

Mechanisms Engineering Test Loop (METL) Operations, Maintenance, and Testing Report – FY2024

September 2024

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Revision No.	Date	Affected Pages	Description

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ACKNOWLEDGEMENTS

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This research was sponsored by the U.S. Department of Energy, Office of Nuclear Energy under Contract DE-AC02-06CH11357. We gratefully acknowledge the support provided by Alice Caponiti of DOE-NE, former Deputy Assistant Secretary, Office of Reactor Fleet and Advanced Reactor Deployment; Brian Smith, DOE-NE’s new Deputy Assistant Secretary, Office of Reactor Fleet and Advanced Reactor Deployment; Janelle Eddins, Advanced Reactor Development Team Lead; Kaatrin Abbott of DOE-NE, Advanced Reactor Technologies, Fast Reactor Manager; Savannah Fitzwater, DOE-NE National Reactor Innovation Center Federal Program Manager, Ashley Finan, National Reactor Innovation Center National Technical Director, Bradley Tomer, Acting National Reactor Innovation Center National Technical Director, and Bo Feng of Argonne National Laboratory, ART R&D Fast Reactor National Technical Director.

The authors would like to extend their gratitude to core and extended METL team members Daniel Andujar, Alex Grannan, and Evan Ogren, for operating METL as well as supporting experimental work. The authors are extremely thankful for the support from Bill Toter and other members of the Argonne National Laboratory Central Shops (ANL-CS) staff as they continue to aid with METL maintenance and expansion as well as test apparatus fabrication. Lastly, efforts from Christian Kourkoumelis, Jay Johnson and Argonne Business and Information Systems (ANL-BIS) were vital in establishing and maintaining a strong and secure network infrastructure to which the authors are grateful.

The authors are also very grateful to the former Argonne personnel who worked on EBR-II and sodium technology in the former Components Technology Division.

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ACRONYMS

DOE	U. S. Department of Energy
INL	Idaho National Laboratory
ANL	Argonne National Laboratory
METL	Mechanisms Engineering Test Loop
GTA	Gear Test Assembly
THETA	Thermal Hydraulic Experimental Test Article
F-STAr	Flow Sensor Test Article
GrTA	Gripper Test Article
EM	Electromagnetic
ART	Advanced Reactor Technologies
ANL-CS	Argonne National Laboratory Central Shops
ANL-BIS	Argonne Business and Information Systems
SFR	Sodium Fast Reactors
LMRs	Liquid Metal Reactors
PM	Planned Maintenance
PRO-AID	Parameter-Free Reasoning Operator for Automated Identification and Diagnosis
SCADA	Supervisory Control and Data Acquisition System
O&M	Operations and Maintenance
XR	Extended Reality
MR	Mixed Reality
NEUP	Nuclear Energy University Project
SBIR	Small Business Innovation Research
Gen-IV	Fourth Generation
GIF	Generation IV International Forum
WVN	Wet Vapor Nitrogen
P&ID	Piping and instrumentation Diagram
UPS	Uninterruptible Power Supply
I&C	Instrumentation and Control
VM	Virtual Machines

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1. EXECUTIVE SUMMARY

This report documents the operations, testing, maintenance, and improvements that were performed at the Mechanisms Engineering Test Loop (METL) and its supporting infrastructure during FY2024. The METL facility had a very successful sixth year of operations while supporting the testing of multiple test article experiments in the facility. The METL facility continued supporting the Gear Test Assembly (GTA) testing and the Thermal Hydraulic Experimental Test Article (THETA) with the completion of its' secondary system. Work to accommodate two additional experiments, a flow sensor test article (F-STAR) gripper test and a fuel handling gripper test article (GrTA) continued as they are expected to make their debut in FY2025. In addition, a new 18” test article, the Sample Testing Basket (STB) was assembled and tested, providing screening tests for sodium service materials.

1.1 Purpose & Background

The METL facility has the capability to test small to intermediate-scale components and systems for advanced liquid metal technology development. Testing various components in METL is essential for the future of advanced fast reactors as it will provide invaluable performance data and reduce the risk of failures during plant operation.

METL continues to provide development opportunities for younger scientists, engineers, and designers who will ultimately lead the advancement of U.S. liquid metal technologies. The hands-on experience with METL, both successes and perceived failures; will ultimately lead to better liquid metal technology programs that can support the commercialization of advanced reactors.

Some examples of technologies that can be tested in METL include:

1. *Components of an advanced fuel handling system* – Fuel handling systems are used for the insertion and removal of core assemblies located within the reactor vessel. Undoubtedly, these components are essential to the successful operation of fast reactors. For liquid metal applications, fuel handling systems need to work inside the primary vessel and typically penetrate through the cover gas of the primary system. As a result, fuel handling systems must address issues associated with ‘sodium-frost’ buildup.
2. *Mechanisms for self-actuated control and shutdown systems* – These components have been conceived by various designers to provide added defense-in-depth for reducing the consequences of beyond-design-basis accidents. These self-actuated control and shutdown mechanisms include devices such as curie-point magnets and fusible linkages.
3. *Advanced sensors and instrumentation* – Advanced fast reactors contain sensors and instrumentation for monitoring the condition of the plant. Sometimes these components are required to work while immersed in the primary coolant. This category includes but is not limited to, sensors for the rapid detection of hydrogen presence in sodium (which is indicative of a leak), the detection of impurities in the coolant (i.e., improvement of plugging meters or oxygen sensors), alternative methods of leak detection, improved sensors for level measurement (E. Kent, 2019) and other advanced sensors or instrumentation that improve the overall performance of the advanced reactor system.
4. *In-service inspection and repair technologies* – These systems include visualization sensors for immersed coolant applications and technologies for the welding and repair of structures in contact with the primary coolant.
5. *Health Monitoring of METL systems and components* – The development of sensors and prognostic techniques for deployment that can monitor and quantify materials degradation in liquid metal-cooled fast reactor primary systems. Technologies that detect degradation early, can survive in typical liquid metal-cooled fast reactor environments over extended periods of time,

and can be embedded in/on structural materials to enable structural health monitoring (e.g., nondestructive examination techniques, remote or automated inspection techniques including visualization in optically opaque coolants) can be tested in METL.

6. *Thermal hydraulic testing in prototypic sodium environment* – A thermal hydraulic test loop could be used to acquire distributed temperature data in the cold and hot pools of a small-scale sodium fast reactor during simulated nominal and protected/unprotected loss of flow accidents. This testing could allow for the articulation of the heated region in the core to allow for a parametric study of IHX/core outlet height difference and its effect on thermal stratification of sodium in the hot pool. Ultimately this data will be used for validating CFD and systems level code.
7. *Human Machine Interface Technology* – Technologies for improving the ability of operators to understand what is happening inside the sodium environment. One example would be the ability to provide a refueling system operator to see in-vessel refueling in a virtual environment during in-vessel refueling.
8. *Artificial Intelligence (AI) and Machine Learning (ML) Algorithm Technology Demonstrations* – METL has the potential to support various AI/ML research initiatives and applications. Software developers may deploy commercially available or under development programs at METL to monitor the ecosystem and notify operators of anomalies and provide corrective actions. METL has been logging data for years of operation, generating a large data set of in-situ values, which would serve as a realistic basis for training neural networks. The METL ecosystem also has a database of work performed and component failures which can be used in conjunction with the digital logbook and instrumentation data for demonstrating predictive/prescriptive maintenance software thereby reducing O&M costs of advanced reactors/METL.

As shown below in Figure 1, the design of the METL facility consists of test vessels connected in parallel to a main sodium loop. The different vessels share an expansion tank, purification system, and several electromagnetic (EM) pumps and flowmeters. This flexible, consolidated design minimizes infrastructure requirements and allows multiple experiments to be performed simultaneously.

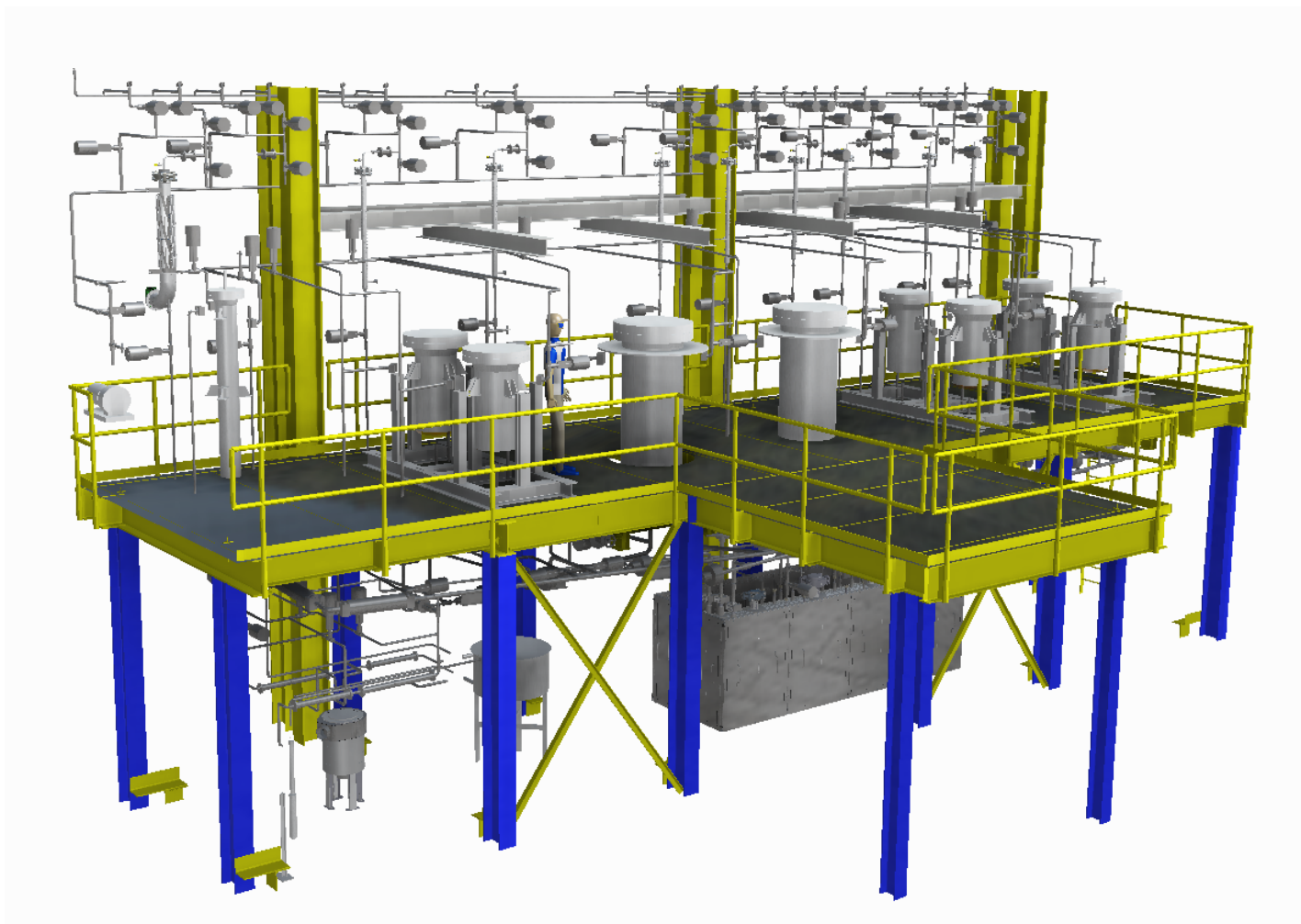


Figure 1- A 3D model of the Mechanisms Engineering Test Loop showing Phase I and four additional test vessels.

