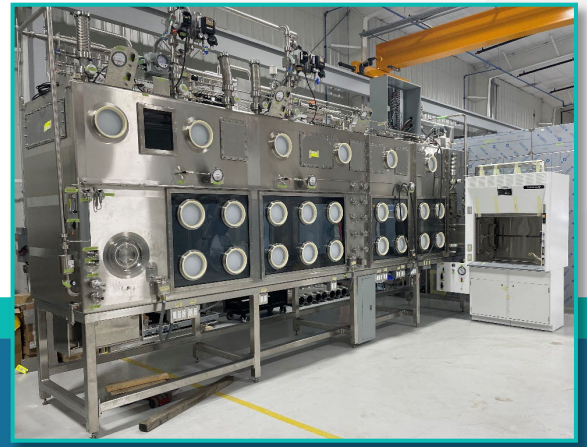
NRIC National Reactor Innovation Center

MSTEC

Molten Salt Thermophysical Examination Capability

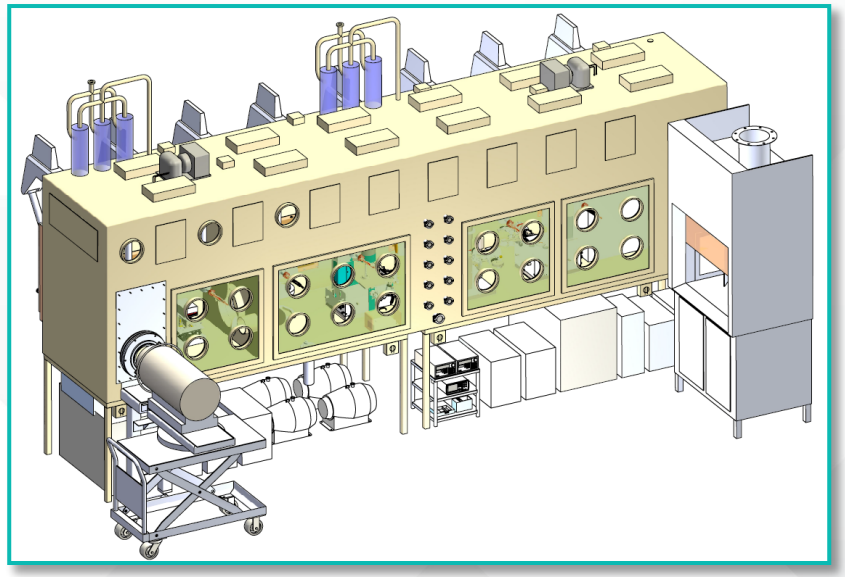
Toni Karlsson (PI/TPOC), Carson Stronks and Steve Warmann (PM's)

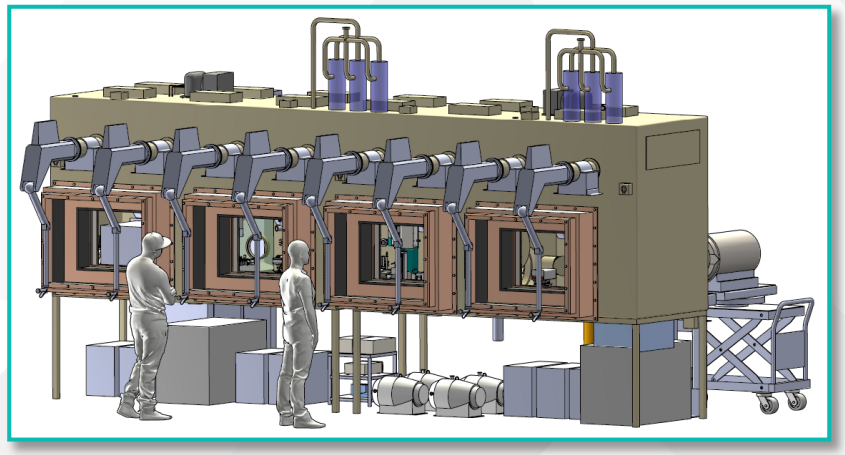


INL/MIS-24-77307

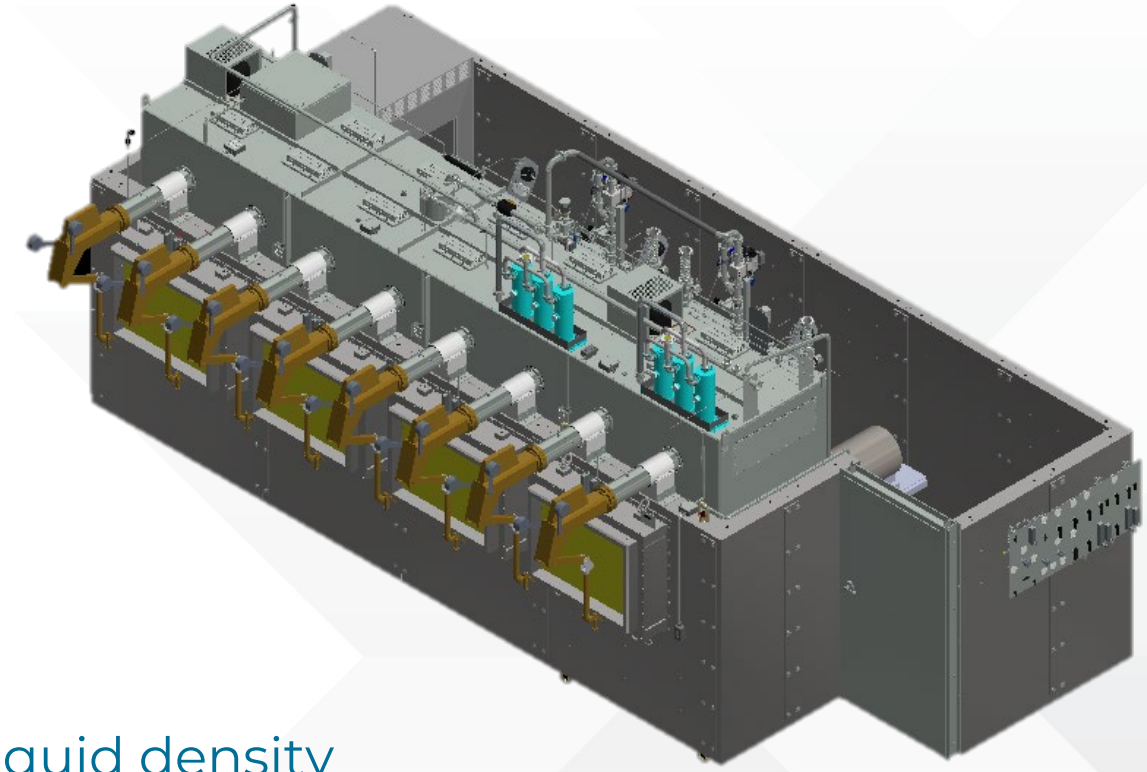
Overview

- Technical Description – a shielded modular hotcell with an inert argon atmosphere, housing characterization equipment for determining thermophysical and thermochemical properties of high temperature liquids not limited to but focusing on irradiated fuel salts
- Location – MFC, FCF, rm 35
- Compatible Materials:
  - Chloride, fluoride salts
  - Fresh fuel salts and irradiated fuel salts
  - Pyrophoric material - U, Pu metal
  - Gases – H_2, HCl, Cl_2, HF, F_2, NF_3
  - Beryllium containing salts
  - Many others





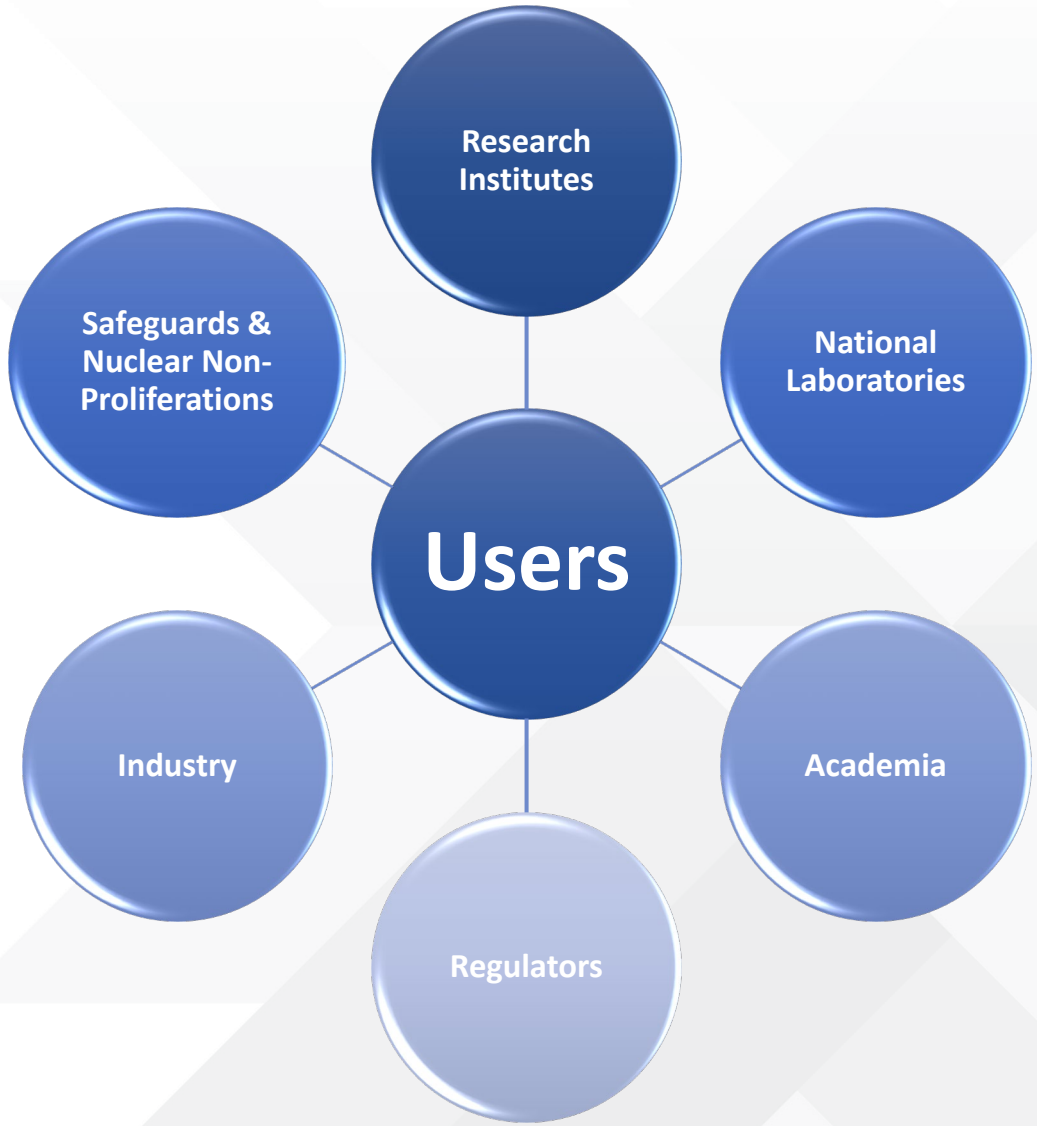
Overview



- Modular hot cell
  - Shielded on one side
  - Glove ports on the other side
- Instrumentation (≥ 1000°C)
  - Rheometer – viscosity
  - Densitometer/pycnometer – solid and liquid density
  - STA – invariant and transition temps, weight loss
  - DSC – specific heat capacity
  - Well furnace – corrosion, salt synthesis, electrochemistry
  - Versatile experimental space

