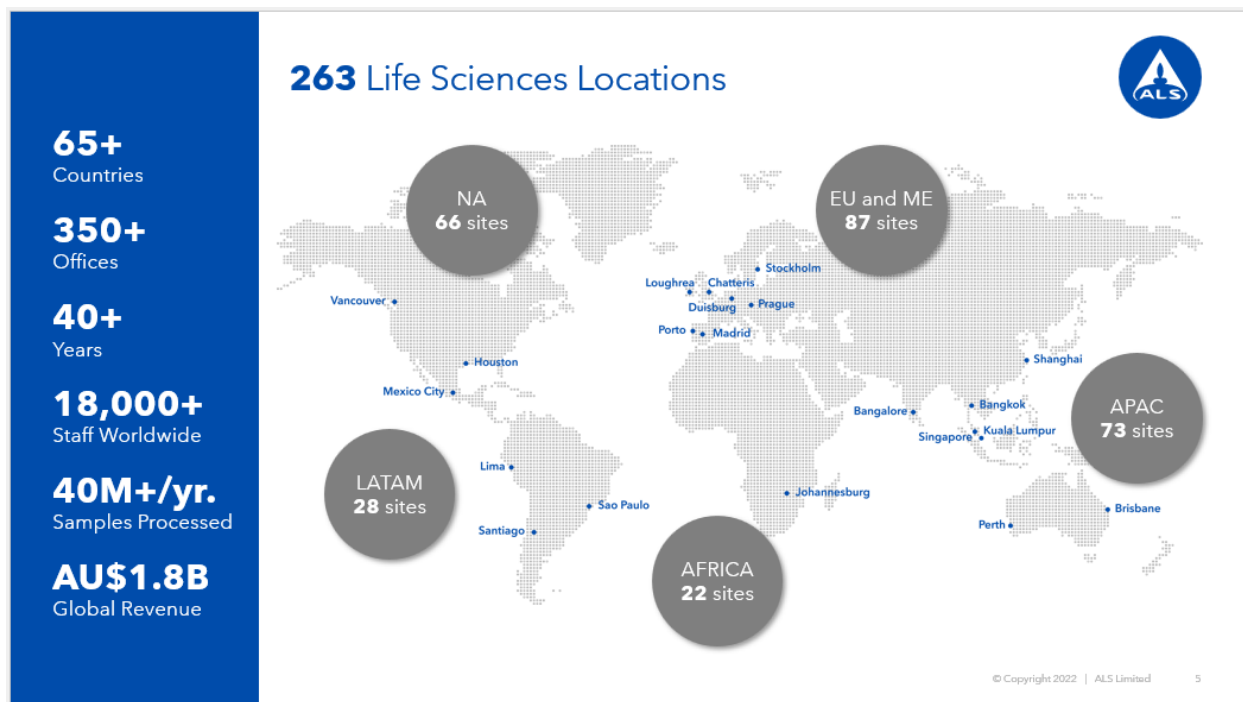
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Our global scale



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ALS Salt Lake City



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7

ALS Salt Lake City



- History of Quality and Innovation
 - NIOSH Industry Partner (32 years)
 - AIHA Accreditation (1974): 300+ air/wipe methods
 - ISO 17025 Compliant
 - DOECAP-AP: 100+ methods
 - DoE, DoD, EPA Projects

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8

ALS Salt Lake City



- Expertise and Customer Service
 - Project Management
 - Sampling Media and Equipment
 - Level 1 - 4 Reporting and custom EDD's
 - 30+ chemists (15 year average tenure at ALS)

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ALS Salt Lake City - Testing Capabilities



- Full-service Laboratory
 - Industrial Hygiene (occupational exposure tests of air and wipes)
 - Metals Analysis:
 - ICP-AES/MS
- Beryllium/Beryllium oxide
 - 7,500+ workorders processed since 2018
 - BePAT Program (10+ years)
 - AIHA PAT (Be/BeO)

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ALS Salt Lake City – Testing Capabilities



- Full-service Laboratory
 - Pesticide/Herbicide Analysis (comprehensive screen of 200+ compounds)
 - Home Inspection/Remediation
 - Illicit Substances (surface testing of Methamphetamine, Fentanyl, and other illicit drugs)
 - Asbestos / Mold / Lead
- ALS Lab Network Advantage – ALS Cincinnati
 - Cross-Lab Capability
 - Continuance of work
 - Equivalent Quality System