1.2 METL Fiscal Year 2024 Accomplishment

The METL facility and team had a successful sixth year of operating the overall METL facility and its supporting infrastructure that provides the environment for liquid metal research and development. The METL team remained very productive during this past year supporting three test articles, the Gear Test Assembly (GTA), the Thermal Hydraulic Experimental Test Article (THETA), and a materials sample basket. In addition, the team supported various future experimental designs, repairing/upgrading METL components and renovations, providing numerous tours and other outreach activities, and supporting industry/academia needs. The following list is the significant accomplishments during the past reporting period of FY 2024:

- The METL facility performed its first startup six (6) years ago when sodium was transferred (via an argon push) from the dump tank to the main loop and vessel system on September 19, 2018.
- METL has maintained its sodium in a hot molten state continuously (either flowing or static) for almost 5.5 years, since September 19, 2018. The METL facility was drained on April 20, 2021, and frozen to implement repairs on the Building 308 scrubber. The facility was in this frozen state for about six (6) months.
- METL was drained on July 15, 2024, and the dump tank frozen in order to make the final piping weld connection for Test Vessel 6 drain piping to the dump tank.
- The METL team performs periodic sodium purification runs in order to maintain purity of the sodium in METL. During these purification runs it was found that the cold trap is reaching the end of its life. The cold trap is currently operated at 170°C, but an external customer wants us to operate at 150C. When trying to cold trap to 150C, flow decreases. A new cold trap (nearly identical to installed one) was procured as well as a new and improved cold trap stand that insulated the bottom of the cold trap. Fabrication of new piping segments to be installed with the new cold trap is nearly completion.
- A cold trap replacement procedure has been prepared. The new cold trap has been modified to add some piping and a Tee in order to pull a vacuum during installation of the new cold trap.
- The new cold trap has been baked out under vacuum.
- A special portable heating cart (Sodium Transfer Console) was designed and built to allow for the heating of drums and bakeout of equipment in support of METL and its test articles. This new heating cart was used for the bakeout of the new cold trap under vacuum and also for the heating of the sodium drum that was transferred into a materials testing loop called SMT-3.
- Completed the METL Facility Annual Operations and Testing Report – September 15, 2024 (M3RC-24AN0206011)
- The METL team supported the operations of the Gear Test Assembly (GTA), which completed Test Campaign 7 and 8. For Test Campaign 7, the test article operated for 14.4 hours of testing and the testing was stopped due to failure of the bearings. The GTA has been removed from the METL Test Vessel 1, processed through the carbonation process, and dismantled.
- The METL team supported the operations of the Thermal Hydraulic Experimental Test Article (THETA). In FY 2023, THETA was refurbished to install thermal insulation around the THETA core barrel and intermediate heat exchanger. In FY 2024, THETA's secondary system was installed on the METL mezzanine and THETA was made fully operational to reject the 38kW of heat to the atmosphere in the highbay.
- The METL team installed an off-the-shelf structural health monitoring (SHM) system on the piping system for Test Vessel 6. This new system will allow monitoring of this piping system and for a demonstration of a high-temperature SHM system.
- The METL team developed a sample basket that was fabricated. This basket allows for the investigation of material samples compatibility with high temperature sodium. The basket consists of

two parts; a part that is submerged in sodium and a part that can hold components in the vapor space. The sample basket is designed for installation in a METL 18-inch test vessel.

- The METL Experimenters Guide was updated and republished. This guide provides information that supports innovators in their quest to design experiments that will go into METL. This guide is located on the METL web site.
- The METL team supported the installation of Test Vessel 6. This Level 2 milestone (M2RC-24AN0206012) work included the installation of piping systems to provide sodium to the test vessel from the main loop and returning sodium to the main loop. In addition, installation of heaters on the installed piping system was 90% completed. A level detector was removed from the dump tank in preparation for connecting the Vessel 6 drain line to the dump tank. As of September 10, 2024, METL has been drained and the dump tank frozen. The drain piping connecting Vessel 6 has been installed and we are awaiting the radiography of the welds before thawing the dump tank. Following the radiography of the piping welds, the piping and vessel will be heat traced and insulated before the bakeout and filling with sodium.
- The METL team designed a Wet Vapor Nitrogen (WVN) system that will be used to augment the moist carbon dioxide sodium cleaning system. Currently, test articles removed from a METL test vessel are cleaned with moist carbon dioxide for week(s) to convert residual sodium on the test article to sodium bicarbonate. This process does not completely clean a test article as many small orifices/crevices do not receive moist carbon dioxide due to large volumetric expansion coefficient of the bicarbonate. In order to react residual sodium more completely, a WVN system is being built which will allow for more sodium to be reacted from a test article before it is removed from the cleaning tank. The parts for the WVN system have been procured as of the writing of this report and being installed. We expect to have this new system tested in early FY25.
- The Fast Reactor program was invited to the ASI program meeting to provide a presentation that covered three areas: ART Fast Reactor Program Sensor Development, Testing Infrastructure, and Fast Reactor Sensor Needs. The 20-minute presentation was given on November 2023 and discussed METL, THETA, and some of the other test articles along with current areas of collaboration with ASI program.
- The METL Team is collaborating with various NEUP awardees in demonstration of various sensor technologies such as flow monitoring, structural health monitoring, and impurity monitoring. The goal is to deploy all of these sensors at METL once they are fully developed.
- Maintained alkali metal program support equipment (Building 308 Scrubber, Superheated Steam System, 18-inch & 28-inch Flexi-Casks, Carbonation System, Glovebox and Qualifying Stations)
- Installed waveguides on the METL Test Vessel 6 piping system to support a DOE Advanced Reactor Technology (ART) program initiative on structural health monitoring of advanced reactor piping and vessel systems.
- Continued demonstration of level sensor technologies (using an inductive level sensor, a differential pressure sensor, and a thermophysical property probe).
- Performed various maintenance and calibration activities of METL and its supporting infrastructure.
- Completed the design of an extension of the METL platform to increase the usable floor space for METL operations and maintenance.
- A contract was let for the fabrication and installation of this new METL platform to increase the usable space in the B308 highbay.
- In 2024, a leak in the ducting of the B308 scrubber system upstream of the venturi was found. The old carbon steel ducting was replaced with stainless steel ducting in September.
- The ART Fast Reactor Program review meeting was held the week of January 2024. Tours of the METL facility was provided to meeting participants.

- Attended the Gen-IV Component Design and Balance of Plant meeting at Korea Atomic Energy Agency, Daejeon, Korea to discuss activities at METL. Our work in the ART program and METL are the main U.S. contributions to the Gen-IV CDBOP project management board. The meeting was in September 2024 at KAERI and was the second in-person meeting of the CDBOP since the COVID Pandemic. Topics of discussion were Overall Country Report, METL, and flowmeter conversion work.
- Attended the Gen-IV CDBOP meeting in CEA site in Cadarache, France in September 2023.
- The METL team gave multiple tours of the facility to different people and groups including:
 - In October 2023, the METL team provided tours to personnel from NA-211 – International Nuclear Safety group. The GTA and THETA experiments were discussed along with the overall METL facility.
 - In December 2023, the METL team provided tour to a number of people from INL including Jess Gehin, Erin Searcy, Monica Regalbuto, Youssef Ballout, Eric Whiting, and Brad Tomer.
 - MeV School participants
 - Advanced Sensors and Instrumentation (ASI) program personnel
 - American Nuclear Society President: Lisa Marshall
 - Principal Deputy Administrator of the National Nuclear Security Administration: Corey Hinderstein
- The METL team gave a presentation on the status of the work in FY23 and FY24 at the NRIC Program meeting held at the INL on April 23, 2024.
- Continued support to an ASI program activity to demonstrate the ability of the PRO-AID program software to monitor the performance of the METL cold trap system. The goal of this work is to have this computer program detect anomalies within the purification and diagnostic system.

1.3 Plans for FY2025 at METL Phase II

The METL facility will continue its molten sodium operations in FY2025. In FY2025, we expect to be retesting the Gear Test Assembly (9th time) which was tested in FY2019-2023 with its new bearing blocks and off-the-shelf bearings (standard and heat treated) and at lower torque settings. The THETA experiment's primary system will continue with its testing that was initiated in FY2024. The THETA primary and secondary system will be operated as a unit for thermal hydraulic code validation with heat rejection. We will be operating the inductive and thermal property probe level sensors and operating an ultrasonic health monitoring system on the Test Vessel 6 primary piping system, system will be operated, and Test Vessel 6 will be installed in METL. Test Vessel 6 piping installation is nearly complete. The remaining section of the Test Vessel 6 to Dump Tank piping needs to be radiographed and dye penetrant tested. Once the piping passes NDE, it will be heat traced and insulated. We will be making preparations for the installation of the third test article. If the third test article is ready (Flow Sensor Test Article or Gripper Test Article), we will be supporting the qualification of this test article for insertion into the METL facility. We will be completing the installation of the west extension to the METL platform to increase the usable space for METL work. This extension will be installed in late FY24/early FY25. We will continue to collaborate with industry (with the expectation of receiving our first industry sponsored test article for testing in METL in FY 2025) and support the nuclear energy university program calls for experimentation in METL.

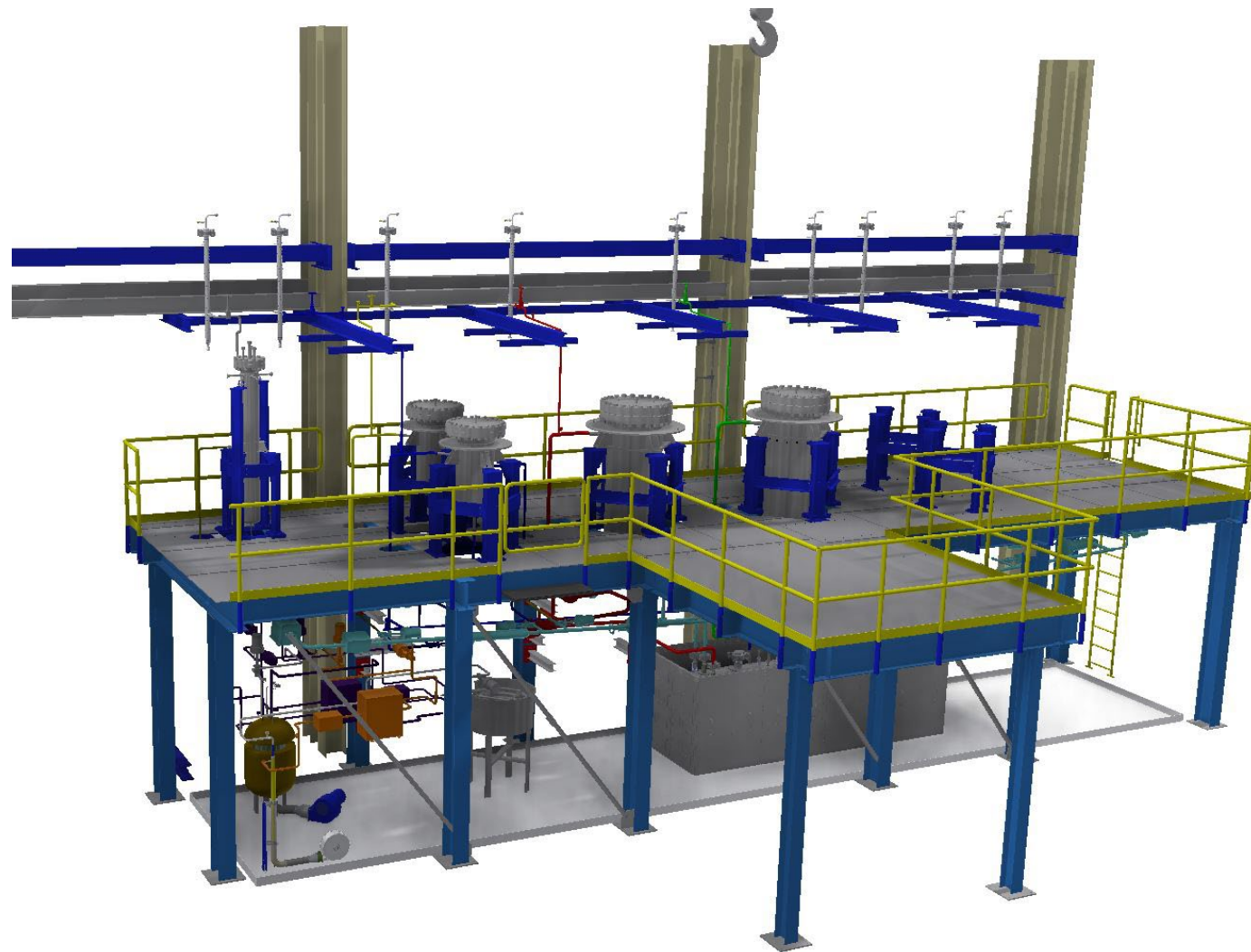


Figure 2 – A 3D model of METL after Phase I was complete.