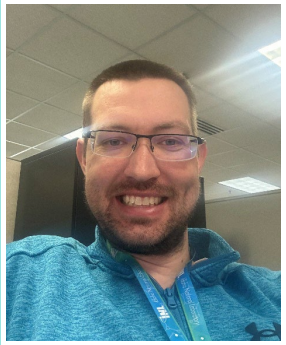
Overview

- Purpose/objective – Provide users with characterization equipment, infrastructure, and technical staff necessary to produce critical data needed to design, demonstrate, license, and operate an MSR.
  - Provide reliable data sets on properties including viscosity, density, heat capacity, thermal conductivity, melt temperature, vapor pressure, redox chemistry, and salt purification methods
  - Offers versatile space for users to setup one-of-a-kind experiments and to perform small-scale exotic salt fabrication



MSTEC Project Overview

Core INL Team Members



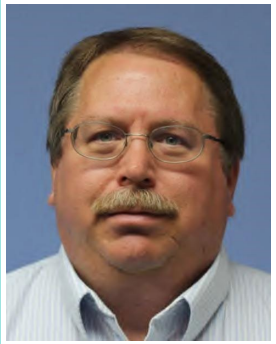
Carson Stronks
Lead PM

Stephen Warmann
PM

Toni Karlsson
Lead Scientist

Adam Butikofer
Lead Design Eng.

Dale Whalquist
Design Eng.



Mark Borland
Glovebox SME

Evan Lovel
Lead Electrical Eng.

Barbara Houck
Lead Nuc. Safety

Numerous other individuals contribute to the success of MSTEC

Subcontracts

- Applied Engineering Services – Engineering support design, construction, ventilation
- DR & Sons Construction – Phase II MSTEC Installation
- Extract Technologies (Walker Barrier) – Glovebox and shielding (complete)
- Wälischmiller Engineering GMBH – Manipulators (complete)
- Amentum – Nuclear safety (complete)
- C&H Construction – Phase I Construction - D&D and Facility Modifications (complete)

Milestones for FY24

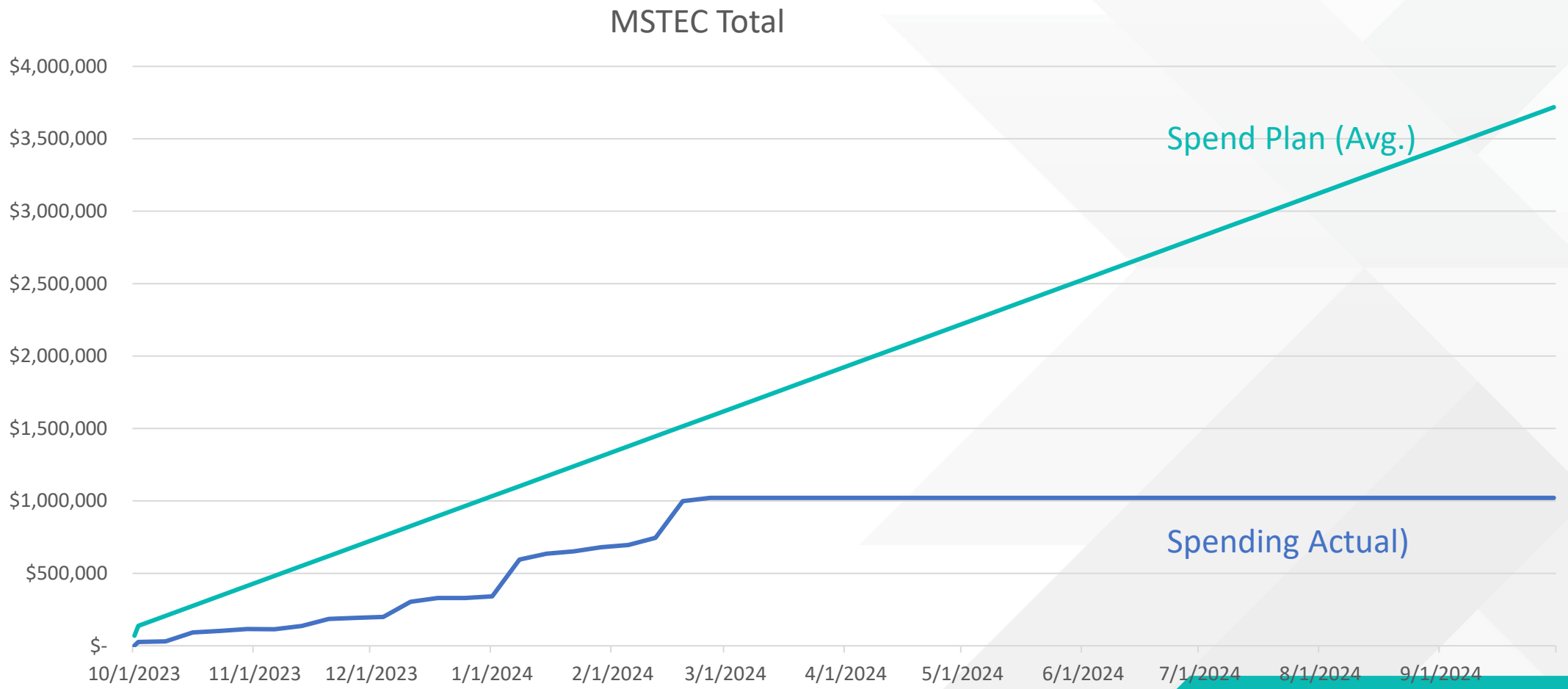
- M2, Milestone memo documenting in person support of the factory acceptance test in Wisconsin, 03/01/2024 (complete)
- M2, Milestone memo documenting beginning of instrument installation, 09/30/2024 (on schedule)
- M2, Milestone memo documenting initiation of acceptance testing of the newly installed MSTEC at FCF, 09/30/2024 (on schedule)

Funding Summary

- All major equipment procurements complete, except final milestone payment of shielded cell itself
  - $49k increase due to steel prices, accounted for in contingency
  - No other major cost increase
- Risks: Unfinished decontamination of room, construction in legacy nuclear facility, Safety Analysis Report (SAR) review pending, Structural upgrades
  - All Mitigated!

Year	Total Funding
2020	$ 1,782,072
2021	$ 3,033,919
2022	$ 3,475,481
2023	$ 2,496,810
2024	$ 3,928,171
2025	$ 900,000
Total	$ 15,616,453

FY24 Spending



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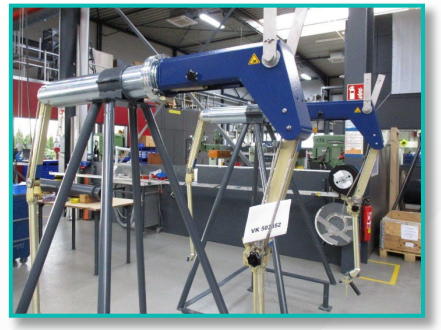
Accomplishments



FY20

- Kickoff, May 1st 2020
- Assembled a team of diverse and uniquely skilled people
- Procured characterization equipment
- Completed the design requirements for MSTEC
- Finished numerous INL engineering documents (source term and shielding calcs, floor loading analyses, south wall removal analysis, ventilation evaluation, installation logistics evaluation, etc.)

FY21

- Instrumentation
  - Integrated feedthroughs (cooling, electrical, gas) in interim glovebox
  - Setup rheometer, TMA, DSC, pycnometer, densitometer
  - Initiated testing equipment in non-rad lab
- Engineering
  - Held several design reviews for MSTEC (>40 people), finalized conceptual design
  - Issued manipulator and hot cell PO's
  - Put out to bid the RFP for construction work for FCF facility mods
- Nuclear Safety
  - Finalized major mod determination
  - Finalized Hazards Evaluation and accident scenarios
  - Reviewed safety design strategy (SDS)

FY22

- Instrumentation
  - Procedure development and demonstration of equipment on non-rad salts
  - Finalized electrical and feed through drawings
  - Finalized modifications needed for hot cell use
  - Developed a Concept of Operations
- Engineering
  - 100% design review with Walker Barrier
  - Engineering design review at INL
  - FAT test for manipulators
  - Decontamination & Initiate D&D of the sodium washroom
- Nuclear Safety
  - Finalize draft revision of SAR-403
  - Submitted and addressed comments from ISRC
  - Drafted DOE-ID submittal letter

Accomplishments

FY23

- Instrumentation
  - Setup and demonstrating well furnace and STA-skimmer
  - Developing MSTEC training and operator qualification plan
  - Writing glovebox and instrumentation operating procedures
- Nuclear Safety
  - SAR submitted to DOE-ID
  - INL Nuclear Safety address comments
  - Awaiting DOE approval of comment resolutions

- Engineering
  - Phase I construction complete in FCF
  - Structural inspections complete confirming no major structural upgrades (major risk mitigation)
  - Removal of south wall
  - Demo work complete
  - Roll-up door installed, outer wall extended, painted, crane removed, Ar lines routed, lighting upgraded
  - Walker Barrier major procurements and fabrication complete
  - Steel shield wall section fabrication, manipulator, and shielded glass fitting complete
  - Phase 2 construction contract for MSTEC installation awarded to DR Sons Construction

Accomplishments

FY24

- **Characterization**
  - Ensured operations of instruments on non-rad standard materials
  - Prepared equipment for transfer to MSTEC
  - Developed training plans and user qualifications
  - Developed operating procedures for glovebox and equipment
- **Engineering**
  - Received glovebox and all auxiliary equipment at INL, 82 tons
  - Repaired Crane
  - Installed MSTEC shielding
  - Installed mezzanine
  - Installed manipulators
- **Nuclear Safety**
  - Continue to work with DOE on SAR/TSR revision