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11

Thank You



- | | |
|---|--|
| <ul style="list-style-type: none">• Bevan Meade (DOE Contact)<ul style="list-style-type: none">– Office: +(801) 266-7700 ex 277– Bevan.Meade@alsglobal.com• Patrick Noteboom<ul style="list-style-type: none">– Office: +(801) 266-7700 ex 381– Patrick.Noteboom@alsglobal.com• Meredith Edwards<ul style="list-style-type: none">– Office: +1 801 266 7700– Meredith.d.edwards@alsglobal.com | <ul style="list-style-type: none">• Lisa Reid (DOE Contact)<ul style="list-style-type: none">– Office: +1 801 266 7700– lisa.reid@alsglobal.com• Stella Hanis<ul style="list-style-type: none">– Office: + 801 266 7700– stella.hanis@alsglobal.com• Jessica Cofrancesco<ul style="list-style-type: none">– Office: +(801) 266-7700 ex 302– Jessica.Cofrancesco@alsglobal.com |
|---|--|

History - Quality - Flexibility - Reliability

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Bureau Veritas North America, Michigan & Illinois, USA

Mike DEW

A banner for the BHSC Spring Meeting. The left side features a photograph of a desert canyon with a large, circular opening in the rock. Overlaid on this image is the Bureau Veritas logo, which consists of a circular emblem with a figure holding a torch and the text 'BUREAU VERITAS' and '1828'. Below the emblem, the words 'BUREAU' and 'VERITAS' are written in white capital letters on a red background. The right side of the banner is white and contains the text 'BHSC Spring Meeting' in a large, black, sans-serif font. Below this, in a smaller font, is 'LIVERMORE, CA' and 'MAY 10'. At the bottom right, the year '2023' is displayed in a small, grey, sans-serif font.

BHSC Spring Meeting

LIVERMORE, CA
MAY 10

2023

A banner for Bureau Veritas Industrial Hygiene Analytical Laboratory Services. The background is a photograph of a person in a lab coat holding a clipboard. The text 'FULL INDUSTRIAL HYGIENE ANALYTICAL LABORATORY SERVICES' is written in large, bold, red capital letters. Below this, the word 'INCLUDING:' is followed by a list of services: 'METALS IN AIR', 'ISOCYANATE ANALYSIS', 'VOLATILE ORGANIC COMPOUNDS', 'CRYSTALLINE SILICA METHOD DEVELOPMENT AND VALIDATION', and 'AND MORE!'. The Bureau Veritas logo is positioned on the right side of the banner, and the words 'BUREAU' and 'VERITAS' are written in white capital letters on a black background below it.

**FULL INDUSTRIAL HYGIENE
ANALYTICAL LABORATORY SERVICES**

INCLUDING:

- | METALS IN AIR
- | ISOCYANATE ANALYSIS
- | VOLATILE ORGANIC COMPOUNDS
- | CRYSTALLINE SILICA METHOD DEVELOPMENT AND VALIDATION
- | AND MORE!

BUREAU VERITAS

Beryllium Methods



Beryllium Methods

- Beryllium NIOSH 7303 ICP
- Beryllium NIOSH 7303-MS
- Beryllium OSHA ID-125G
- Beryllium NIOSH 7303 MS/ASTM D7939-14
- Beryllium (Bulk) EPA 3050/6010D
- Beryllium (Bulk) EPA 3050/6020



Beryllium Oxide Methods

- Beryllium Oxide OSHA ID-125 MS/ASTM D7939-14
- Beryllium Oxide OSHA ID-125G
- Beryllium Oxide Bulk OSHA ID-125G-MS/ASTM D7939-14



Media

- Mixed Cellulose Ester (MCE) Filters
- PVC Filters



Report Limits

- ICP (NIOSH 7303 and OSHA ID-125) 0.02µg
- ICP/MS (NIOSH 7303-MS) 0.005µg
- Surface Wipes (EPA 6010C) 0.05µg