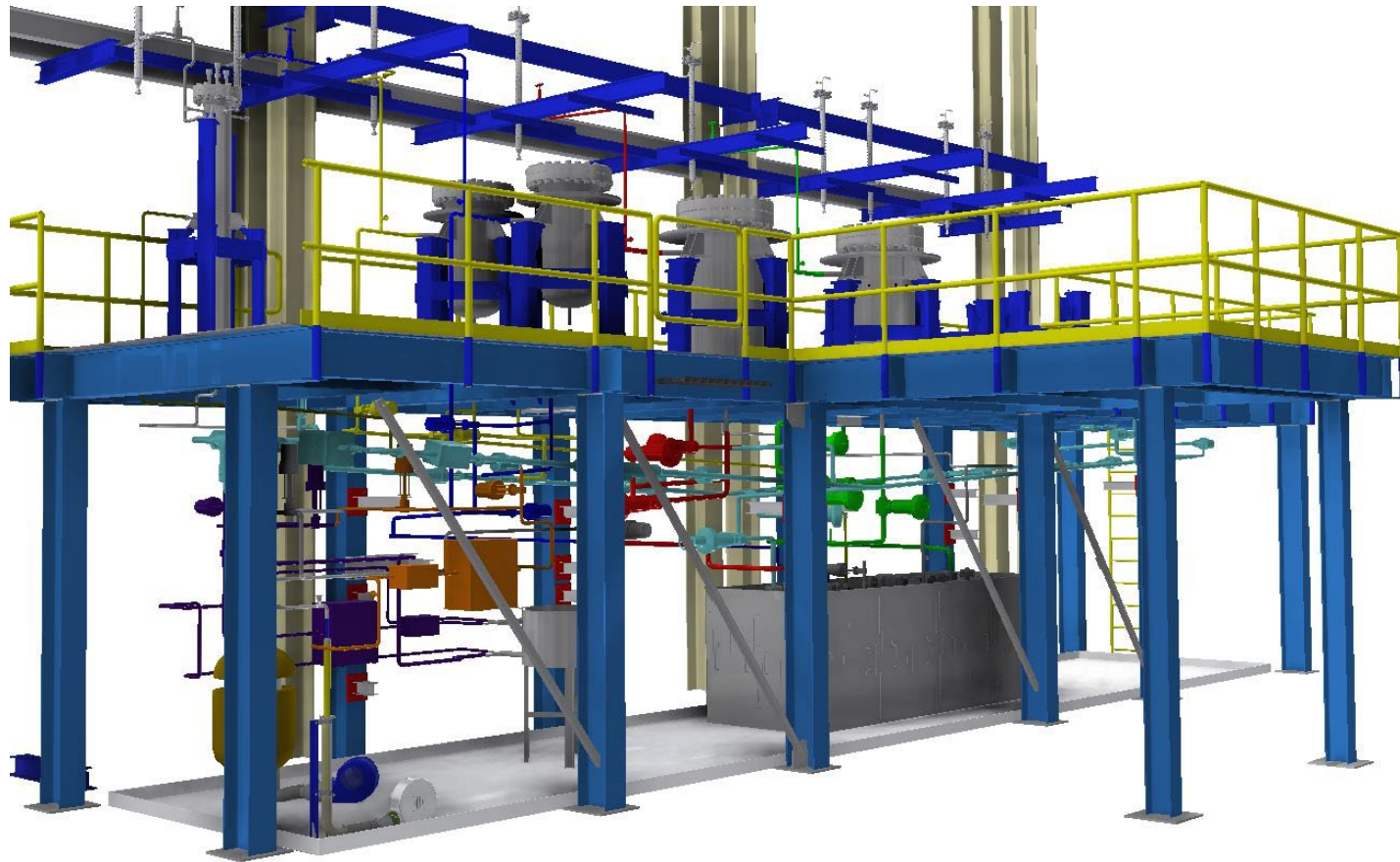


Figure 3 - A 3D model showing the Phase I piping and equipment arrangement underneath the mezzanine.

2. BACKGROUND AND OBJECTIVES

The successful operation of sodium-cooled fast reactors will largely depend on how well their components work within a sodium environment. Therefore, the mission of the Mechanisms Engineering Test Loop (METL) is to provide the infrastructure and technical expertise required to test advanced technologies in a high-temperature sodium environment. In turn, the results gleaned from experiments performed in METL will help to develop state-of-the-art advanced reactors.

2.1 Design Overview

The layout of METL follows the characteristic design of a sodium test facility. The facility consists of multiple test loops in which tanks/vessels, valves, and other components, interconnected via piping and tubing. The system is designed to handle both static and flowing sodium which permits each test vessel to provide the environment suitable for the specific needs of an experiment. During operation, the sodium is purified by passing it through the METL cold trap. Impurity levels can be continuously monitored using the plugging meter. The general design temperature of the facility is 1000 [°F] but the maximum design temperature rating of a 28” test vessel is 1,200 [°F] (Figure 2).

3. METL OPERATIONS, TESTING, AND MAINTENANCE

METL is a unique U.S. facility within the Department of Energy complex as it provides opportunity for researchers to test small to intermediate scale sodium components but also acts as a platform for experimentation itself. METL’s infrastructure promotes flexible operations to accommodate virtually any device that fits within the volume of the test vessels but also has open mezzanine area for experimentation. In addition, METL’s 30+ year operational life (corrosion life) will garner and provide information and experience essential for SFR commercialization that small/benchtop test apparatus, which are periodically operated, cannot supply.

METL’s resemblance of a liquid metal reactors (LMRs) intermediate heat transport system yields data directly applicable to operations and maintenance of LMR systems and components. METL’s configuration, scale, and years of continuous operation establishes a proving ground not only for SFR equipment but also supporting equipment and operational methods.

3.1 Purification of METL’s Sodium

Prior to FY 2022, purification operations were conducted after filling a test vessel, so an experiment had consistent testing environments. The METL team has operated the purification system on a weekly basis since FY 2022. The weekly purification operations serve as a preventative maintenance (PM) measure. The purification PM was initiated after recovering from a sodium oxide plug on the inlet to the cold trap and has also provided larger data sets to identify performance variations.

3.1.1 Cold Trap Performance

Degradation in cold trap performance was detected in FY 2023 when operators noticed a drop-in sodium flow rate while other parameters remained constant. This initiated an increase in cold trapping temperature from 150°C to 170°C. An investigation into the root cause of the decreasing flow rate was pursued in FY 2024. The METL team brainstormed potential reasonings behind this behavior:

- The air-side configuration of the cold trap has the air entering the bottom hemisphere of the cold trap and then traveling up the sides along the cooling fins of the cold trap. This configuration results in the bottom of the cold trap being the coldest section and is inches away from the process control thermocouple. Thus, when we are cold trapping at 170°C, we are not measuring the actual coldest temperature of the cold trap.

- METL piping heaters have two thermocouples per zone. Heater zones on the inlet of the cold trap are over eight feet long so thermocouples are placed at two and a half foot increments. This could lead to the pipe heater not maintaining a high enough set point, where sodium loses a sufficient amount of heat after the pipe heater's process thermocouple. A cooler cold trap inlet line would result in depositing sodium oxides at the inlet nozzle, thus creating a pressure drop/flow rate decrease.

The air-side configuration theory was tested by installing a thermal baffle at the air-side inlet of the cold trap. This baffle diverted inlet cooling air to the outer walls of the cold trap instead of the bottom. This resulted in the lower annulus of the cold trap being the coldest region instead of the bottom hemisphere. Numerous purification runs have been performed but have not yielded distinct changes in overall behavior of the cold trap because 50% of the cold trap lower hemisphere is not insulated.

METLs' expansion tank and piping temperatures were adjusted from 300°C to 400°C in an attempt to remedy the potential deposit of sodium oxides in the cold trap inlet. The solubility of sodium oxide in sodium increases with temperature thus, flowing hotter sodium through the cold trap inlet should dissolve sodium oxides collected at the inlet and transfer them to the cold trap. Multiple purification operations were performed at these elevated temperatures without change in the behavior of the cold trap. Other strategies to clear lines or redistribute oxides within the cold trap included:

- Stratify cold trap vessel heater set points, creating a large temperature gradient. Ensuring much higher temperatures at the top of the cold trap would ensure oxides are only collecting at the very top of the vessel.
- Attempts to stratify cold trap vessel temperatures were further pursued by decreasing the pump speed to increase the time sodium spent in the cold trap.
- Increased pump speed over 60% to determine if the oxides or obstruction could be cleared by pushing it into the cold trap vessel. Increasing the pump speed also confirmed that the developed differential pressure was not due to a constant obstruction. If the differential pressure was obstructed by a solid metal object for instance, the differential pressure should increase with flow but then equalize. During this exercise, the differential pressure continued to increase at the higher pump speeds, indicating it was oxides building up at the lower cold trap temperatures (i.e. an increase in pump speed increased the rate of differential pressure increase/rate of flow rate decrease).

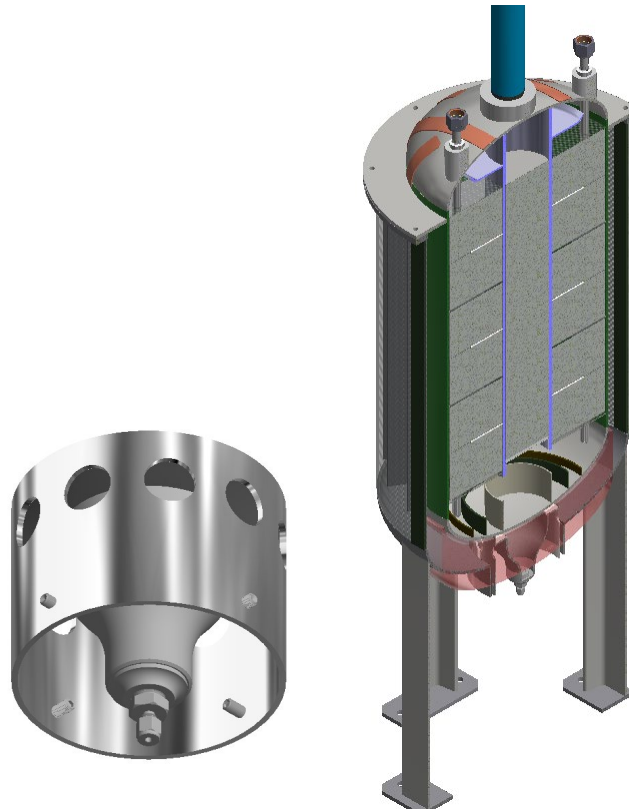


Figure 4. Cold Trap Thermal Baffle (left) Modeled onto Existing Cold Trap (right).

When a corrective action was implemented, operators would decrease the cold trapping temperature in steps while fixing the pump speed to observe the influence of cold trapping temperature on flow rate as shown in Figure 5. Differential pressures across the cold trap (Figure 6) provided further verification if a flow restriction remained.