Remaining Activities

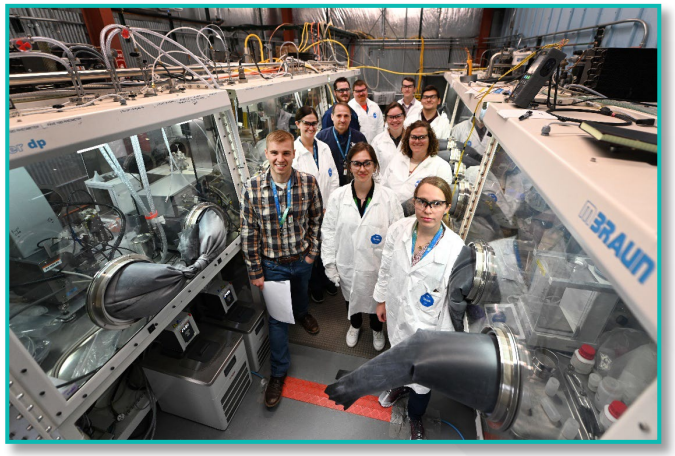
- Major activities remaining
  - FY24
    - DOE review/approval of SAR/TSR revision
    - Construction contract, Phase II, MSTEC installation
    - Installation of characterization equipment into MSTEC
  - FY25
    - FCF SAR/TSR implementation
    - MSTEC management self assessment
    - MSTEC contractor readiness assessment
    - MSTEC DOE readiness assessment and final commissioning

Securing future MSTEC work

Agreement	Description	Contract Value Related to Thermophysical Properties of MSR Fuel Salts
SPP with Seaborg Technologies of Denmark	5-year agreement to study thermophysical properties of unirradiated molten salt, irradiate molten salt in NRAD core, and measure thermophysical properties of irradiated salt in MSTEC.	$2,500,000
CRADA with Korean Atomic Energy Research Institute	5-year agreement to study thermophysical properties of unirradiated molten salt, irradiate molten salt in NRAD core, and measure thermophysical properties of irradiated salt in MSTEC.	$1,000,000
MCRE ARDP	2-year effort to measure thermophysical properties of unirradiated fuel salt.	~$1,500,000
MRTI Molten Salt Irradiation	3-year LDRD to irradiate molten salt fuel in the NRAD core and subsequent thermophysical property measurements on the irradiated salt. Serves as basis for KAERI and Seaborg irradiations.	$2,000,000
DOE MSR Campaign	Recurring annual scope to study thermophysical properties of plutonium-bearing MSR fuel salts.	$500,000
Safeguard & Nonproliferation Workshop	Meeting to gather the SMEs on molten salts from all DOE labs to discuss MSTEC utilization plans for Safeguarding and proliferation deterrence	$65,000
INL Internal Investment (NSUF)	Indirect funds provided to continue to mature INL scientist capability in measuring thermophysical properties of molten salts.	0.20 FTE
Total		**$7,600,000**

We would like to see this grow!

MSTEC Needs



Talent Pipeline and Scientist Development

- MSTEC thus far is a physical capability
- To be fully utilized, MSTEC needs to develop the human capability
  - Researcher
  - Instrument Scientists
  - Operators

Spreading the Word!

- We need your help!
  - Conferences & Publication (need funding)
  - Integration with other DOE campaigns, safeguards, industry
  - Making industry aware of the capabilities

Questions?

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www.nric.inl.gov

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METL

Mechanisms Engineering Test Loop Operations, Testing, Maintenance, and Improvements (O&M)

Christopher Grandy
Deputy Director, Nuclear Science and Engineering Division
Argonne National Laboratory

04/23/2024

METL O&M Project Overview (1/2)

- This work provide the necessary funding to operate and maintain the Mechanism Engineering Test Loop facility and supporting infrastructure located at Argonne National Laboratory
  - NRIC provides funding for METL O&M (+Improvements and testing support) - starting around April 2022.
  - Prior to April 2022 – this work was funded by DOE's Advanced Reactor Technologies (ART) program
- Personnel working on METL O&M
  - Derek Kultgen – Manager of the METL Facility
  - Teddy Kent – METL Operations Engineer
  - Jordan Rein – METL Operations Engineer
  - Matt Weathered – METL Operations Engineer
  - Alex Grannan – METL Operations Engineer
  - Evan Ogren – METL Operations Engineer
  - One plus technician
  - Other support personnel from various organizations on site

METL O&M Project Overview (2/2)

- *ART-FRP Program Objective - Develop advanced fast reactor technology solutions to allow commercial deployment*

1. Train next generation engineers and scientists by engaging them in advanced reactor concept design and analysis and fundamental studies that support fast reactor R&D
2. Design and develop scalable advanced technologies for reducing the cost and/or increasing the performance of fast reactor technology
   - Cost reduction
   - Improve safety performance
   - Increase system reliability
3. Preserve and manage data, knowledge, and experience related to past U.S. DOE fast reactor design, operations, tests, and component technology.
4. Re-establish the U.S. infrastructure to support the testing of advanced technologies for fast reactor applications.
5. Collaborate internationally on advanced reactor R&D through bilateral or multilateral agreements
   - Utilize international collaborations to leverage and expand R&D investments

- METL supports all of these Program Objectives
- METL also supports the NRIC Mission to support the deployment of advanced reactors

METL Facility Purpose - Re-establish U.S. infrastructure

To test small or intermediate scale advanced liquid metal components and instrumentation in sodium for the future of advanced fast reactor system development

To develop and provide performance data on systems and components used in sodium and reduce the risk of failures during reactor plant operations

Will provide needed U.S. infrastructure (both personnel and hardware) to test liquid metal systems and components

This work supports our international collaborations

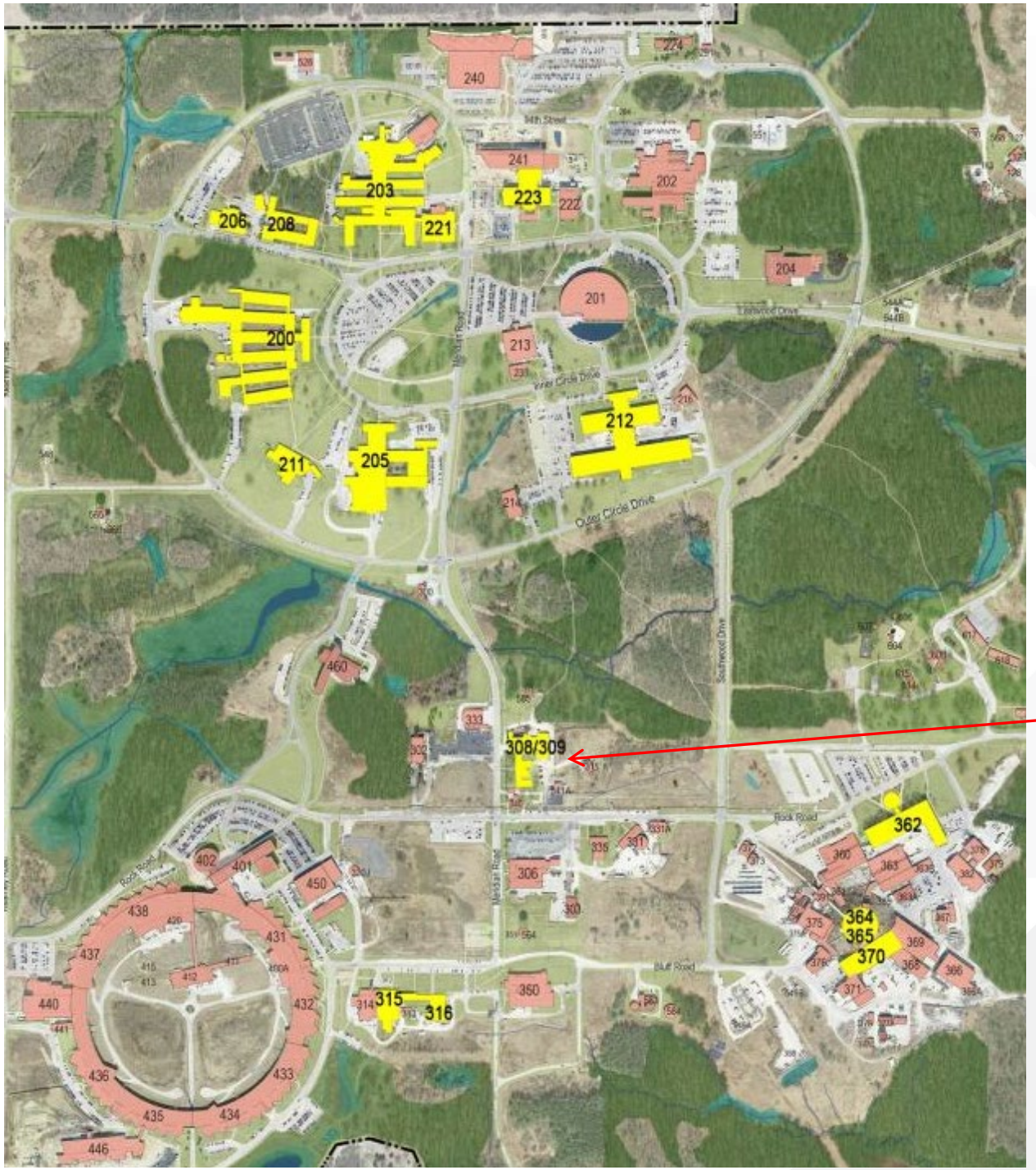
The U.S. lacks this testing infrastructure

https://www.etec.energy.gov/

METL

- Located in B308
- Large highbay structure
- Historically used for liquid metal technology development
- Currently houses
- METL
- NSTF
- USV/TAS/H_2

APS



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METL is located in B308 Highbay

- B308 is protected by an alkali metal passivation booth
- Permitted for alkali metal treatment
  - 300 lbs/hr – normal
  - 600 lbs/hr in emergency
- 30,000 scfm scrubber blower
- Can treat all alkali metals via burning and reaction
- Facility is unique in the DOE and U.S. complex
- B206 is also protected by an alkali metal passivation booth