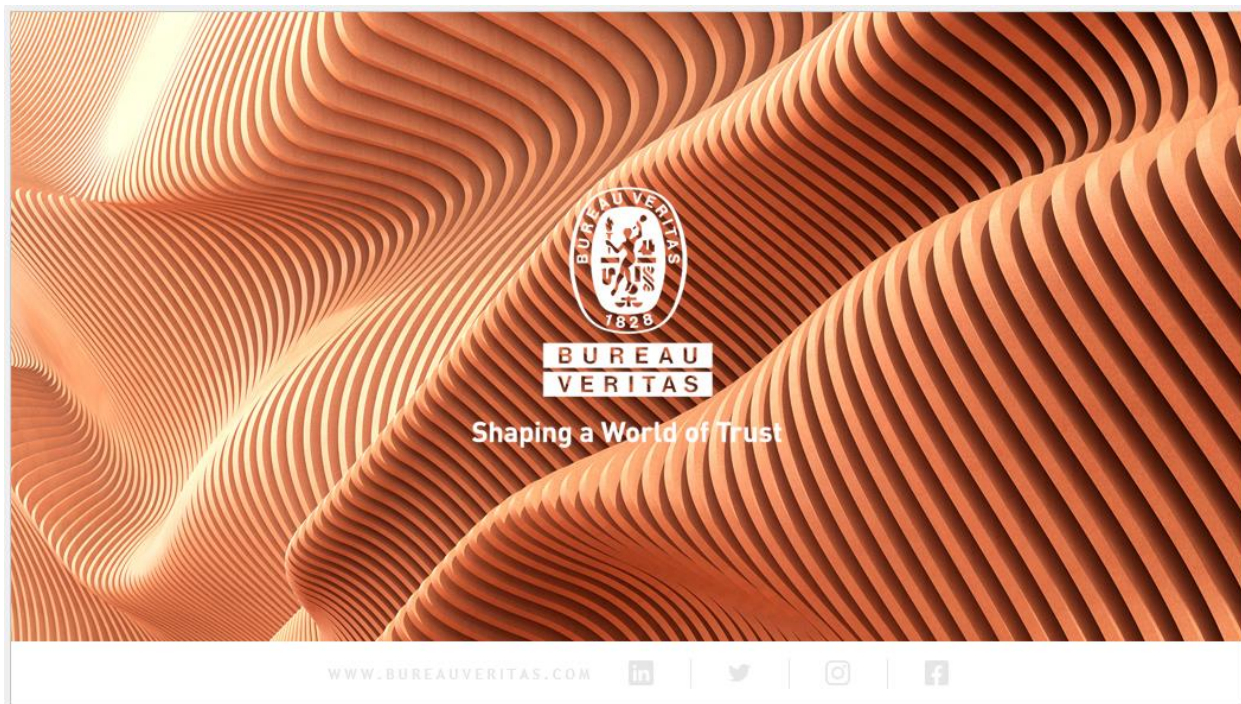
Contact Information

Michigan
22345 Roethel Drive
Novi MI 48375

Illinois
95 Oakwood Road
Lake Zurich IL 60047

Mike Dew
Business Development Manager West Region
224-475-6556
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Scientific Sales, Inc., Oak Ridge, Tennessee, USA
Cynthia BULLARD



Scientific Sales, Inc.

*A Small, Minority and
Woman-Owned Business*

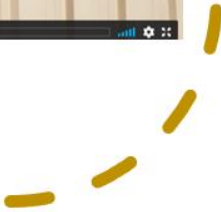
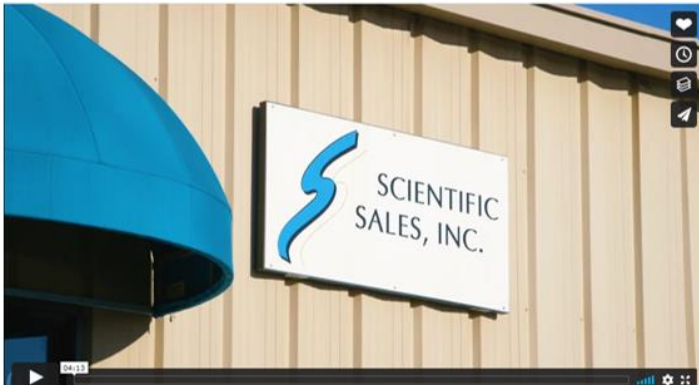
Since 1987

May 10, 2023

Headquartered in Oak Ridge, TN



Introducing Scientific Sales, Inc. (SSI)



SSI Introduction

- SSI is a small woman and minority-owned distributor founded in 1987 by Vicki Dyer (current President and Owner).
- Began by representing one national lab supply company, then negotiated distributor agreements with other major lab supply companies.
- Offices and warehouse are in Oak Ridge, TN, but SSI conducts business throughout the United States.
- SSI has done business with DOE and the Federal government for over 35 years developing an extensive list of Safety, Industrial, and Environmental product offerings.