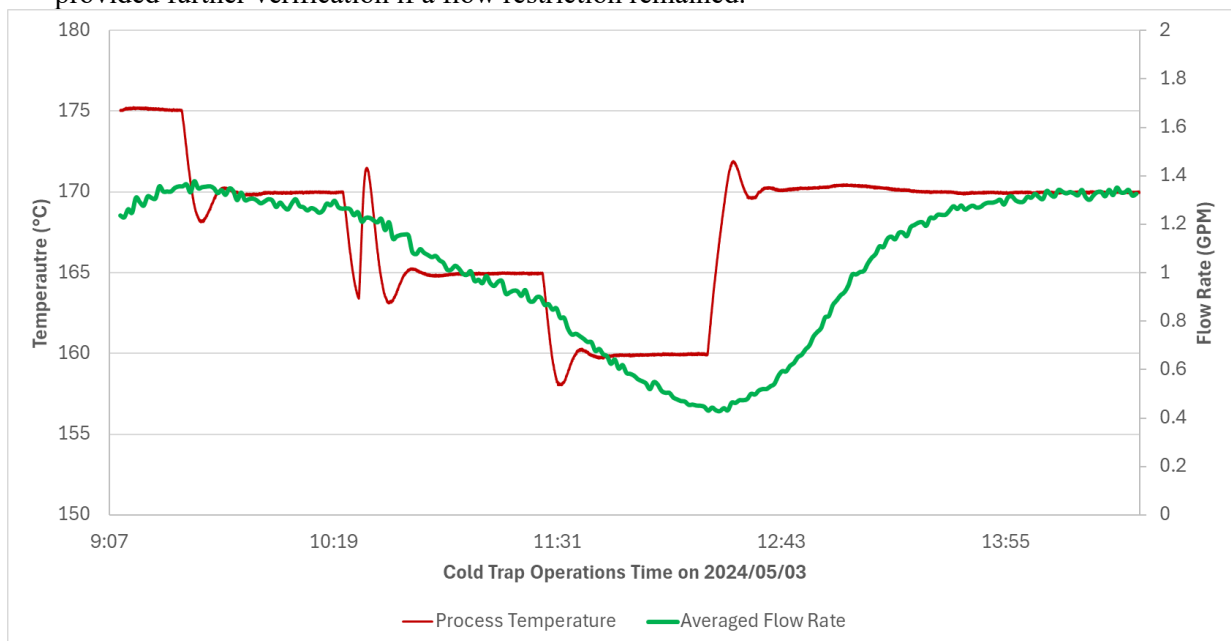


Figure 5. Cold Trap Temperature Influence

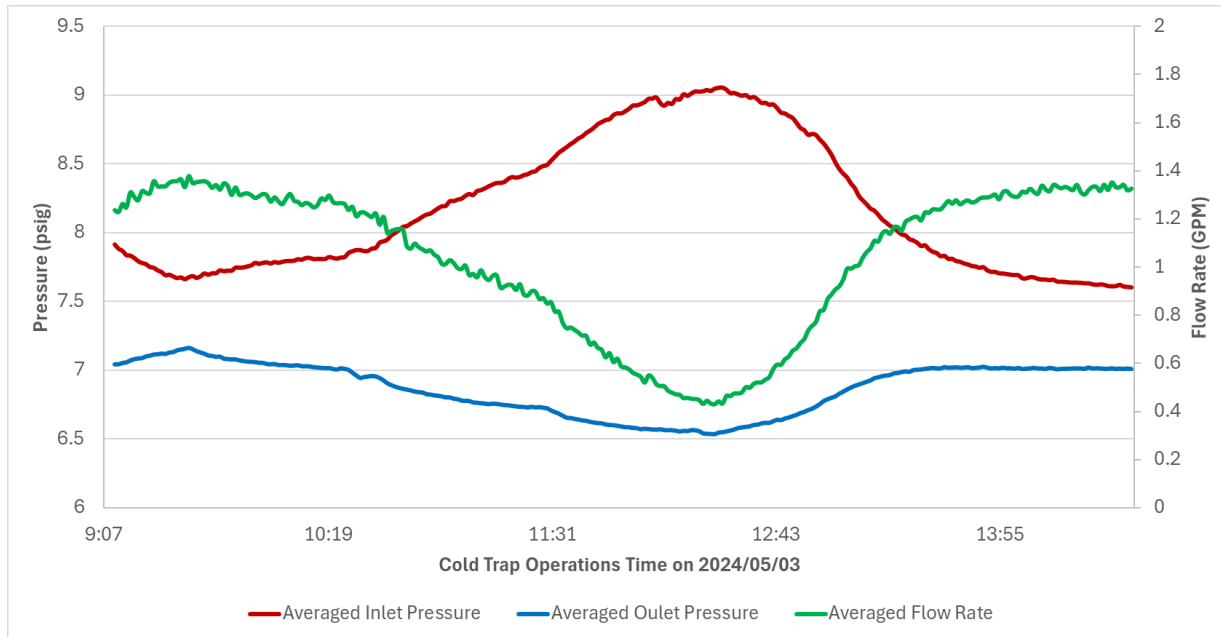


Figure 6. Cold Trap Saturation Verification.

3.1.2 Replacement Cold Trap

A corrective action for the existing cold trap performance has yet to be identified and given the extensive troubleshooting campaign, the METL team reached a consensus that the original cold trap has reached the end of its useful life. The cold trap has been considered a consumable since METL's conception. Expecting its eventual replacement, a new cold trap was ordered in FY 2019. In June of 2024, the METL team began preparing to replace the cold trap by baking out the new cold trap using the Sodium Transfer Console (discussed in section 5.1). The new cold trap was heated to 538°C while simultaneously pulling a vacuum for an entire week. Next, three argon flushes were performed by isolating the vacuum pump and filling the cold trap with argon and subsequently reestablishing a vacuum. The cold trap was kept under argon pressure as it cooled, completing the bake-out process (Figure 7, left).

A new air jacket (Figure 7, right) was designed, fabricated and test-fit with the new cold trap. The new air jacket incorporates a baffle like the one deployed to the original cold trap in Figure 4. The new air jacket provides insulation and blocks cooling air flow around the bottom hemisphere of the cold trap. It is expected this will cause sodium oxides to precipitate out above the hemisphere in the bulk volume, collecting those oxides in the bottom hemisphere, extending the cold traps operational life.

In FY 2024, a procedure was drafted for the removal of the existing cold trap and installation of a new cold trap. The cold trap is located on the same floor as the dump tank, preventing drainage. Therefore, an outline of the procedure is provided in the following bullets:

- Freeze cold trap vessel and inlet/outlet lines
- Remove insulation, heaters, and instrumentation from vessel and lines.
- Cut the inlet and outlet lines with a pipe cutter.
- Clear out solid sodium in the piping lines and clean surfaces.
- Weld-in new cold trap without disturbing sodium inside the piping
- Perform non-destructive examination of welds.
- Reinstall heaters, instrumentation, and insulation.
- Bake-out cold trap and lines.
- Thaw the inlet/outlet lines
- Fill with sodium and commission.

- Demonstrate purification to 150°C.

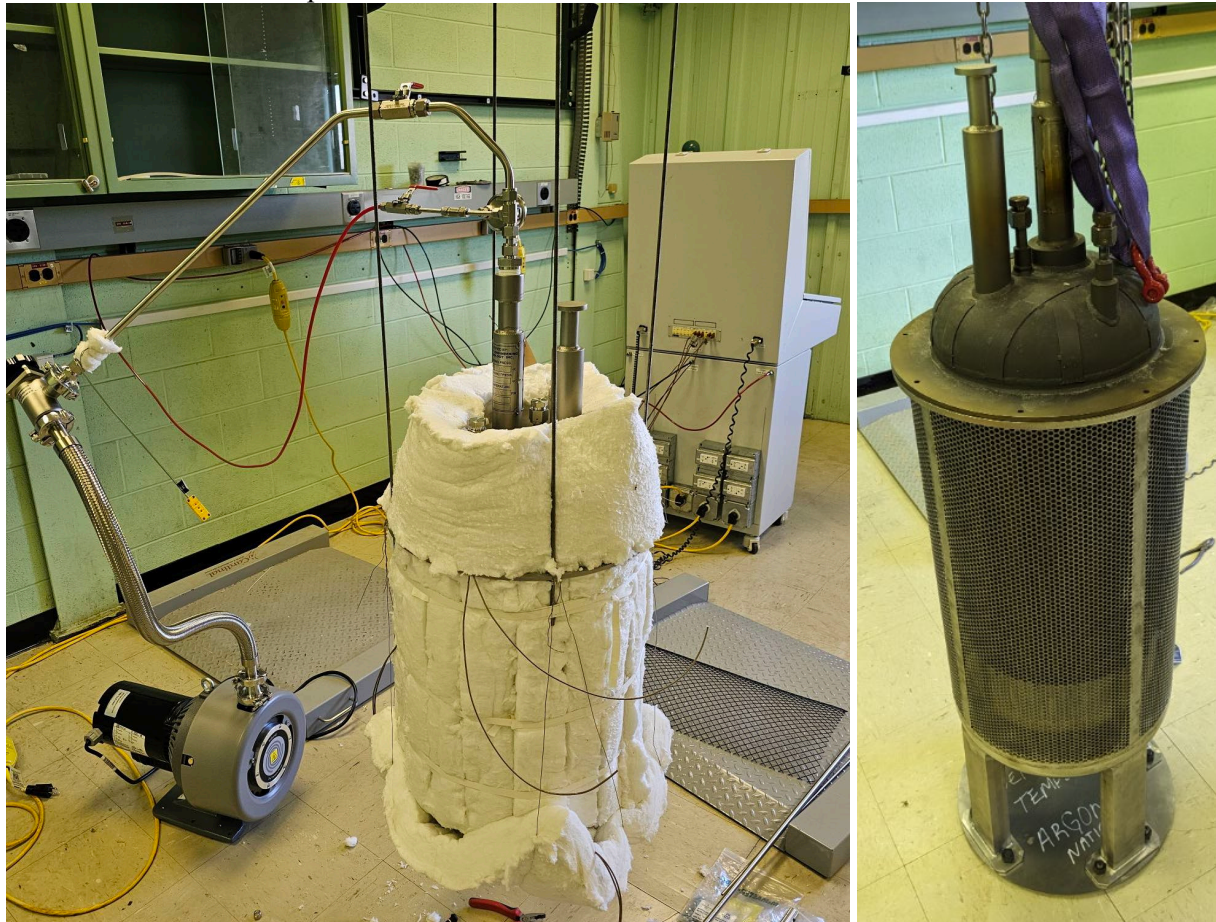


Figure 7. Cold Trap Bake-Out (left) and New Air Jacket (right).

3.2 Electromagnetic Flowmeters

METL’s converted Electromagnetic Flowmeters (EMFMs) have proven to be valuable instruments both during normal operations and as diagnostic tools for off-normal events. There were issues with the originally installed flow meters which required them to be changed from hall effect flowmeters to permanent magnet flow meters (Mk-1). While the Mk-1 flowmeters have performed well, there are several upgrades that will enhance their operation. Therefore, a second iteration of the flowmeters (Mk-II) was developed to incorporate these improvements. These improvements include 1) a new magnet mount and housing for the installation of larger magnets, increasing the signal output; 2) higher temperature-rated magnets that result in a reduced spacing, also increasing the signal output; and 3) better performance magnets that eliminate worries about overheating. Finally, the Main Loop (ML) flowmeter was never converted. Thus, completing this conversion would allow METL to also monitor flowrates in the main circuit.

Since the previous report, all flowmeter parts were fabricated. Figure 8, left, shows a photo of the three Mk-II flowmeter enclosures. Note that this design is common across all three of METL’s flowmeters. Additionally, the high temperature SmCo magnets were manufactured and set into their mounts. **Figure 9** shows a photo of the mounted magnets with instrumentation installed. Prior to installation, all three flowmeters were mocked-up to check the fit of each component. During this mock-up, it was discovered that the mounting bracket reduced the overall heated conduit length, resulting in a gap and a potential cold spot. Therefore, the mounting bracket was redesigned and fabricated. Figure 9

shows a photo of the completed bracket. Furthermore, a design for the new leads was completed (Figure 8, right). shows a 3D model the new lead fixturing. The new leads will be attached to the outside of the conduit by TIG welding. This method will be more robust than the method used in the Mk-I iteration (a simple spot weld).

Finally, the electrical signal noise issues observed during flowmeter operations were eliminated. The solution was discovered while troubleshooting THETA's EMFM, where a 60 Hz rejection filter on a National Instruments 9219 isolated analog input card was applied. This eliminated the flowmeter signal noise. It is believed that the AC Conduction Pump on THETA's secondary system was the source of the noise. Since METL also includes two of these pumps in close vicinity to its flowmeters, NI 9219 analog input cards were added to METL's subRIO and the flowmeter signal inputs switched to them. Like in THETA, this eliminated the signal noise from the Mk-I flowmeters. The same analog input cards will be used in the Mk-II upgrade.

At the time of this report, all materials to complete the flowmeter upgrade to the Mk-II iteration are on hand. Additionally, the new leads were fabricated, and spare flowmeter conduits were procured for welding practice. Currently, the project is waiting for the completion of the METL Cold Trap replacement, since the Mk-I flowmeters will be critical to verify flow is reestablished. Additionally, the project is also waiting for a window in available of the Central Machine Shop welders. Once the Cold Trap is replaced and welders are available, the project will proceed with removing the Mk-I flowmeters and implementing the Mk-II iteration. Once installed, future work includes recalibrating all three flowmeters using a similar procedure to the Mk-I flowmeter calibration. After completion of this upgrade, METL will have robust flow instrumentation on the Main Loop, Cold Trap, and Plugging Meter, which will continue to support operations and enhance the capabilities of the facility.

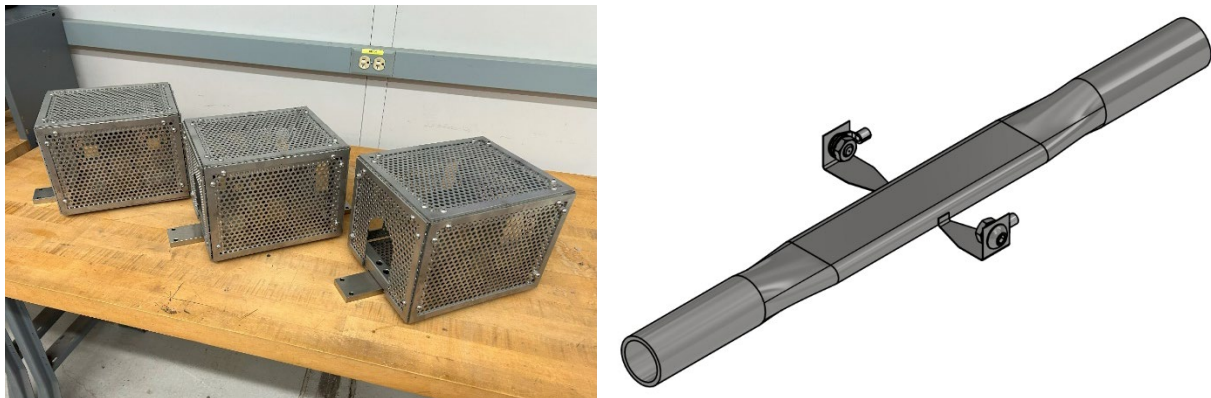


Figure 8. Fabricated METL EMFM MK-II enclosures (left) and 3D model of the new lead design (right). The new leads will be tack welded to the outside of the conduit using TIG welding which will result in a more robust fixturing of the leads.