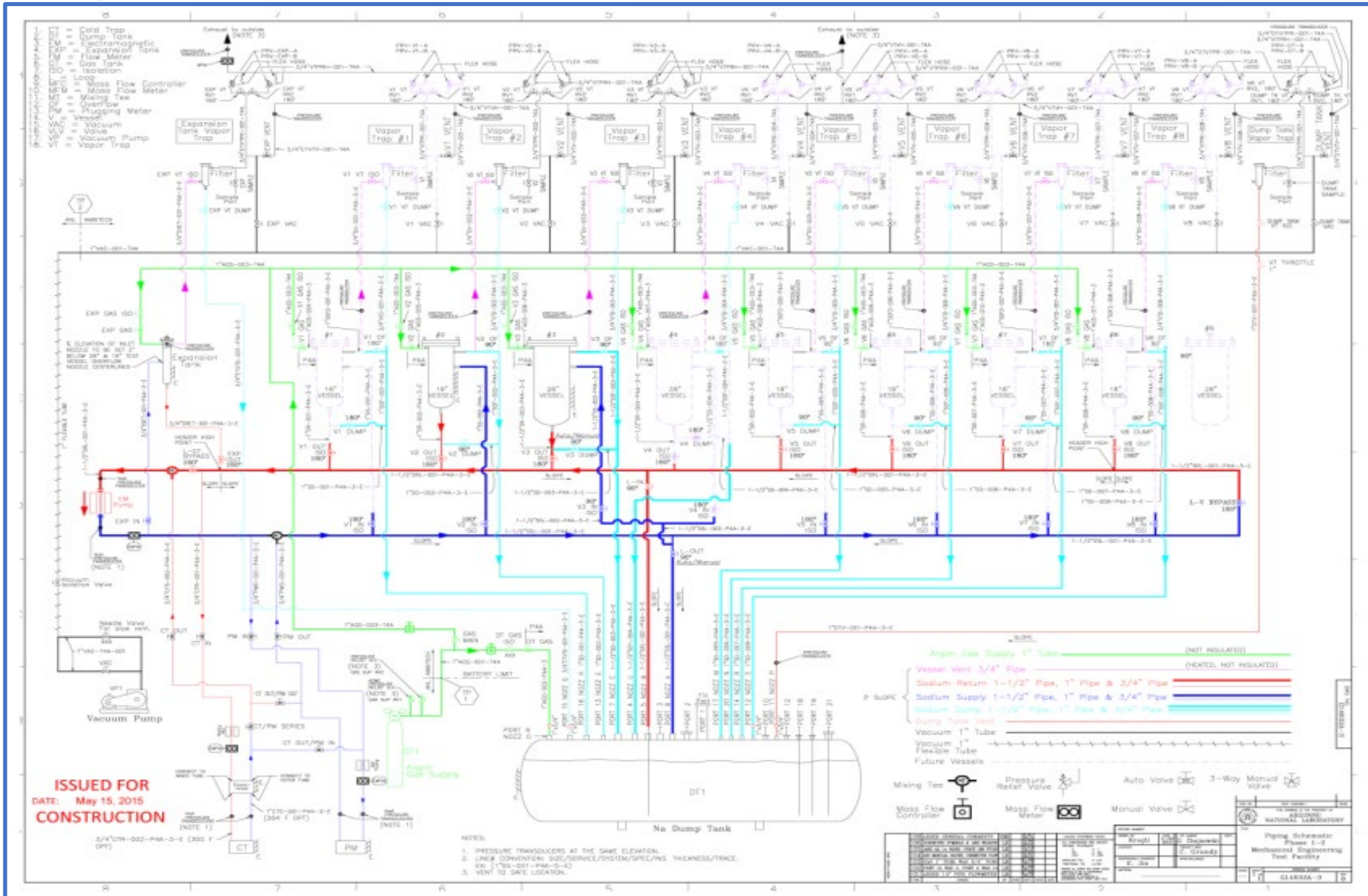
Mechanisms Engineering Test Loop (METL)

- **To test small or intermediate scale advanced liquid metal components and instrumentation in sodium (e.g.):**
  - Gear Test Assembly for Compact Refueling Machine
  - Sodium Level sensor technology
  - Thermal-Hydraulic Experimental Test Article (THETA)
  - Gripper Device for Compact refueling machine
- **METL consists of:**
  - ~3,000 kg of reactor-grade sodium – purified via cold trap
  - Two 18-inch test vessels and two 28-inch test vessels (Phase I)
  - Max system temperature = 1000°F (except for 28-inch test vessels – 1200°F)
  - Test vessels can be isolated from main loop
- **Provides much needed U.S. infrastructure (both personnel and hardware) to test liquid metal systems and components**

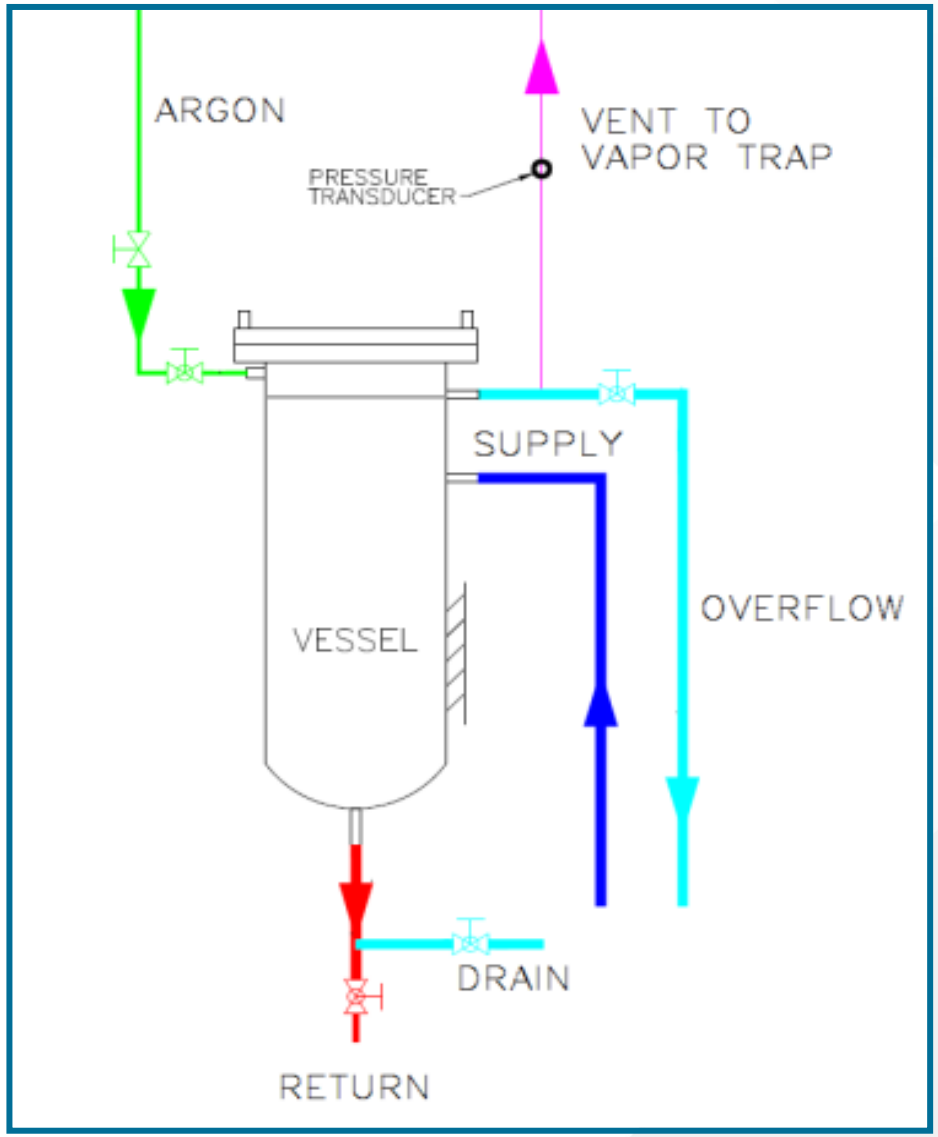
METL Systems and Components

- METL consists of:
  - Four Test Vessels (18 and 28 inch)
  - Dump Tank
  - Expansion Tank
  - Purification System (cold trap)
  - Plugging meter
  - Vapor trap
  - Inert gas system
  - Valves
  - Connected piping system
  - Mezzanine
  - Catchpan
  - R-grade sodium
  - Heat Tracing
  - Heater and Valve control cabinets
  - Instrumentation and Control
- METL Auxiliary and supporting Infrastructure and systems

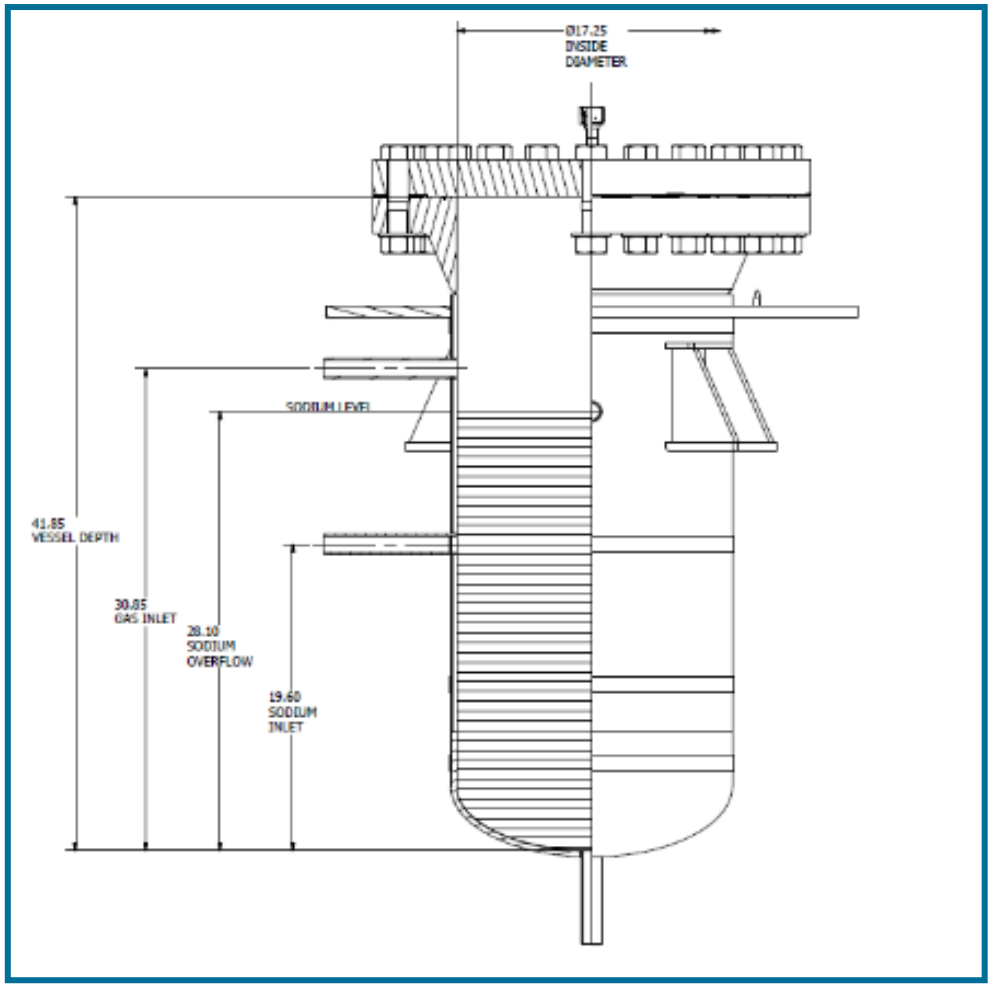
METL P&ID


ISSUED FOR
DATE: May 15, 2015
CONSTRUCTION
Vacuum Pump
Na Dump Tank
Argon Gas Supply 1" Tube
Vessel Vent 3/4" Pipe
Sodium Return 1-1/2" Pipe, 1" Pipe & 3/4" Pipe
Sodium Supply 1-1/2" Pipe, 1" Pipe & 3/4" Pipe
Vacuum 1" Tube
Vacuum 1" Flexible Tube
Future Vessels
Mixing Tee
Pressure Relief Valve
Auto Valve
3-Way Manual Valve
Mass Flow Controller
Mass Flow Meter
Manual Valve