The SSI Advantage

- Extensive experience supporting construction and remediation projects with safety and industrial products in situations involving Beryllium, Mercury, and many more hazardous materials.
- Strong vendor relationships, extensive experience supplying Lab, Safety, Facilities Maintenance, and Industrial products to customers throughout the US.
- Competitive Pricing through over 2,000 direct relationships with a variety of vendors helping mitigate stock-out situations.
- Unmatched ability to source hard to find items.
- Experienced and Award-Winning Customer Service staff with excellent product knowledge and problem-solving capabilities
- Investing now in first class e-commerce technology to improve the customer purchasing experience.

First Class Customer Service and E-Commerce Experience



- Magento 2.4 B2B E-Commerce Platform by Adobe Commerce Cloud with over 2 million products
- AI-enhanced search capabilities
- Compatible with any marketplace system (e.g. SAP Ariba, Coupa, Oracle Cloud)
- Landing page tailored to the customer
- Third party integrations and PunchOut catalogs available
- Enhanced user experience allows for custom quotes, invoice retrieval, order status and history, order tracking, and wish list creation



Customers include:

- **Government Agencies** including DOE, DOD, EPA, US Military, USDA
- **Government Contractors** including CNS (Y-12), UCOR, UT-Battelle (ORNL), Fluor, Bechtel, Jacobs, Amentum
- **Utilities** including Tennessee Valley Authority, Duke Energy, Florida Power and Light
- **Automotive Customers** including Denso and Aisin
- **Universities** including University of Tennessee, Vanderbilt University, University of Alabama - Birmingham, Arizona State University, Northern Arizona University
- **Industrial Accounts** throughout the United States

Distributor of Safety Products



- Head to Toe PPE
- Fall Protection
- Respiratory Equipment
- Heat Stress and Cold Weather Items
- Safety Showers and Eyewash Stations
- Tool Storage/ Tethering
- Signs and Markings
- Fire Extinguishers
- First Aid

Distributor of Facilities Maintenance and Industrial Products



- Head to Toe PPE
- Hearing Protection
- Tools/Tool Storage/Tethering
- Abrasives and Sorbents
- Protective Clothing
- Work Apparel
- Signs and Markings
- Fire Extinguishers
- First Aid

Lab Related Products

3M Science.
Applied to Life.™

ACCUFORM
Justrite Safety Group

Ansell

TROEMNER
Honeywell

Dräger

DUPONT

UTRAX
Justrite Safety Group

Bradley

Justrite

fend-all

SPEAKMAN

**Millipore
Sigma**

**RICCA
CHEMICAL
COMPANY**

HACH  **LABCONCO**
Protecting your laboratory environment

**ENVIRONMENTAL
EXPRESS**

FIRST AID ONLY
Acme United Corporation



- Flammable Storage Cans and Cabinets
- Laboratory Matting
- Safety Showers and Eyewash Stations
- Labeling Products
- Laboratory Signage and Markings
- Fire Extinguishers
- Goggles
- Protective Apparel

Award Winning Service

- 2022 – UCOR Small Disadvantaged Business of the Year
- 2020—City of Knoxville—Minority-Owned Business of the Year
- 2018—City of Knoxville—Minority-Owned Business of the Year
- 2017—Department of Energy - Small Disadvantaged Business of the Year
- 2017—UCOR - Woman-Owned Small Business of the Year
- 2016—CNS-Y12 - Small Business Achievement Award
- 2016—City of Knoxville - Woman-Owned Business of the Year
- 2015— Oak Ridge National Laboratory - Small Business Impact Award
- 2015—Bechtel National, Inc. – Small Business Impact Award
- 2013—URS/Ch2M – Small Disadvantaged Business Award
- 2010—Wackenhut Services, Inc. — SBA Small Woman-Owned Business of the Year, Nominated
- 2010—Oak Ridge National Laboratory – AVID Supplier of the Year Award
- 2009—Tennessee Minority Supplier Development Council –Minority Supplier of the Year, nominated by TVA



Contact SSI:

Scientific Sales, Inc.
130 Valley Court
Oak Ridge, TN 37830



www.scisale.com



Vicki Dyer, President
Wendi Arnold, VP of Sales
Don Evans, VP of Operations
Cynthia Bullard, Dir. Outside Sales
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1.800.229.7252 or 865.483.9332