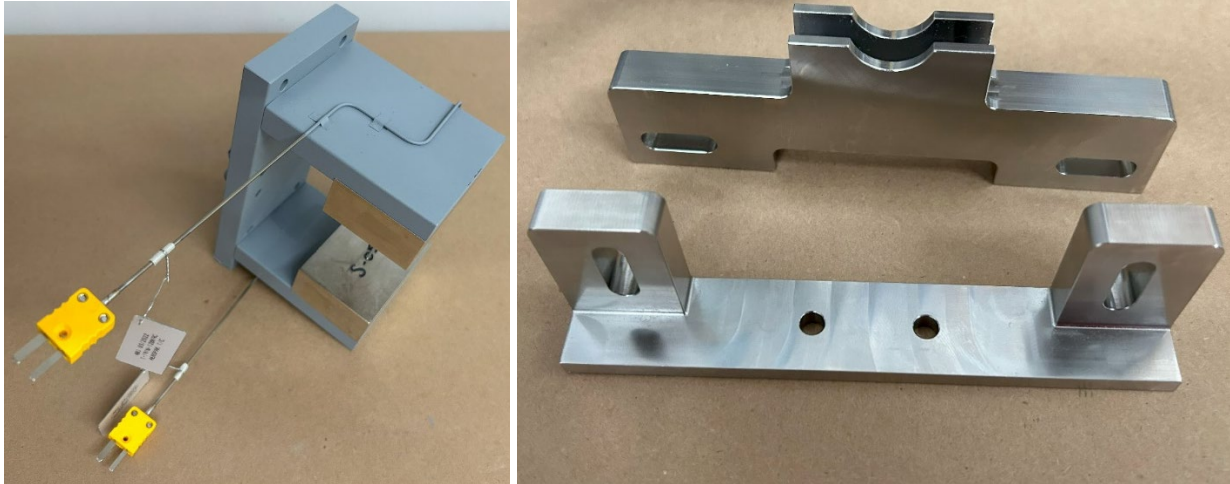


Figure 9 – Assembled magnet mount with high-temperature SmCo magnets and thermocouples installed (left). Newly fabricated mounting bracket that eliminates a potential cold spot introduced by the old bracket design (right).

3.3 Experimental Test Article Support

In FY2024, the METL team supported three active experiments, the Gear Test Assembly (GTA) the Thermal Hydraulic Experimental Test Apparatus (THETA), and the sample basket in addition to making preparations for future experiments such as the Flow-Sensor Test Article (F-STAr), Gripper Test Article (GrTA) and industry test article. Investments and modifications to METL to support experimental programs will continue, assuring researchers have resources to perform a successful demonstration of their technology or quality data for code validation.

3.3.1 Gear Test Assembly Testing Support

The Gear Test Assembly (GTA) is an experimental test apparatus built and installed in the Mechanisms Engineering Test Loop (METL) at Argonne National Laboratory (ANL). The focus of GTA has been to test larger radial spur gears sets machined from Inconel 718 along with a variety of bearing components that are to be used in the advanced fuel handling machines built for use in liquid metal reactors. The testing in GTA also informs the design and material choices for the full-scale Gripper Test Assembly (GrTA) being developed by Argonne. To date, the Inconel 718 gears used in all six GTA experimental campaigns have completed over 26.4 million revolutions under various loads equivalent to approximately 79,292 simulated fuel assembly maneuvers (removal from and reinsertion to core) using a conventional height of a core assembly. While the heat treated and untreated tapered roller bearings and cylindrical pin thrust bearings used in the first five experimental campaigns have experienced mechanical or material failure after completing a range of fuel assembly maneuvers ranging from as early as 575 operations in Campaign #5 to 9,800 operations in Campaign #1, Campaign #6 was the most successful campaign, achieving 22,563 maneuvers and was concluded before any catastrophic failure occurred.

During this past reporting period, the METL team supported the insertion of GTA into METL Test Vessel 1 for Test Campaign #7 and #8 and provided periodic sodium purification runs for the GTA. After it was determined that GTA Campaign #7 was completed, the Test Vessel #1 was drained and allowed to cool. The 18-inch flexicask was then used to remove the GTA from the test vessel while keeping the vessel and GTA inerted with argon gas. The extracted GTA was then transported over to the carbonation system where it underwent about 1-2 weeks of moist carbonation processing followed by cleaning (ethanol and steam) and disassembly on the 18-inch test stand. After inspection and non-destructive examination of the gears and complete cleaning, the GTA was reassembled for test campaign #8 which

was also performed in FY24. Using the flexicask, the GTA was inserted into Test Vessel #1 and preparations are being made for testing campaign #9. A full report on GTA FY2024 progress is provided in the reference section (Grannan A. , et al., 2024).

3.3.2 Thermal Hydraulic Experimental Test Article (THETA) Testing Support

THETA (Figure 10) is METL’s flagship thermal hydraulic experiment which has a myriad of test applications such as instrumentation calibration/demonstration, thermohydraulic phenomena investigation, thermal hydraulic data for code validation, and equipment/material evaluation. As noted above, THETA was reinstalled in Test Vessel 4 before the end of FY 2023 and its intermediate sodium piping was installed and underwent radiography in FY 2024. The overall THETA system was brought on line in FY 2024 and multiple purification runs were performed supporting the testing that was conducted in THETA. Over 100 tests were performed with THETA in support of a GAIN award with OKLO. Further details regarding THETA and results from its test matrix are included in its FY 2024 report (Weathered, et al., 2024).



Figure 10. THETA with Secondary System Installed.

3.3.3 Sample Testing Basket

A Sample Testing Basket (STB, Figure 11) was designed, fabricated, and demonstrated in FY 2024 to rapidly perform material/sodium compatibility screening tests. The STB has two sections that enable simultaneous testing of material samples in a sodium vapor and liquid sodium environment. The STB was attached to an 18” test vessel flange to leverage the use of the 18” flexi-cask for insertion/removal into/from an 18” test vessel. Two STB campaigns were completed in FY 2024 to support Small Business Innovation Research (SBIR) awardee, internal, and industry material compatibility projects. Complete details on the STB capabilities is provided in their report (Ogren, Kent, Grannan, & Grandy, Sample Testing Basket - Design and Capabilities Report, 2024).



Figure 11. Sample Test Basket.

3.3.4 Client Test Article Development

The METL team has been assisting an Advanced Reactor Demonstration Program (ARDP) awardee for the past couple of years and performed a material screening test using the STB. Consultation efforts are expected to increase in FY 2025 and pending cold trap performance, the METL team expects to receive their first test article which will be installed in one of the 18” test vessels. Further guidance will be provided to the ARDP partner to design/construct a second test article for insertion into METL.

3.4 Complementary Support Activities

Repeating earlier discussions, METL’s primary mission is hosting experiments to advance SFR development but the facility itself can also support experimental needs not just experiments installed in the test vessels. The later statement continues to hold true as various uses of METL, and the data generated from METL operations and testing have resulted in research activities which weren’t initially considered. In addition to pursuing cross-cutting initiatives, the METL team has assisted internal and external collaborators with understanding METL and its data. METL crew members are co-applicants on numerous NEUP proposals and provided presentations at industry conferences and forums.

3.4.1 Cybersecurity and Safeguards Activities

Realizing economically viable fourth generation (Gen-IV) nuclear power plants (NPPs) will require cross collaboration between many organizations and subject matter experts as flexible and remote operations are pursued. Industry 4.0, also called the Fourth Industrial Revolution, introduced digitization of the industrial sector, rise of data and connectivity between machinery and Industry 5.0 is introducing humanization into industrial processes. Incorporating Industry 4.0 & 5.0 into Gen-IV plants can ensure optimal performance but require robust cybersecurity measures to prevent malicious actors from interrupting operations. Where LWR cybersecurity breaches are primarily concerned with safety, Gen-IV plants are inherently safe, but infiltrators could interfere with the plant’s productivity, limiting their adoption and wide scale use. METL partnered with Argonne colleagues in the Strategic Security Sciences (S³) Division and NSE Plant Analysis & Control & Sensors department to leverage METLs capabilities and similarities with aspects of Gen-IV plants in demonstrating cybersecurity methods and verifying the methods with attacks on METL’s infrastructure. An OUO report “Artificial Intelligence Reference Architecture for Advanced Reactor Cybersecurity Protection” has been generated summarizing the findings among the collaborators. There is an expectation for follow-on work for an actual cybersecurity experiment to be conducted at METL in FY 2025.

Gen-IV NPPs economic longevity requires consideration of the plant’s entire lifecycle. The decades long operation of NPPs is beneficial economically but presents design challenges due to the amount of foresight required. METL crewmembers assisted a NNSA Advanced Reactor International Safeguards Engagement Program (ARISE) team in organizing a Design Information Verification/Design Information Questionnaire (DIV/DIQ) exercise to provide reactor developers the opportunity to consider inspections by regulatory agencies in their designs. METL hosted the ARISE team (Figure 12) for two days where they went through a “mock” DIV/DIQ exercise at the METL flagship facility. The similarities between METL with a commercial plant and the lack of METLs consideration for fuel safeguards (there are no radioactive sources used on METL) showcase a real-world facility where designers can see first-hand implications of failing to ensure ease of inspection. The ARISE team plans to utilize the METL facility in FY 2025 to host the exercise with Gen-IV developers.



Figure 12. ARISE Team Planning the DIV/DIQ Exercise at METL Flagship Facility.

3.4.2 Industry and Academia Support

METL team members have ensured knowledge gained through the operation, maintenance, and expansion of the facility is transferred to related organizations. This has occurred indirectly through publishing of yearly reports on the facility’s website: www.anl.gov/nse/metl and directly via on-site and remote meetings. Many suppliers have contacted the METL team for consultation as they plan to respond to request for proposals from ARDP awardees. The experimenter’s guide (working document) on the METL website has also been a valuable resource for current future clientele for conceptualizing their test equipment.

The METL facility has partnered with five universities through the Nuclear Energy University Program (NEUP). A recently completed project involved demonstrating fiber optical sensors for measuring sodium flow rate on METLs primary loop. Three active projects aim to improve structural health monitoring using technologies with different principles of operation. An experimental electromagnetic acoustic transducer (EMAT) was deployed to test vessel 1 for (Figure 13, left) for in-situ operation and preliminary self-powered wireless strain sensors (SPWLSS) were installed on test vessel 6’s piping system (Figure 13, right). An industrialized version of the SPWLSS and a Micro-Electro-Mechanical System (MEMS) acoustic emission sensor will be demonstrated on test vessel 6 piping in FY 2025. METL crew members have assisted a newly awarded NEUP project throughout 2024 which utilizes laser-induced breakdown (LIBS) spectroscopy to measure sodium impurities. In future years, the METL team will assist with the installation and operation of this technology at the flagship facility.

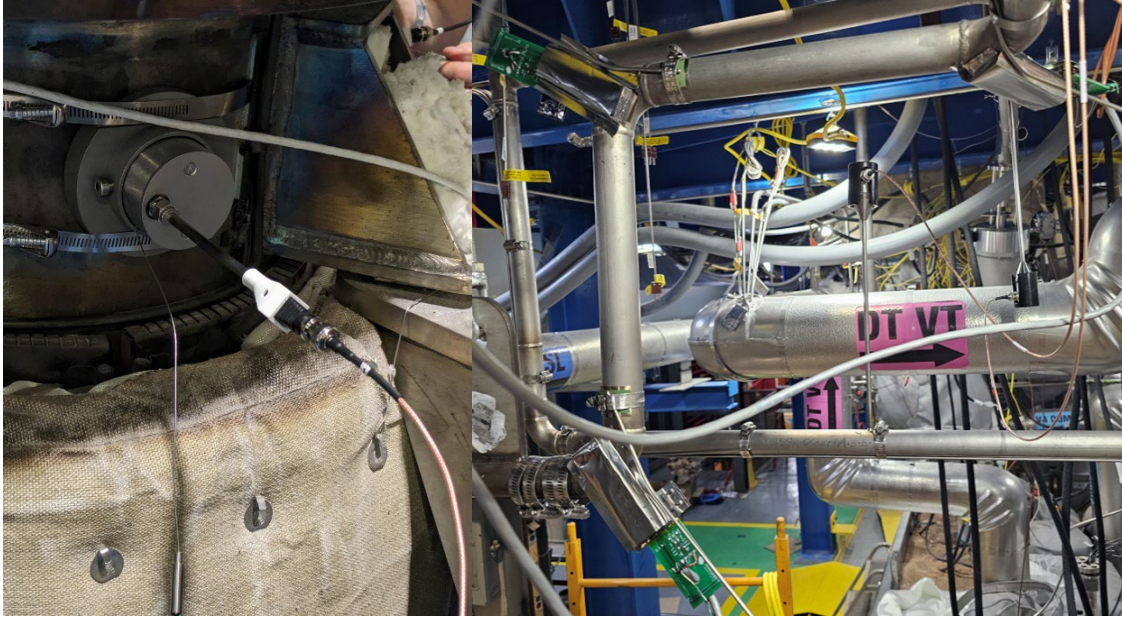


Figure 13. NEUP Project Installations, EMAT (left) and SPWLSS (right).