METL Test Vessel – generic flow

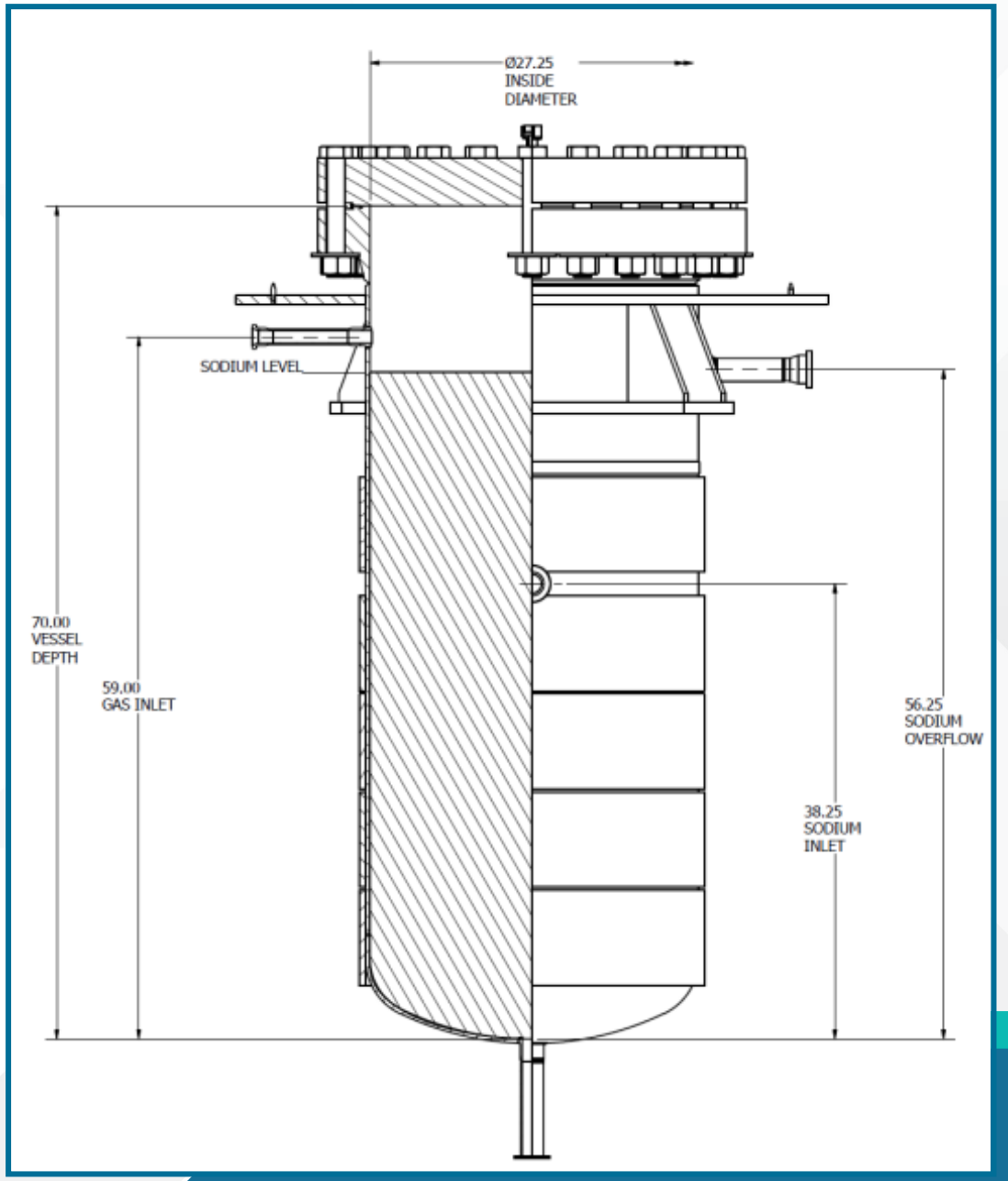


18-inch vessel + 28-inch vessel

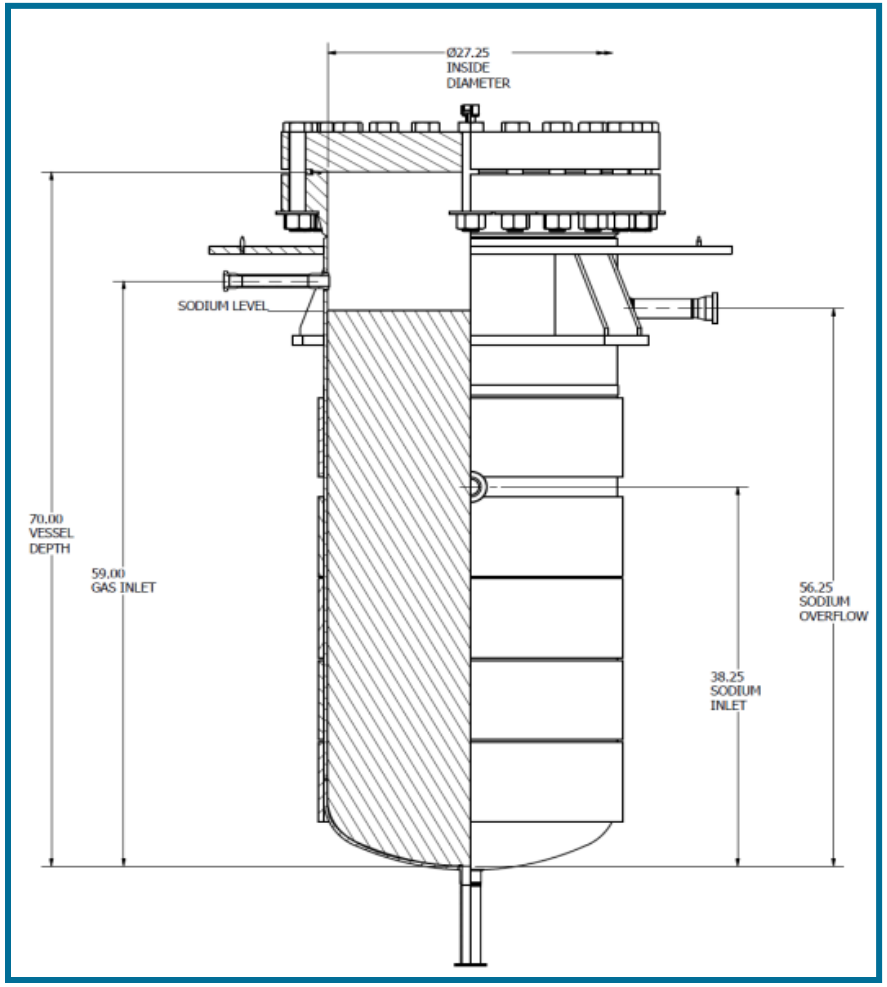


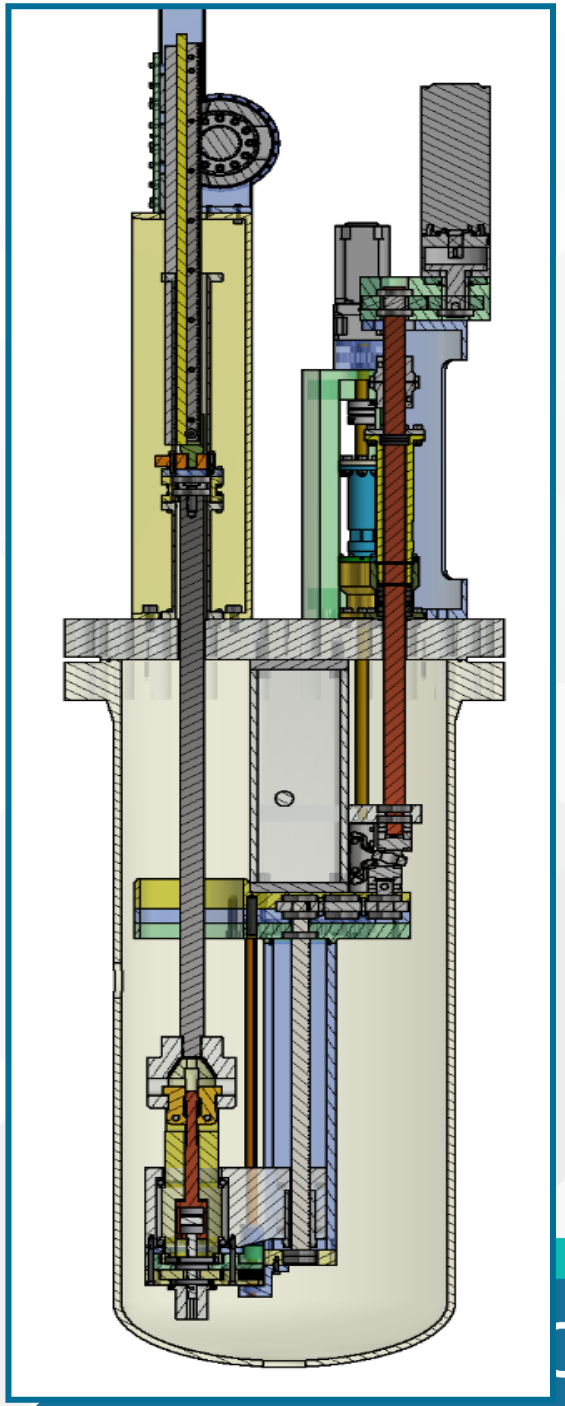
18-inch vessel - ~50 gallons

28-inch vessel - ~150 gallons



28-inch test vessel experiment – example





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METL Virtual Tour and Web Site