Appendices

BHSC 2023 Spring Meeting Participants List

<u>Family Name</u>	<u>First Name</u>	<u>Organization</u>	<u>Country</u>	<u>Status</u>
ADAMS	Eric	Dept of Energy ORAU/ORISE	USA	Online
ADAMS	Wes	National Nuclear Security Administration	USA	Online
ARDAIZ	Mike	Dept of Energy	USA	Online
ASHLEY	Kevin	Ashley Analytical Associates LLC	USA	In person
BAILEY	Brian	National Nuclear Security Administration	USA	In person
BANTA	Gregory	Dept of National Defence	Canada	Online
BARKER	Lisa	National Jewish Health	USA	In person
BARKER	Matthew	UK Atomic Weapons Establishment	UK	In person
BENNETT	Jack	Lawrence Livermore National Lab	USA	In person
BERNHOLC	Nicole	Dept of Energy Brookhaven National Lab	USA	Online
BRISSON	Mike	National Nuclear Security Administration	USA	In person
BROUNSTEIN	Robert	TerranearPMC LLC	USA	Online
BROWN	April	Dept of Energy HQ	USA	Online
BRYSON	Drew	National Nuclear Security Administration	USA	Online
BULLARD	Cynthia	Scientific Sales Inc.	USA	In person
CASALINA	Cynthia	National Nuclear Security Administration	USA	Online
CHAUHAN	Ankur	Bhabha Atomic Research Centre (BARC)	India	Online
CHRETIEN	Roland	National Nuclear Security Administration	USA	In person
CIBUZAR	Mike	Advanced Research Corp.	USA	In person
COPPERSMITH	Pamela	Dept of Energy RL	USA	Online
DAVIS	Lindsay	National Nuclear Security Administration	USA	In person
DEW	Mike	Bureau Veritas North America	USA	In person
DORN	Chris	Kyoto Fusioneering America Be4FUSION LLC	USA	In person
DUELTGEN	Eric	National Nuclear Security Administration	USA	In person
FADEL	Gus	Dept of Energy Office of Science	USA	Online
FECHSER	Matthew	National Nuclear Security Administration	USA	In person
FIELD	Dan	National Nuclear Security Administration	USA	In person
FOWLER	Julie	National Nuclear Security Administration	USA	In person
GARG	Kul	National Nuclear Security Administration	USA	In person
GILL	Joanne	UK Atomic Weapons Establishment	UK	Online
GOLDEN	Ashley	Dept of Energy ORAU/ORISE	USA	In person
GORAIEB	Aniceto	Karlsruhe Beryllium Handling Facility	Germany	Online
GRIFFIN	Gary	GEG Consulting, LLC	USA	In person
HANEUTH	Julie	Dept of Energy ANL	USA	Online
HELDT	Gregory	Materion Brush Inc.	USA	In person
HELLAND	Jessica	ALS Testing Services	USA	In person

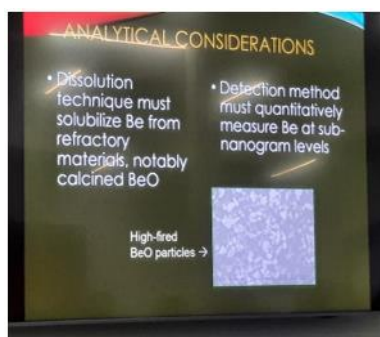
Family Name	First Name	Organization	Country	Status
HOLEY	Brandy	National Nuclear Security Administration	USA	Online
HOWE	Teresa	General Dynamics Mission Systems	USA	In person
JENSEN	Daniel	National Nuclear Security Administration	USA	Online
KELLER	Patrick	National Nuclear Security Administration	USA	Online
KOLANZ	Marc	Materion Corp. (Retired)	USA	Online
KRUIZENGA	Alan	Kairos Power LLC	USA	Online
KUPRIYANOV	Igor	Bochvar Research Institute	Russia	Online
KURINSKIY	Petr	ITER Organization	France	Online
LEWIS	Kelly	Dept of Energy Idaho National Laboratory	USA	Online
LEWRY	Erik	UK Atomic Weapons Establishment	UK	In person
LUCERO	Diego	National Nuclear Security Administration	USA	Online
MAESTAS	Lynn	National Nuclear Security Administration	USA	Online
McDOWELL	Bob	Dept of Energy Hanford Site	USA	Online
McGREGOR	Drake	American Industrial Hygiene Association	USA	Online
McKEON	Eilish	UK Atomic Energy Authority	UK	Online
MEADE	Bevan	ALS Testing Services	USA	In person
MEYER	Ken	National Nuclear Security Administration	USA	In person
MERWIN	Augustus	Kairos Power LLC	USA	Online
MOORE	Mary	National Nuclear Security Administration	USA	In person
MUSGROVE	James	N/A	N/A	Online
NETTLES	Wyman	National Nuclear Security Administration	USA	Online
OH	Thomas	National Nuclear Security Administration	USA	Online
PASS	K.D.	Sandia National Laboratories	USA	Online
PHILLIPS	Karen	Dept of Energy	USA	Online
QUINN	Kevin	Dept of Energy Office of Science	USA	Online
QUINN-VAWTER	Chris	National Nuclear Security Administration	USA	In person
RHAMBAROSE	Harrichand	DOE Office of Enterprise Assessments	USA	In person
ROBICHAUD	Victoria	Cameco Corp.	Canada	Online
ROBINSON	June	Dept of Energy Hanford Site	USA	Online
RODDY	Crystal	Cameco Corp.	Canada	Online
ROSENOW	Michael	National Nuclear Security Administration	USA	Online
ROTH	Michael	Sandia National Laboratories	USA	In person
SHIREY	Pamela	BWX Technologies, Inc.	USA	Online
SMITH	Keith	Materion Brush Inc.	USA	In person
SOBIERAJ	Josef	National Nuclear Security Administration	USA	In person
STACY	Laura	Kairos Power LLC	USA	Online
STEIN	Elliot	Dept of Energy Office of Science	USA	In person
STUBER	Ed	SGS Environment, Health & Safety Services	USA	In person
TARURU	Seuri	Mission Support & Test Services	USA	In person