3.4.3 Outreach Efforts

METL hosted numerous tours throughout FY 2024. The facility and its' mission were displayed to members in academia, industry and government. Notable visitors were the American Nuclear Society President – Lisa Marshall and Principal Deputy Administrator of the National Nuclear Security Administration – Corey Hinderstein. METL team members also supported the Modeling, Experimentation & Validation (MeV) School by providing tours to its' attendees. Representatives from Idaho National Laboratory, AALO, and NA-211: International Nuclear Safety group also visited METL in FY 2024.

4. METL EXPANSION

GTA and THETA are installed in an 18” and 28” test vessel, respectively, which represents two of the available four test vessels at METL. Starting in late FY 2025, the remaining two test vessels are expected to be occupied for several years as more test articles are developed by Industry and DOE’s Advanced Reactor Technology (ART) development program. Either a Gripper Test Assembly (GrTA) or Flow Sensor Test Article (F-STAr) will occupy the other 28” test vessel and if GTA and the STB are inserted into the 18” test vessels, METL will have a “no vacancy” status. METL was designed to accommodate eight test vessels; the original four test vessels were installed during Phase 1. Effort to expand METLs testing capacity (phase II) has been incrementally underway since FY 2021, with the receipt of a 5th 18” test vessel. While installing this vessel, two additional 18” test vessels along with their support structures have been received as well.

4.1 Test Vessel 6

The fifth test vessel to be installed was placed in the location of Test Vessel 6 (V6) as the area for test vessel 5 is occupied by THETA’s secondary system. The upgrade of ANL’s Advanced Photon Source and fabrication of Sodium Material Test 3 strained Argonne welding resources during FY 2024. Furthermore, there are additional complexities with installing a new subsystem onto METLs flagship facility which operates 24/7. METL crewmembers were responsible for maintaining and operating the flagship facility while concurrently supporting its’ expansion. All the conductors which energize METLs existing and future heaters are routed through a 14x14” wire trough. Prior to pulling conductors out of the wire trough and landing the conductors on their feed and load terminals, an energized electrical work permit (mode 3) was required due to access the raceway and enclosures with energized electrical equipment. A mode 3 permit is valid for a maximum of two months, must have just cause (de-energizing must be impractical/impossible not just inconvenient) and must be signed by subject matter experts, directorate COO and safety leadership.

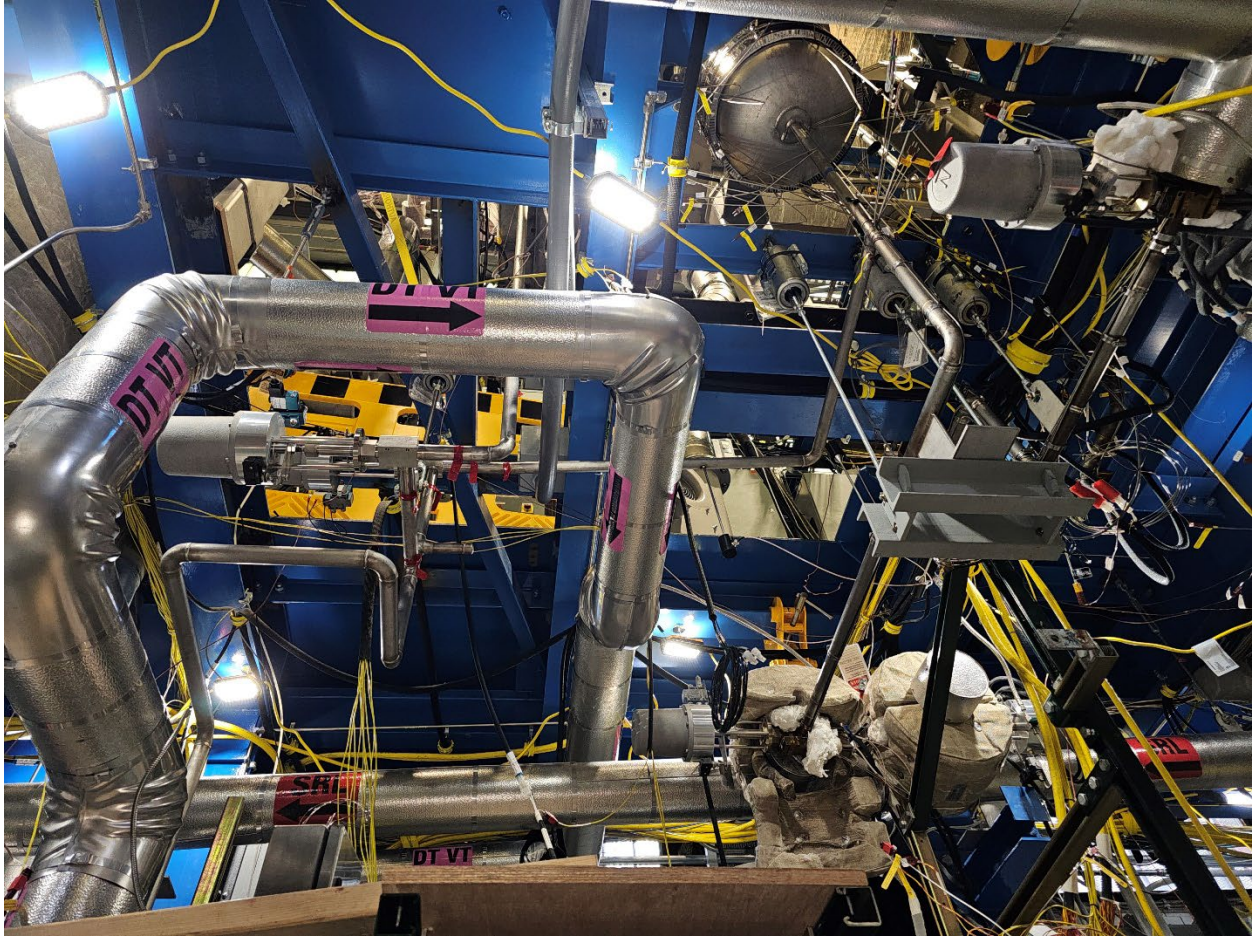


Figure 14. V6 Piping Awaiting Radiography.

4.1.1 Dump Tank Lever Sensor Removal

A differential pressure level sensor (DPLS) was installed in the dump tank to measure sodium height during the transfer of sodium from (15) 55-gallon drums into the dump tank and calibrate an inductive level sensor. Port “N” on the dump tank was chosen as it was not a dip tube and was in the axial centerline, allowing the exact level of the sodium in the dump tank to be measured. Port “N” was also designated as the V6 dump line connection. Moving this connection for Test Vessel 6 drain line would require a piping re-design, potentially triggering a reevaluation of ASME B31.3 pipe code. The costs associated with a re-design and minimal value obtained from measuring sodium level in the dump tank using the differential pressure sensor motivated the extraction of the DPLS.

The operating principle of the DPLS requires a dip tube for bubbling argon to the bottom of the dump tank. Ideally, equipment would be removed from a sodium service component while it is frozen but the presence of the DPLS dip tube prevented this approach as it would be “stuck” in the frozen sodium. Therefore, the removal of the DPLS had to be removed while the sodium remained molten. The dump tank temperature was reduced to 125°C and was isolated from the rest of the METL flagship facility. Argon cover gas pressure was lowered to ≈ 1 psig. A mezzanine deck plate was removed, and a confined-space winch was placed over the opening. The winch was attached the DPLS, the mechanical connection was removed (i.e., 1-1/2” grayloc) and the winch was operated to slowly raise the DPLS out of the dump tank (Figure 15, left) while purging argon. Once the DPLS was clear of the port it was left suspended while operators installed a blind hub and torqued its bolts (Figure 15, right) to the proper torque specification. The DPLS was then pulled through the deck plate opening. The team proceeded to

decontaminate and dispose of the DPLS, reinstall deck plate and set the dump tank to its' normal operating conditions.



Figure 15. Differential Pressure Level Sensor Extraction (left) and METL Crew Members Installing Blind Grayloc Hub to Port (right).

4.1.2 Test Vessel 6 Instrumentation and Control

Alluded to earlier, funding availability forced the METL flagship facility to be constructed in phases. Challenges associated with augmenting an operating plant influenced the decision to install instrumentation and control (I&C) capable of supporting not only V6 but the remaining three test vessels as well. Through this planning exercise, it was thought that the existing vessel power enclosures only have enough vessel heater zones to support one additional test vessel after V6. However, review of the power enclosures reveal there is sufficient power and space to reconfigure the vessel power enclosure so the entirety of the test vessels can be supported. However, an entire shut-down of METL would be required or another mode 3 energized electrical work permit would need to be issued.

Three additional data acquisition chassis and seven thermocouple umbilical enclosures (Figure 16 left and right, respectively) were installed. This hardware adds an additional 408 thermocouple, sixteen digital input, and sixteen digital output channels. Unique to V6, commercially available acoustic emission (AE) instrumentation was installed in FY 2023 for structural health monitoring (SHM). The METL team hosted the AE manufacturer's lead engineer for a week to provide training on the use of their SHM system as well as data analysis to discern noise versus actual events and identify microfracture signatures and their different modes.

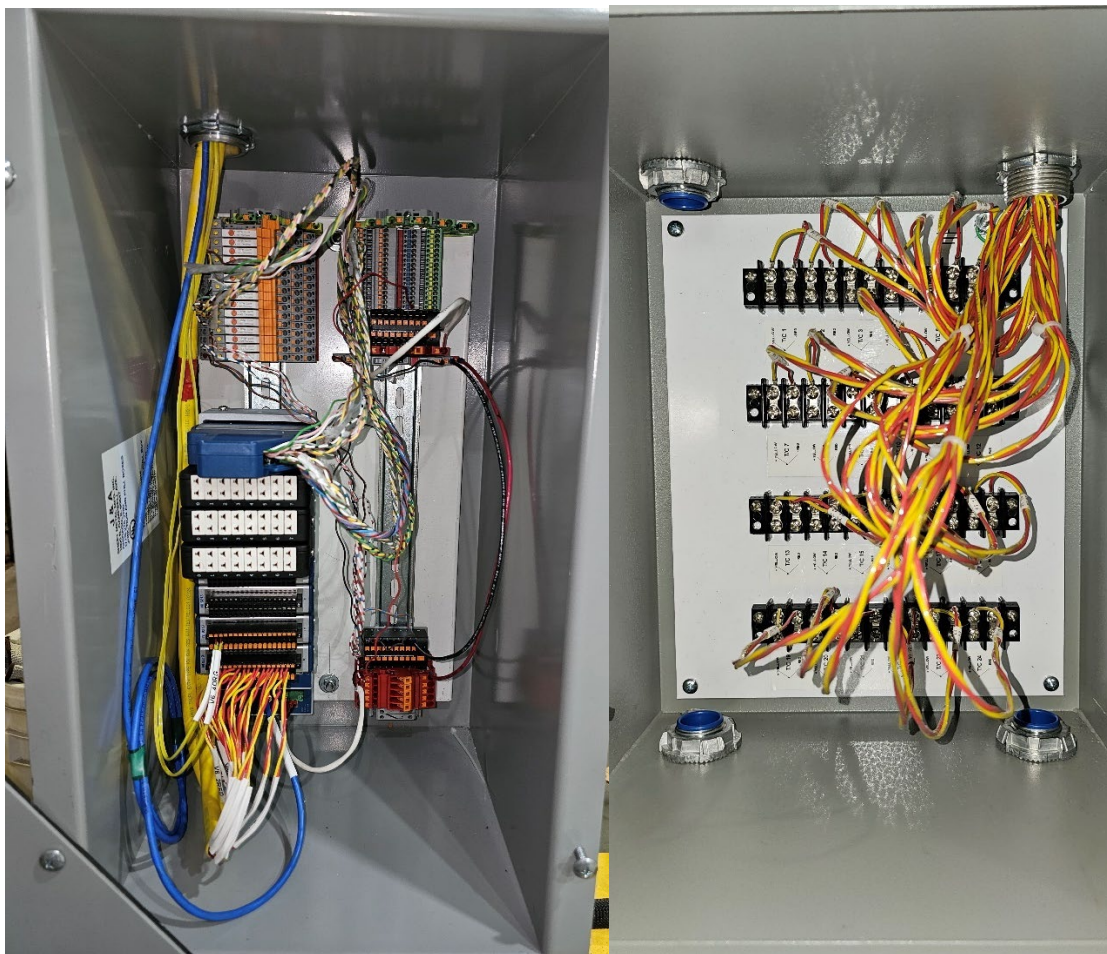
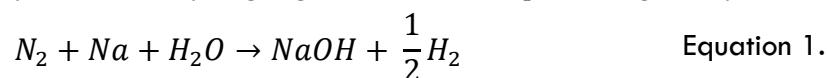


Figure 16. Data Acquisition Chassis (left) and Thermocouple Umbilical (right).