Virtual tour of METL

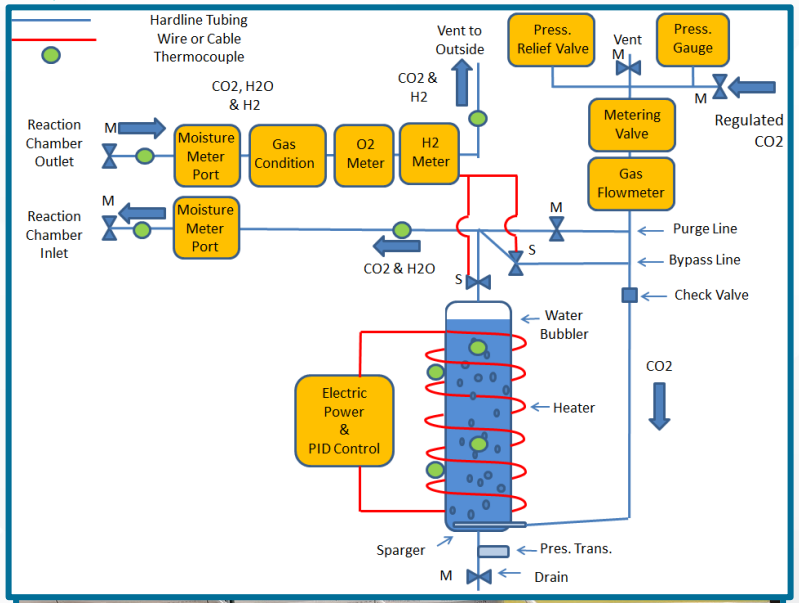
https://youtu.be/W4tfBd8rZ68

METL web site:

https://www.anl.gov/nse/METL

METL O&M Project Progress (1/6)

- What is the full cost and schedule of the project?
  - METL has a corrosion design life of 30 years
  - Requested funding of ~$3.5M/ year
- METL O&M project work scope includes (e.g.)
  - Operating, maintaining, and improving METL
  - Operating, maintaining, and improving the supporting infrastructure for METL
  - Periodic circulation and purification of sodium in METL
  - Qualification and coordination of experiment installation, removal, and cleaning in METL infrastructure
  - Qualification of the 28-inch flexicask system
  - International collaborations under Gen-IV – CDBOP under the technical area of testing facilities
  - Increasing the mezzanine space for METL
  - Adding additional test vessels and support systems



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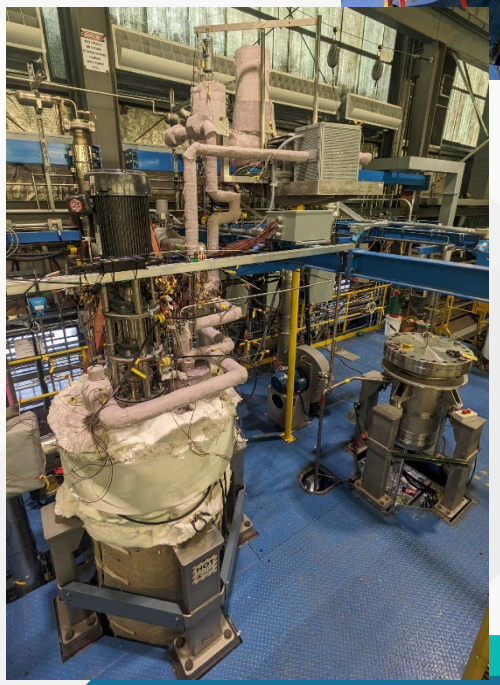
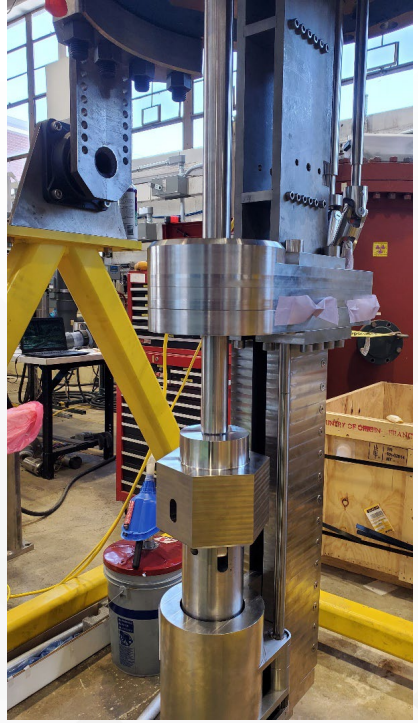
METL O&M Project Progress (2/6)

- Accomplishments for FY23/24
  - METL was successfully operated continuously from September 19, 2018
    - About 5.5 years
    - METL was drained on April 20, 2021 and then frozen to effect modifications to the B308 scrubber unit – first time for drain and freeze
  - METL is maintained in a hot molten state 24 hours a day, seven days a week. Team brought METL out of a cold and frozen state for the very first time (FY22)
  - The METL team maintained purification of the sodium via cold trapping down to 5pmm oxygen.
  - METL supported the installation and testing of two test articles – GTA (test #6 and #7) and THETA
  - METL supported the cleaning of the GTA and THETA using the carbonation system
    - THETA removal was first time we cleaned a 28-inch test article
  - Assembled and qualified the 28-inch flexicask system for removal and insertion of 28-inch test articles – modifications were made to the sliding gates
  - An off-the-shelf structural health monitoring system was installed on Test Vessel 6 piping

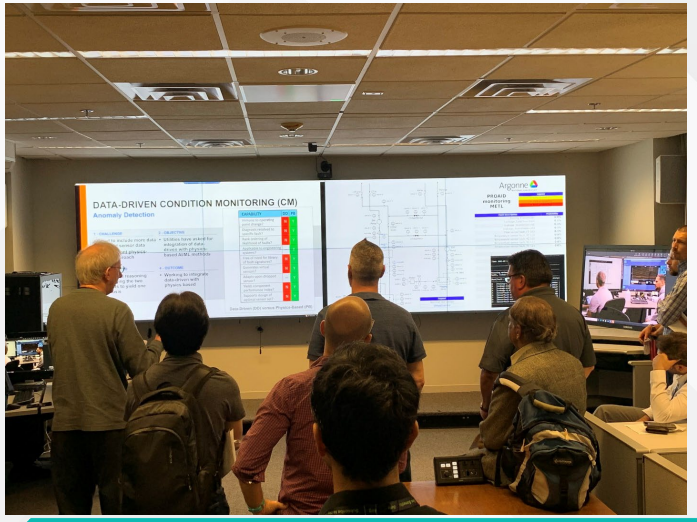


METL O&M Project Progress (3/6)

- Accomplishments for FY23/24
  - We are in the process of installing another 18-inch vessel (Test Vessel 6) – most of piping is installed, awaiting final segments to connect to the dump tank
    - Awaiting welders completion of SMT-3
  - METL Experimenters Guide was published
  - Operate and Maintain METL to support testing
    - GTA testing – related to milestone – M3AT-23AN0502011 / M3AT-24AN0502012
    - THETA testing – related to milestone – M2AT-23AN0502012 / M2AT-24AN0502011
    - Installation of piping health monitoring system – M4AT-23AN0502015
  - Making preparations for GrTA and F-STAr testing
  - We are also making preparations for our first Industry test article
  - Provided support to ASI program for a diagnostic Software demonstration program
    - METL provides a unique facility for demonstrating diagnostic and prognostic software



Gripper Test Article



METL Prognostic Demonstration

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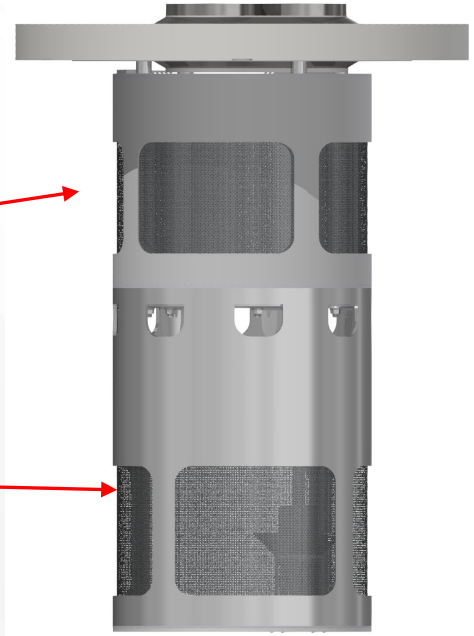
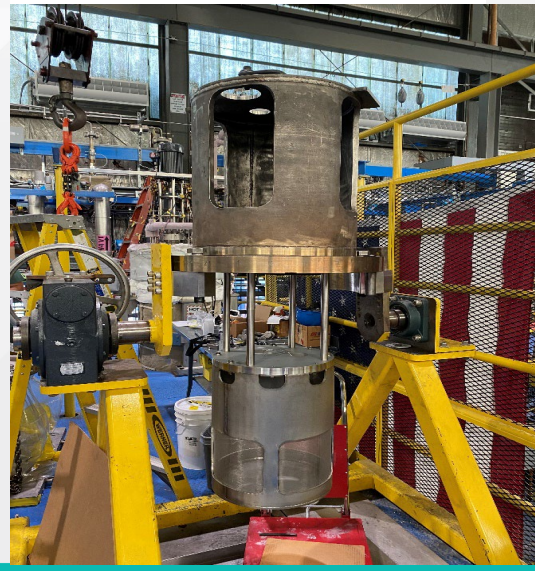
METL O&M Project Progress (4/6)

- METL Sample basket is composed of two parts
  - Upper vapor basket
  - Lower sample basket



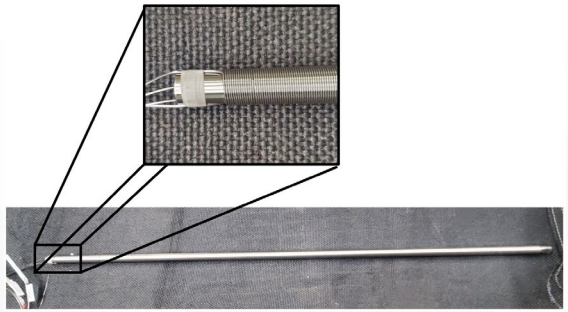
- The METL sample basket is designed to be installed in one of the METL 18-inch test vessels



- 18-inch test vessel max temperature – 1000F = 538C

METL O&M Project Progress (5/6)

- FY23/24 Milestones
  - M3RC-23AN0206023 – Completed Report of METL Inductive Level Probe Development – March 1, 2023
  - M2RC-23AN0206024 – Completed Business Plan in NRIC User Guide Template – March 31, 2023 – Completed in July 2023
  - M2RC-23AN0206022 – Completed Mechanisms Engineering Test Loop Facility Annual Operations and Testing report – September 28, 2023
  - M2RC-24AN0206011 – Complete Installation of Test Vessel 6 – June 30, 2024
  - M2RC-24AN0206012 – Complete Mechanisms Engineering Test Loop Facility Annual Operations and Testing report – September 15, 2024



Inductive Level Sensor

Test Vessel 6

METL O&M Project Progress (6/6)

- METL funding FY24
  - NRIC program - $2.5M in new FY24 funding (at low target)
- METL outyear funding
  - Request is $3.5M/year
- What are the risks?
  - Some upset to the METL facility
    - We have an active CMMS and perform routine maintenance and purification on METL, but old scrubber has required some attention in FY21, 22, and 23 to repair piping and replace parts.
    - We will need to replace the cold trap at the not too distant future!! This cold trap replacement process will take METL down for 2-3 months.
  - Stability of funding
    - We carryover sufficient funds due to CR
  - Cost inflation of components
    - We do have some spare parts on hand

Additional Funding?