<u>Family Name</u>	<u>First Name</u>	<u>Organization</u>	<u>Country</u>	<u>Status</u>
TEBBS	Andy	UK Atomic Energy Authority	UK	Online
UPPAL	Bibake	Kyoto Fusioneering America	USA	In person
VANDERMARK	Lee	General Dynamics Precision Machined Products	USA	In person
VENUTO	Margaret	Dept of Energy	USA	Online
WALKER	Beth	Safer Environment Ltd.	UK	Online
WHATLEY	Todd	National Nuclear Security Administration	USA	In person
WHITE	Annette	Atkins Global Nuclear Services	UK	Online
WHITNEY	Gary	Los Alamos National Laboratory	USA	Online
WILMOT	Zeke	Los Alamos National Laboratory	USA	In person
WILSON	Leah	National Nuclear Security Administration	USA	In person
WIRGAU	Tom	Dept of Energy	USA	In person
YADA	Shian	Cameco Corp.	Canada	Online
ZHOU	Weiyue	Massachusetts Institute of Technology	USA	Online

Meeting & Venue Photos



Left: Roland CHRETIEN, BHSC Chair, delivers his opening remarks. Right: More than 40 in-person attendees listened to Richard BEALE giving his presentation about beryllium use in the National Ignition Facility (NIF) prior to going on guided tours of the facility. Photo credits: Julie FOWLER, NNSA.



Left: A slide from the presentation of Dr. Kevin ASHLEY, which was focused on beryllium analytical techniques. Center & Right: Vendors had display tables where they shared information on the latest developments in beryllium detection and control technologies. Photo credits: Julie FOWLER, NNSA.



NIF Tour Group 1 from the BHSC 2023 Spring Meeting on Tuesday, 9 May 2023. Photo credit: LLNL.



NIF Tour Group from the JOWOG Meeting held on Thursday, 11 May 2023. Photo credit: LLNL.



In-Person Participants at the BHSC 2023 Spring Meeting taken in front of the building where the Meeting was held on Wednesday, 10 May 2023. Photo credit: LLNL.



Left: From left to right, Josef SOBIERAJ, BHSC Meetings & Symposia Sub-Committee Chair, Jack BENNETT of LLNL, and Eric ARELLANO of LLNL. Jack and Eric were two of the key people at Livermore who provided local support for the organizing of the Spring Meeting. Right: BHSC Board Members, from left to right, Lisa BARKER of National Jewish Health, Danny FIELD of NNSA, Julie FOWLER of NNSA, Josef SOBIERAJ of NNSA, and Roland CHRETIEN, BHSC Chair. Photo credits: LLNL.



Left: Josef SOBIERAJ of NNSA, also serves on the BHSC Board as the Meetings & Symposia Sub-Committee Chair. Josef was leader within BHSC for the organizing of the Spring Meeting. Right: BHSC 2023 Spring Meeting logo. Photo credit: Julie FOWLER, NNSA. Logo design: Chris DORN of Kyoto Fusioneering America Ltd. and Be4FUSION LLC.