4.2 Test Article Cleaning

The Alkali Metal Passivation Booth (AMPB) is typically used for the treatment of residual sodium on test articles that will be disposed as waste. In the cleaning of sodium test articles that will be reused or repurposed for new experiments, different treatment processes are used. The first process is a moist carbonation system whereby carbon dioxide is bubbled through a tank of heated water, maintained at $\sim 80^{\circ}\text{C}$. The carbon dioxide picks up the water vapor and is transported to a vessel holding the test article. The residual sodium on the test article reacts with the moist carbon dioxide producing sodium bicarbonate and hydrogen gas. While extremely effective in general, the downside of this carbonation treatment is that the sodium bicarbonate builds up on the surface of the sodium and acts as a diffusion layer that slows the reaction process. In addition, the sodium bicarbonate density is less than sodium so it occupies about five times the volume which can hinder the equipment disassembly process if sodium bicarbonate gets compacted into the equipment.

Another method that is used in sodium passivation is the wet-vapor Nitrogen (WVN) that uses controlled mixture of water vapor (steam) and the inert gas Nitrogen to react with the remaining sodium on test articles producing sodium hydroxide and hydrogen gas. The reaction equation is given by:



The benefits of this sodium cleaning process are that it is capable of treating the residual sodium more quickly and the resulting sodium hydroxide does not expand and hinder the test article disassembly. In addition, this method is also commonly known and used in industry, and the users of the METL facility will develop expertise in its usage. To support this system, a more expansive heating system is required to maintain the reaction vessel where passivation takes place at an elevated temperature (150°F-170°F), so passivation reactions take place, and the temperatures are high enough such that steam condensation does not occur and the temperatures are low enough such that sodium hydroxide corrosion of test article metals does not occur.

The design and procurement of the WVN system components was begun in late 2023. The design of the WVN system was the first METL experiment to follow the analysis process outlined in the new Argonne Design Manual. A schematic of the initial design for the WVN system is shown in Figure 17. After the arrival of the principal components in Spring 2024, the assembly of the WVN experiment is underway as of Summer 2024. The mixing control system, Figure 18, is a custom-built programmable logic controller, built by Process Control Solutions, that generates and controls the steam-nitrogen mixture. The water storage, gas inlet manifold, and mixing control units have been installed, Figure 19. The WVN mixture will be transported to the reaction vessel via the heated transfer line already in place. The reaction vessel and monitoring system for off-gas effluents are the same as those of the carbonation system. For the remainder of CY2024, the WVN system will be fully assembled and tested using sodium samples.

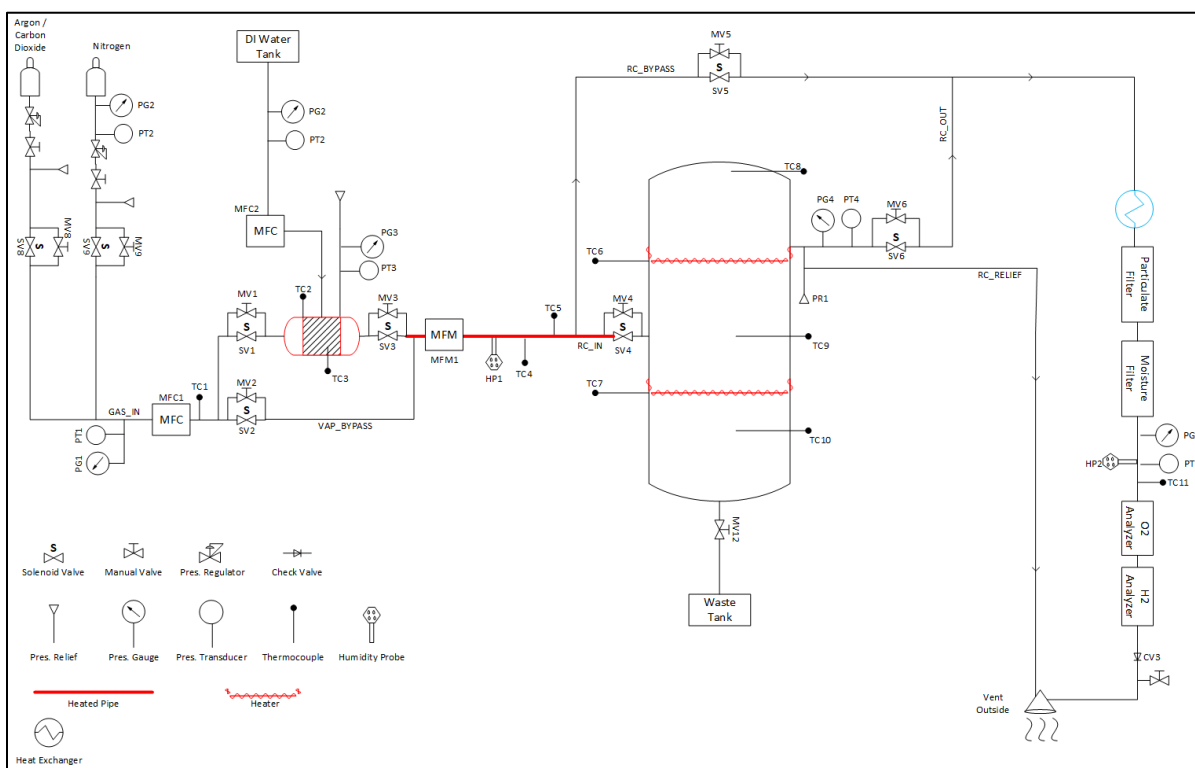


Figure 17. WVN P&ID



Figure 18. WVN Mixing Control Unit and Computer



Figure 19. Nitrogen gas and water vapor mixing system (left) and gas supply manifold (right).

4.3 Mezzanine Extension - West

The METL team worked with Architectural and Engineering (A&E) firms in FY 2024 for an additional mezzanine extension. Referencing Figure 20, the original METL flagship facility mezzanine is shown in the blue area. A southern extension was completed earlier (purple area) and the A&E firm expects completion of the western extension (green area) in 2024. The southern extension proved vital for supporting GTA and THETA simultaneously. The western extension is needed for accommodating additional test articles from industry but is also necessary for relocating the carbonation/wet vapor nitrogen system (CO₂/WVN). Currently, the CO₂/WVN systems occupy the eastern end of the METL mezzanine and the northwestern corner of the NSTF mezzanine. The installation of test vessels 7 and 8 will require moving CO₂/WVN hardware off of the METL mezzanine and the western mezzanine extension can provide the space to do so.

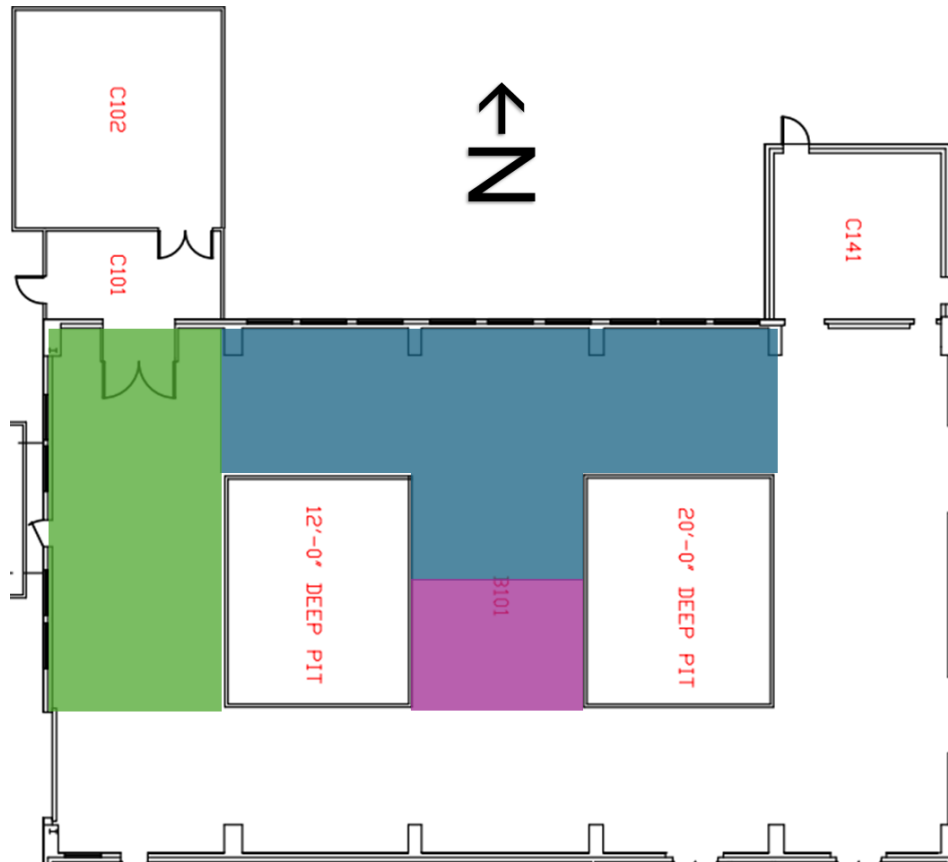


Figure 20. High Bay Floor Plan. Original Platform (blue), South Extension (purple) and West Extension (green).

4.4 Client Infrastructure

Integrating an additional three, potentially four test vessels requires the necessary supporting infrastructure and services. METL provides 100A of 1 Φ 240VAC from a panelboard in room B162 and a ½” argon “tap” from its’ 1000L micro-bulk system to every test vessel. Each test vessel has a switch-rated 100A receptacle to provide power to experiments as well as a ½” quarter turn plug valve to feed argon to various components. As shown, these services are secured to blue cantilever arms on METLs’ flagship facility to keep the floor uncluttered in the vicinity of the test vessels. Installing increasingly complex experiments (such as THETA and F-STAr) into METLs’ test vessels has also motivated the repurposing of equipment and space to facilitate their operation.

4.4.1 Power

Power is the most required service by an experiment for energizing motors, data acquisition, and ancillary heaters. To support future experiments, four 3 Φ 240VAC switch-rated receptacles were installed on the north wall of the METL mezzanine near test vessels 1 through 4. These receptacles are fed from a dedicated 100A bus plug on a 3 Φ - Δ , 400A, 240VAC bus duct. Diversifying voltage sources allows utilization of existing infrastructure, reducing the cost and time associated with installing a new 3 Φ 480VAC bus duct, panelboard, or routing power from the southern end of the high bay.

Single phase 240VAC receptacles identical to those for test vessels 1 through 4 were installed for test vessels 5 through 8 in FY 2023. Supply chain constraints prevented the installation of the transformer and panelboard in FY 2023. The hardware was received in late FY 2024 and the electrical contractor was able to finish the project with the installation of the 480:240 transformer and panelboard (Figure 21). A power

meter monitors the energy on the feed to the 240 panelboard providing data for determining if future loads can be fed from this panel. Each circuit breaker is also equipped with a shunt which allows remote operation enabling the METL control program to open the circuit if needed.



Figure 21. New Transformer and Panelboard for Experiment Support.