- Additional Loop
  - We have removed an old test loop adjacent to the METL facility – called the steam generator test facility
  - Would design a larger and taller test facility for the testing of tall test articles and thermal-hydraulic systems

METL Collaborations with NEUP

Fiscal Year Funding	Project FY-ID	Title	Organization	PI First Name	PI Last Name
2018	18-14908	Experimental measurements of fission product retention in liquid sodium	University of Wisconsin-Madison	Mark	Anderson
2018	18-15471	Integral Experimental Investigation of Radioisotope Retention in Flowing Lead for the Mechanistic Source Term Evaluation of LFR	University of New Mexico	Osman	Anderoglu
2019	19-16754	Simultaneous Corrosion/Irradiation Testing in Lead and Lead-Bismuth Eutectic: The Radiation Decelerated Corrosion Hypothesis	Massachusetts Institute of Technology	Michael	Short
2019	19-16811	Liquid metal-cooled fast reactor instrumentation technology development	University of Wisconsin-Madison	Mark	Anderson
2019	19-17355	Development of Versatile Liquid Metal Testing Facility for Lead-cooled Fast Reactor Technology	University of Pittsburgh	Jung-Kun	Lee
2020	20-19524	Non-Intrusive Flow Monitoring for Liquid Metal and Molten Salt-Cooled Reactors	Virginia Polytechnic Institue and State University	Gary	Pickrell
2021	21-24162	Self-powered wireless sensor system for health monitoring of liquid-sodium cooled fast reactors	University of Notre Dame	Yanliang	Zhang
2021	21-24389	High Temperature Electromagnetic Acoustic (EMAT) Transducers for Structural Health Monitoring	University of Cincinnati	Joseph	Corcoran
2022	22-27082	Dual Mode High Temperature MEMS Ultrasonic Sensor for Structural Health Monitoring of Liquid Metal Reactor	University of Illinois at Chicago	Didem	Ozevin
2022	22-26857	Characterizing Fast Reactor Failure Mode through Separate Effect and Prototypic Tests	Oregon State University	Guillaume	Mignot
2023	23-2903	Optical Sensors for Impurity Measurement in LMFRs (IC-1 Program)	University of Michigan	Milos	Burger

EMAT Sensor installed on Test Vessel 1

Collaborations with Industry

- We have an SBIR call for mechanical bearings for sodium applications
  - We are working with a couple vendors who have received SBIR funding or who are in process of applying for SBIR funding
- We have a GAIN award with OKLO for the testing at the THETA test article which is located in METL Test Vessel 4
  - THETA supports the validation of OKLO and Argonne TH codes
- We have a pending CRADA with another company to test multiple test articles in METL
- In discussions with a company to perform experiments in METL

METL O&M Summary

- METL has been in an operational status since September 2018
  - About 5 month pause in operations in FY21
  - Operational about 5.5 years
- It provides the infrastructure and capability of testing multiple test articles in a prototypic sodium environment
- It is the largest facility of its kind in the DOE complex
- It is supporting DOE R&D, NEUP and SBIR awardees, and industrial vendors (contracts in progress)

Thank you!

Questions?
Time Permitting

Contact: Cgrandy@anl.gov

Visit: https://www.anl.gov/nse/mechanisms-engineering-test-loop-facility

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HFEF-15 Cask Modifications

Enabling the Large Experiment Capability at TREAT

Greg Core, TPM/WPM
Jeanie Hernandez, INL Project Manager
James Angell, INL System/Project Engineer

April 23, 2024

HFEF-15 Cask Upgrade Project Overview

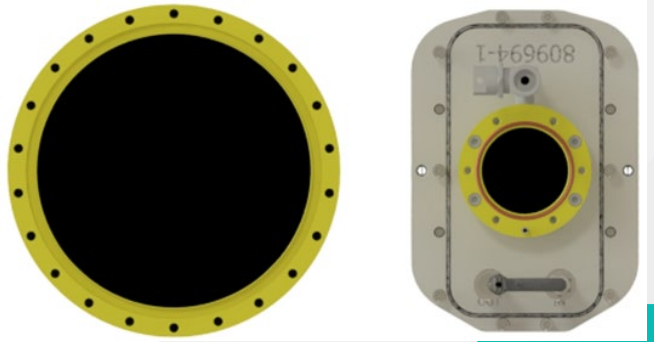
- **Technical Description** – Upgrading the HFEF-15 shipping cask to allow larger format experiments includes designing, fabricating, and installing new components, updating procedures, and performing an INL-internal informal readiness assessment.
- **Location** – INL: Materials and Fuels Complex (TREAT & HFEF)

Benefits to the Mission

"inspire stakeholders and the public, **empower innovators**, and deliver successful outcomes through efficient coordination of partners and resources"

Larger format experiments will enable no less than five unique testing vehicles supporting sodium fast reactor, microreactor, molten salt reactor, and advanced light water reactor technology

Comparison of existing (right) and LEC-enabled diameter available for experimentation



HFEF-15 within the Large Experiment Capability

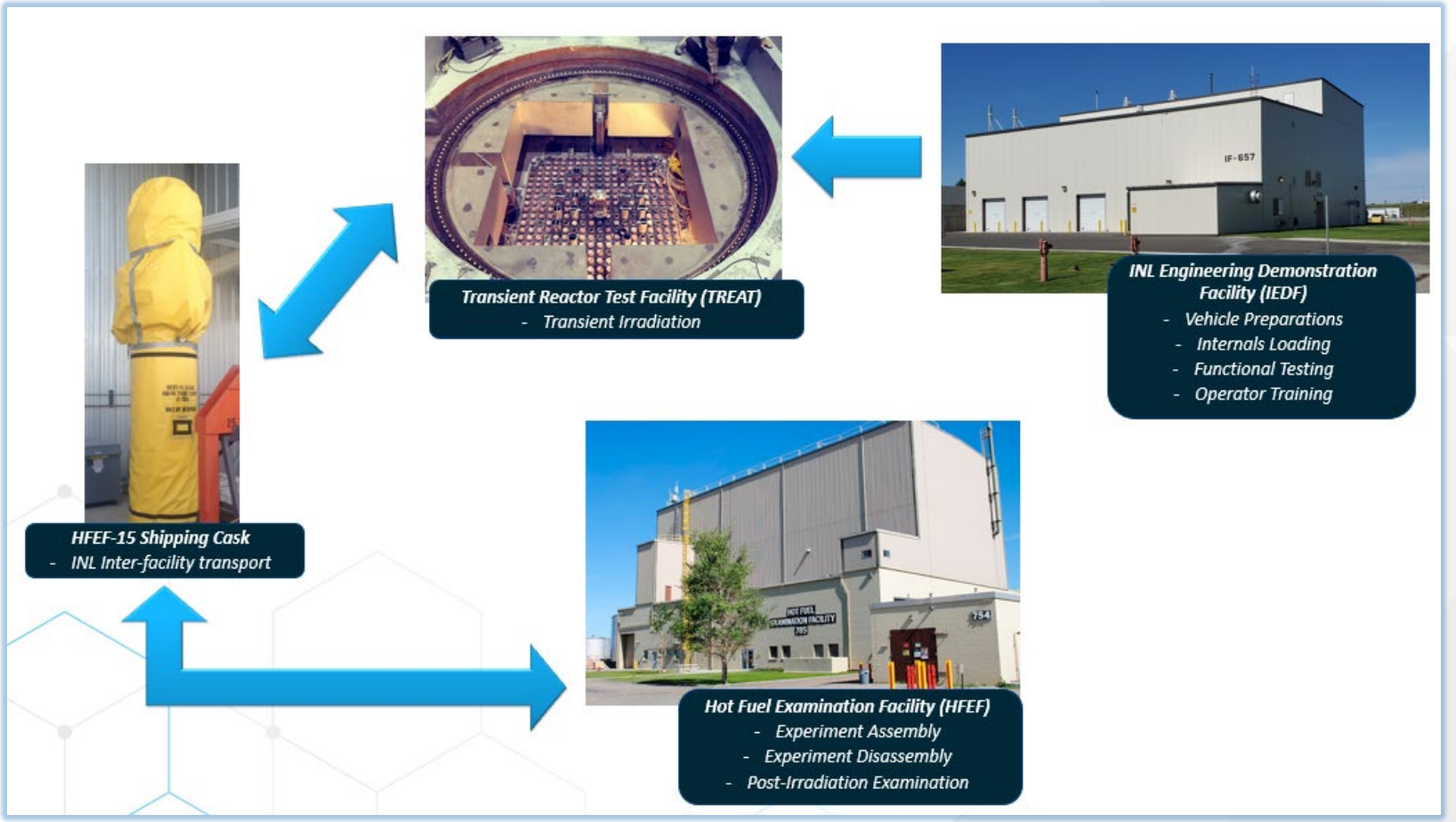
The TREAT Large Experiment Capability (LEC) involves inter and intra-facility infrastructure to support larger format experiments, expanding the capabilities of transient testing to prototypic mechanical and thermal-hydraulic conditions.