The north wall of the high bay is valuable space due to the proximity to the test vessels. This area is primarily used for hanging electrical enclosures to support METL operations as well as experiments. Post-installation of GTA and THETA, a need to free-up the north wall became evident. In FY 2023, disconnects on the north wall were removed to make space for an electrical enclosure for a fast reactor developer's test article. AC power of various voltages and argon were previously identified as common services among test articles. Instrumentation and control (I&C) is also a building block for test apparatus and the majority of I&C requires DC power. A 500A 24VDC power supply (Figure 22) was installed in FY 2024 to consolidate the various smaller DC power supplies for METL as well as provide (10) 20A

24VDC receptacles for experiments. The DC power supply is fed from a 20kVA UPS which is fed from an automatic transfer switch allowing power to be supplied from a 100kW diesel generator in the absence of utility power. Providing this resilient DC power service to experimenters eliminates the need for each test apparatus to incorporate their own DC power supplies, redundancy modules, and UPS. This reduces the number/size of electrical enclosures on the north wall and also simplifies lock-out-tag-out as their AC power and DC power enclosures can be completely segregated.



Figure 22. Centralized 24-Volt DC Power Supply

5. ALKALI METAL INVESTMENTS

Constructed in the late 1950s, Building 308 (B308) was built to conduct alkali metal research and technology development, and it continues to support this mission today. Maintaining and reinvesting into its infrastructure is essential to ensure a safe and holistic alkali metal research program. Previous fiscal years efforts included replacing the roof, painting the siding, increasing the electrical capacity of the power coming into the building from 1,000KVA to 2,000KVA, high-bay air conditioning, renovating the alkali metal scrubber, rebuilding the superheated steam system and replacing the 100kW redundant power supply/generator. In FY 2024 incremental effort was placed on alkali metal support hardware such as building a dedicated sodium transfer console, disposing of legacy sodium service equipment, and reclaiming vacant areas.

5.1 Sodium Transfer Console

METL's dump tank was filled by transferring fifteen 55-gallon drums of sodium. This was achieved by creating a drum heating system using parts on hand. Future sodium transfer activities were expected such as the material testing loop (SMT-3), decommissioning activities, and the filling of 30-gallon pressure vessels. The ongoing need to transfer sodium and high-hazard nature of the operation motivated the fabrication of dedicated equipment. A sodium transfer console (Figure 23) was created to consolidate hardware for sodium transfers. The sodium transfer console (STC) is constructed of (3) enclosures, the pedestal (bottom), desk (center), and top console (top).



Figure 23 - Sodium Transfer Console (NaX).

The STC has a pneumatic system mounted to its pedestal as shown in Figure 24, left. The pneumatic system has a back pressure and tank blanketing regulator for precise inert gas pressure control of the origin container (vessel filled with sodium). The door of the pedestal is 50% occupied, providing ample space for an identical system to control the pressure on the destination container (vessel requiring sodium). A DC power supply and power distribution unit are mounted to the inner sides of the pedestal leaving the inside, back panel vacant for future electronics to support larger heaters. The rear of the pedestal has receptacles mounted to it, 75% of the receptacles can be remotely energized/de-energized while the 25% are constantly on when plugged in; providing versatility as heaters can be controlled with the sodium transfer console program or with their own internal controls.

The desk portion of the STC contains processors for the scales used to weigh the origin and destination containers. A majority of the desk is empty and is used to store procedures/documentation. The top console of the STC has a touch-screen monitor which is connected to a micro-PC. The instrumentation, control, and micro-PC are housed inside of the top console on a back panel as shown in

Figure 24, right. The top console of STC has all the equipment necessary to support both the sodium supply container and the destination tank or vessel.

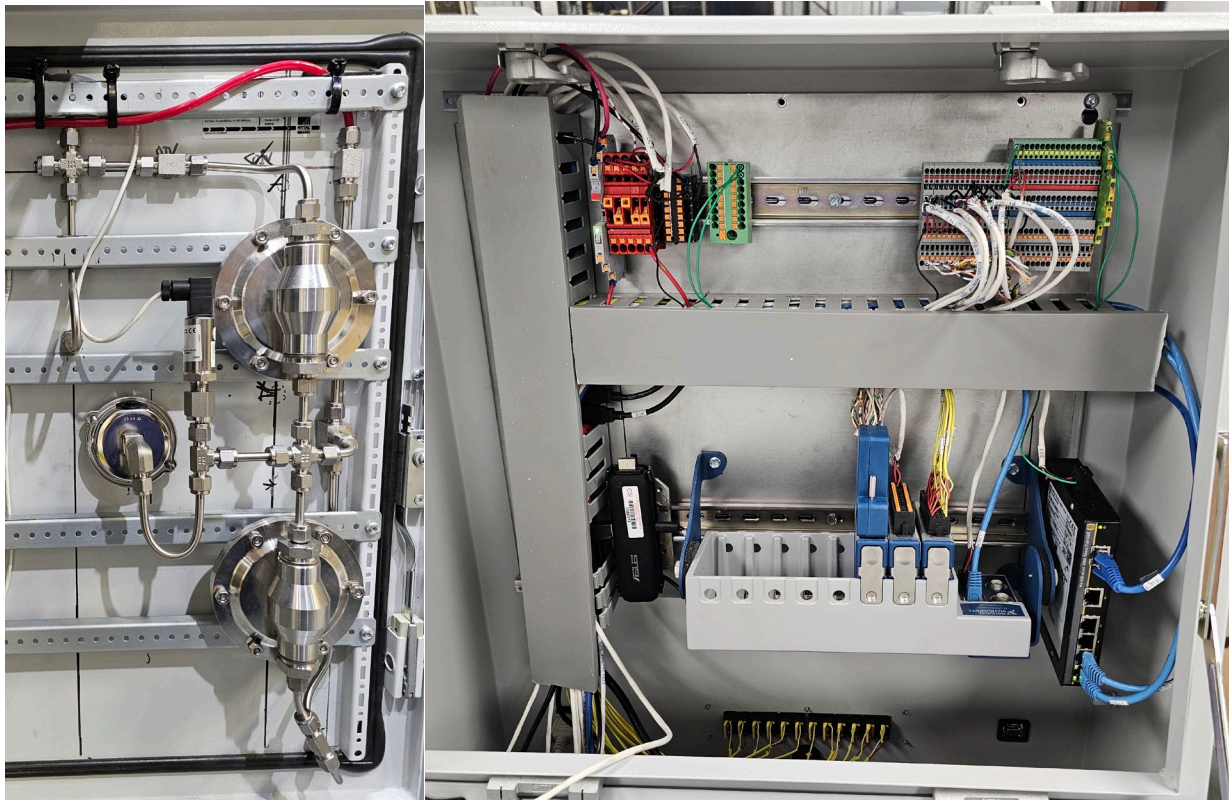


Figure 24 - NaX Argon Control (left) and I&C (right).

5.2 Alkali Metal Scrubber

The METL team has taken a proactive stance on B308 Scrubber rehabilitation by ordering replacement equipment as it dates to the late 1970s. The B308 scrubber is a part of the safety posture for the METL facility and is critical for cleaning/disposing of sodium service components. Subsequently discussed in the section 5.2.1, the B308 scrubber has not been operated this extensively since the transfer of sodium into METLs dump tank. After one post-burn operation, white streaks were noticed on one of the inlet ducting joints (Figure 25, left). Further inspection of the joint revealed yellow residue, rust accumulation, and broken welds on the reinforcement rings (Figure 25, top right). This ducting is being replaced with the project expected to be completed in September 2024.



Figure 25 - Leakage from Duct Elbow (left), Broken welds on Elbow (top right), and Patched Expansion Joint (bottom right).



Figure 26 – Construction Crew installing new ductwork

5.2.1 Decontamination

The primary method to dispose of bulk, non-radioactive sodium is to burn the contents of sodium service equipment in the B308 burn stall which is ducted to the B308 alkali metal scrubber. A total of 11 burn operations were completed in FY 2024. Each burn requires at least two personnel for an entire day (disregarding time required to plan/prep for the burn) as prior to burning, many components must be cut into sections (Figure 27) to expose enough sodium surface area to ensure a complete burn.

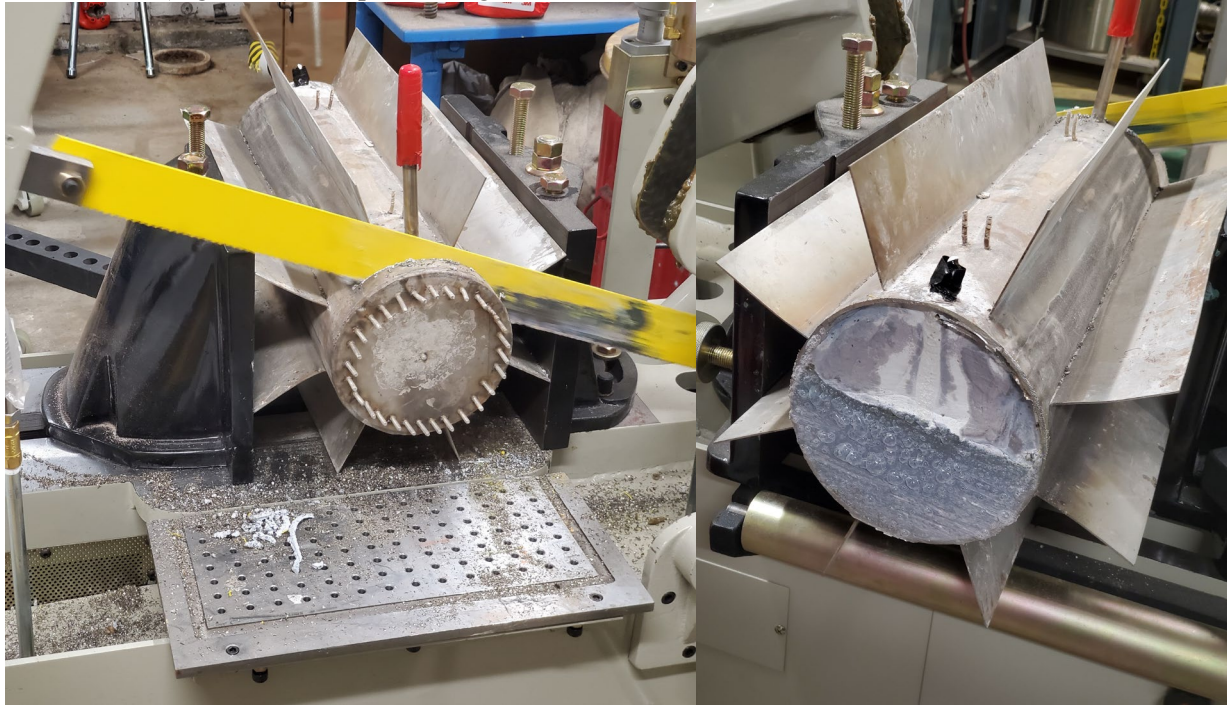


Figure 27. Hacksaw Cutting End Off of Legacy Cold Trap (left) and Exposed Sodium (right).

Various sodium service components were successfully decontaminated including cold traps, dump tanks, valves, piping, and a heat exchanger. Larger components required a dedicated operation (Figure 28) whereas smaller components can be individually drained and burned together (Figure 29). In total, roughly 30 gallons of sodium was disposed of in FY 2024. Alkali metal infrastructure in the U.S. is rare and many reactor developers have expressed interest in the burning process and other decontamination methods. The hazards associated with handling alkali metals limits the work to only highly trained personnel, thus the METL team produced a preliminary video on the burning/steaming operations which can be accessed with this url: <https://www.youtube.com/watch?v=pB9cBDAkxtk> or by searching “Alkali Metal Decontamination”.



Figure 28. Legacy Dump Tank Contents on Fire (left) and Rinsing Dump Tank with Water Post-Burn (right).



Figure 29. Various Sodium Service Components on Fire.

6. SUMMARY

This FY2024 year report provided a summary for the status of the METL facility as of early September 2024. A tremendous amount of effort has gone into demonstrating METL’s capabilities for another year, continuing with experimentation in METL, upkeeping a preventative maintenance/corrective action program, building upon current functions, and supporting future experimenters. The METL crew continues to work on expanding METL into Phase II, grow Argonne’s alkali metal capabilities, developing and qualifying potential Sodium Fast Reactor technologies, and working to ensure METL remains a state-of-the-art testing facility by investing in new talent, components, and methods.

As of the writing of this report, METL is drained and the dump tank frozen to support Test Vessel 6 installation. After the piping welds undergo NDE, we will be heat tracing and insulating the piping and Test Vessel 6. The dump tank will be heated, and the sodium melted. The facility will be refilled and made operational. After planning is complete, the cold trap system will be frozen, and the cold trap replaced with the new one. That new cold trap will be welded into the cold trap system and then brought on line.

In conclusion, METL is a high-temperature sodium test facility, designed with an emphasis on testing flexibility to support near endless designs for experimental apparatus and has proven its ability to demonstrate Sodium Fast Reactor and other alkali metal technologies as well as further the understanding of associated phenomena.

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