- **Core Upgrades** - Specially-designed moderator assemblies that accommodate large format experiment vehicles
- **Cask Modifications** - Changes to existing casks that allow efficient and safe transfer of experiments inside and between INL facilities
- **Hot Cell Upgrades** - Various systems and equipment enabling post-irradiation examination and loading of pre-irradiated specimens
- **Non-nuclear Support** - Systems providing operator training, vehicle preparations and check-out testing, and instrument testing

Supported Environments

- *Flowing Liquid Sodium (Mk-IIIR NLC)*
- *Flowing Hydrogen (SIRIUS-4 +)*
- *Flowing Water (TWERL)*
- *Water LOCA Blowdown (TWIST)*
- *Microreactor System Scale (NIMBLE)*

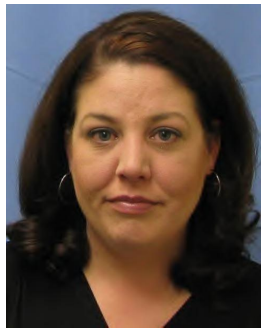
Concept of Operations



HFEF-15 Cask Project Overview (2)

Core INL Team Members

Greg Core
NRIC TPOC/TPM



Jeanie Hernandez
Project Manager

James Angell
Lead Design Engineer

16-month duration // $2M funding provided in FY 23

- APR. 2023: Project Started
- SEP. 2023: Draft Drawings Completed
- FEB. 2024: Procurements Issued
- JUL. 2024: Fabrications Complete
- MAY 2024: Installations Begin
- JUL. 2024: Readiness Reviews Complete
- JUL. 2024: Project Complete

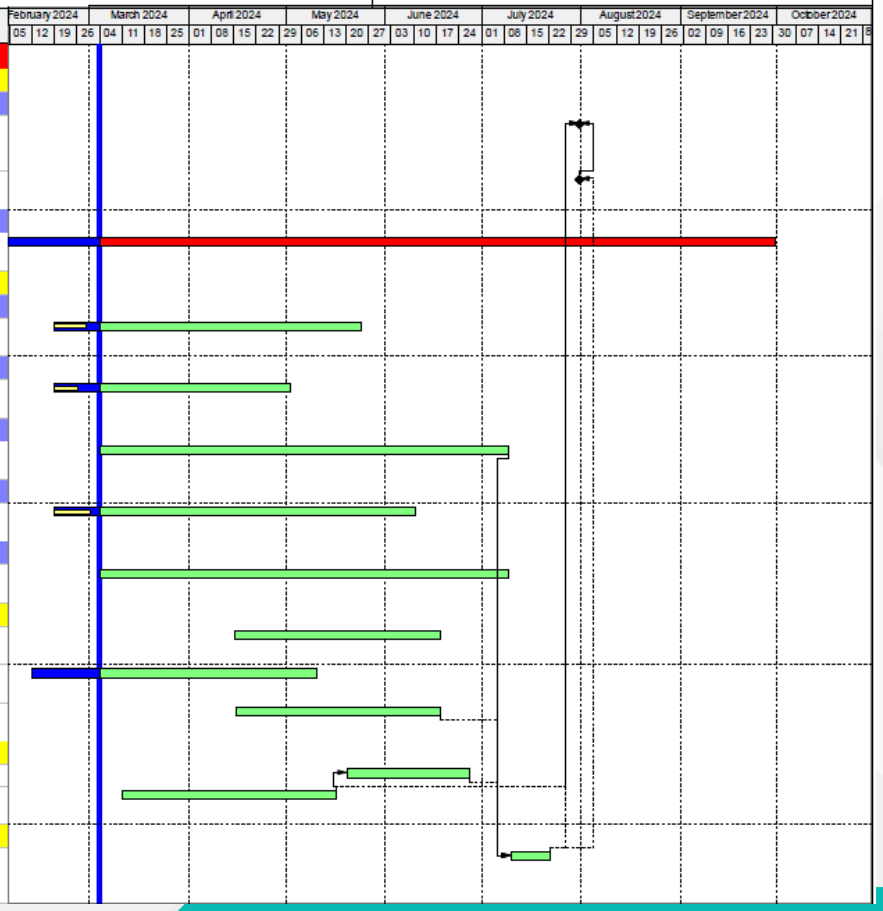
HFEF-15 Cask Project Schedule and Critical Path

TREAT - Weekly Update

HFEF-15 Cask Upgrade - Supporting Infrastructure to Support TREAT NLC

04-Mar-24 11:20

#	ACTIVITY ID	ACTIVITY DESCRIPTION	NST-KEY EVENT	ACTIVITY LEAD	PERFORMER	OD	RD	TOTAL FLOAT	% COMP	SCHEDULED START	SCHEDULED FINISH	PREDECESSORS	SUCCESSORS	Doc#
1	HFEF15CU-P	HFEF-15 Cask Upgrade - Supporting Infrastructure to Support TREAT NLC				483d	131d	0d		16-Jan-23 A	30-Sep-24			
2	HFEF15CU-P.01	Project Management				483d	131d	0d		16-Jan-23 A	30-Sep-24			
3	HFEF15CU-P.01.01	Project Milestones				0d	0d	37d		31-Jul-24	31-Jul-24			
4	HFEF15-10	HFEF15 - Project Complete				0d	0d	37d	0%		31-Jul-24	HFEF15-65, HFEF15-95, HFEF15-MS10		
5	HFEF15-MS10	HFEF15 - M2- Complete Readiness for HFEF-15 Cask Modifications (07.31.24)				0d	0d	0d	0%		31-Jul-24*	HFEF15-65	HFEF15-10, NATNaL-3090	
6	HFEF15CU-P.01.02	Coordination and Management				483d	131d	0d		16-Jan-23 A	30-Sep-24			
7	HFEF15-70	HFEF15 - Project Management Support				483d	131d	0d	60%	16-Jan-23 A	30-Sep-24	HFEF15-05		
8	HFEF15CU-P.03	Procurement				89d	80d	51d		19-Feb-24 A	09-Jul-24			
9	HFEF15CU-P.03.1	New Top Ring and Shield Ring				62d	53d	78d		19-Feb-24 A	24-May-24			
10	HFEF15-25	HFEF15 - Order Materials and Fabricate New Top Ring and Shield Ring				62d	53d	78d	10%	19-Feb-24 A	24-May-24	HFEF15-20	HFEF15-85	
11	HFEF15CU-P.03.2	Security Cans				48d	40d	92d		19-Feb-24 A	02-May-24			
12	HFEF15-50	HFEF15 - Procure Fabrication Services to Fabricate Security Cans				48d	40d	92d	10%	19-Feb-24 A	02-May-24	HFEF15-45		
13	HFEF15CU-P.03.3	New Interface Ring				80d	80d	6d		04-Mar-24	09-Jul-24			
14	HFEF15-80	HFEF15 - Complete redline drawings and modify Interface Ring at TREAT				80d	80d	6d	0%	04-Mar-24*	09-Jul-24	HFEF15-75	HFEF15-65	
15	HFEF15CU-P.03.4	New Top Hat Spacer				62d	62d	69d		19-Feb-24 A	10-Jun-24			
16	HFEF15-90	HFEF15 - Order Materials and Fabricate New Top Hat Spacer				62d	62d	69d	10%	19-Feb-24 A	10-Jun-24	HFEF15-85		
17	HFEF15CU-P.03.5	J-Hook Spreader Bar				80d	80d	51d		04-Mar-24	09-Jul-24			
18	HFEF15-105	HFEF15 - J-Hook Spreader Bar Procurement and Stand Fabrication				80d	80d	51d	0%	04-Mar-24*	09-Jul-24			
19	HFEF15CU-P.04	Update Procedures at HFEF and TREAT for HFEF-15 Modified Cask Operations				80d	67d	64d		12-Feb-24 A	18-Jun-24			
20	HFEF15-30	HFEF15 - Update Procedures at HFEF and TREAT for HFEF-15 Cask Modifications				40d	40d	65d	0%	15-Apr-24*	18-Jun-24			
21	HFEF15-37	HFEF15 -Perform and Archive Drop Analysis				58d	44d	87d	0%	12-Feb-24 A	10-May-24			
22	HFEF15-55	HFEF15 - Update Procedures at HFEF and TREAT for Security Cans				40d	40d	19d	0%	15-Apr-24*	18-Jun-24		HFEF15-65	
23	HFEF15CU-P.05	Perform Work - Modification				69d	69d	13d		11-Mar-24	27-Jun-24			
24	HFEF15-35	HFEF15 - Install New Top Ring & security Cans				25d	25d	13d	0%	20-May-24	27-Jun-24	HFEF15-95	HFEF15-65	
25	HFEF15-95	HFEF15 - Remove existing Top Ring & security Cans				44d	44d	13d	0%	11-Mar-24*	16-May-24		HFEF15-10, HFEF15-35	
26	HFEF15CU-P.06	Complete Readiness for HFEF-15 Cask Modifications				8d	8d	6d		10-Jul-24	22-Jul-24			
27	HFEF15-65	HFEF15 - Complete Readiness for HFEF-15 Cask Modifications				8d	8d	6d	0%	10-Jul-24	22-Jul-24	HFEF15-35, HFEF15-55, HFEF15-80	HFEF15-10, HFEF15-MS10	



Currently cask interface ring represents the critical path with two weeks of total float to M2 final milestone

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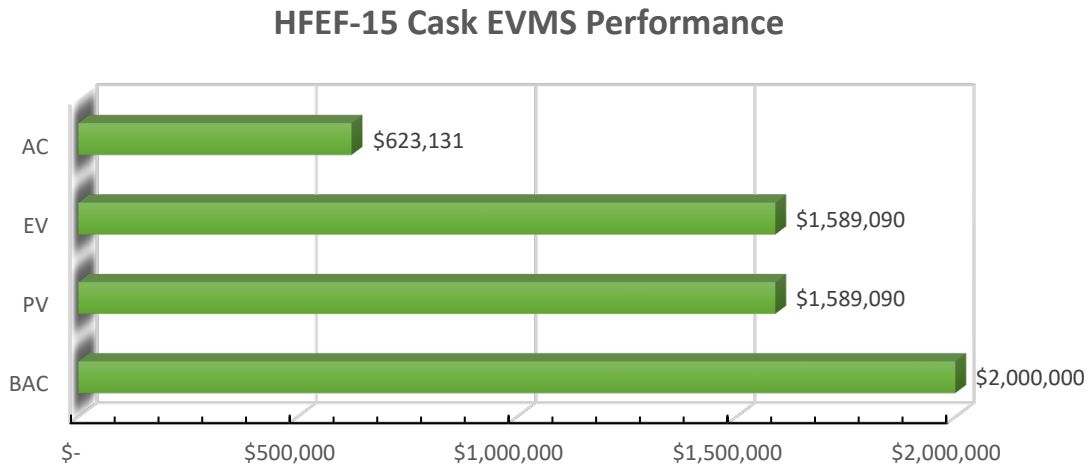
Project Status (March 2024)

- Completed Design and Issued Procurements for all safety-related items
- Drop analysis in progress
- Project team engaging in a TREAT Sodium Loop Integrated Product Team to ensure interface requirements are met and issues addressed



Tracked Risks
Cask Contamination
Missed Design Requirements
Fabrication Delays
Unavailable Human Resources
MFC Priorities
Readiness Requirements

Questions?

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