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Mechanisms Engineering Test Loop (METL) Operations and Testing Report – FY2023

September 2023

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Argonne National Laboratory

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REVISION LOG

Revision No.	Date	Affected Pages	Description

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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 FY2023. The METL facility had a very successful fifth year of operations while supporting the testing of multiple test article experiments in the facility – its first year of more than one concurrent operating experiment at METL. METL facility continued supporting the Gear Test Assembly (GTA) testing and hosted its first 28" test vessel experiment, called the Thermal Hydraulic Experimental Test Article (THETA). THETA was inserted into Test Vessel 4 and operated for the very first time in sodium. The METL team supported the installation of the THETA secondary sodium system – which is expected to be completed in September 2023. 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 FY2024 and FY2025, respectively. In addition, the new steam system for the B308 alkali metal passivation booth was made operational and a new blower for the scrubber finally arrived. These new scrubber components will ultimately replace the existing scrubber components when those 1970's era components require replacement. The B308 scrubber had to be placed in emergency mode only to support the replacement of the ductwork that connects the cyclone separator to the blower. The original ductwork had extensive corrosion after 50 years of service at the location where the ductwork connects to the blower via a vibration isolation system and required replacement.

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 (1) 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.

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.

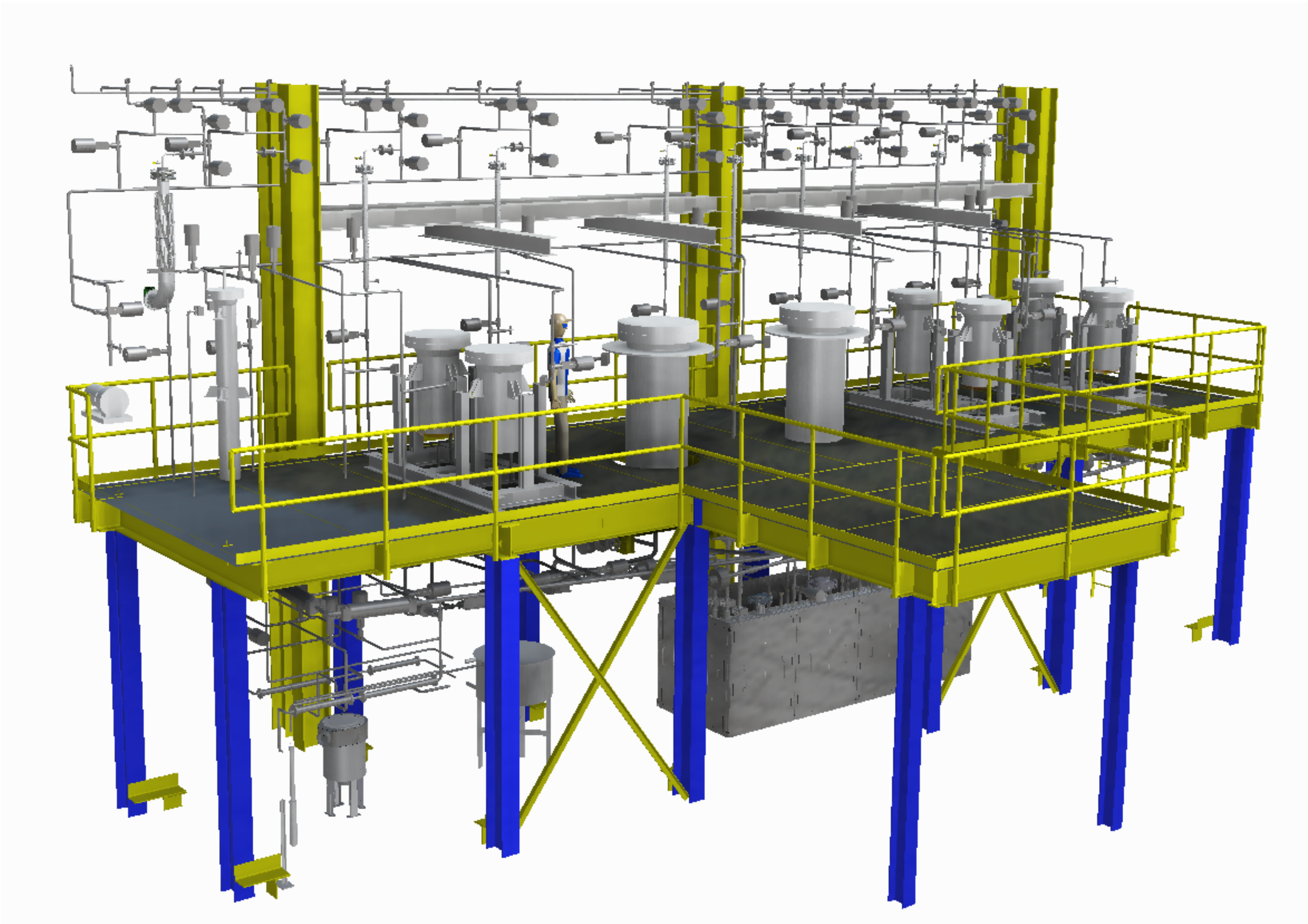

Figure 1– A 3D model of the Mechanisms Engineering Test Loop showing Phase I and four additional test vessels.

1.2 METL Fiscal Year 2023 Accomplishment

The METL facility and team had a successful fifth 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 two test articles, the Gear Test Assembly (GTA) and the Thermal Hydraulic Experimental Test Article (THETA). 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 FY23:

- The METL facility performed its first startup five (5) years ago when sodium was transferred (via an argon push) from the dump tank to the main loop and vessel system on September 19, 2028.
- METL has maintained its sodium in a hot molten state continuously (either flowing or static) for almost 4.5 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.
- Multiple sodium flowing and purification 'batch' campaigns were performed. METL is normally maintained in a hot molten state 24 hours a day, seven days a week.
- Completed the business operating plan in NRIC user Guide template in July 2023 (M2RC-23AN0206024)
- Completed the METL Facility Annual Operations and Testing Report – September 15, 2023 (M2RC-23AN0206022)
- Completed the Report of METL Inductive Level Probe Development – March 2023 – (M3RC-23AN0206023)
- The METL team has continued to confirm the functionality of the sodium purification cold trapping system and has purified the METL sodium down to 150°C, an inferred 5 ppm oxygen level. During the purification runs and over the course of a few months, signs of an oxide plug in the cold trap surfaced, However, after heating up the cold trap to 170°C temperature the pressure differential and flow rate values went back to normal. At some point in time, the cold trap will be loaded with impurities to the degree that it can no longer function and will need to be replaced.
- Upgrade to the Building 308 scrubber system controls was implemented.
- A new Building 308 scrubber system blower was received and placed into storage.
- The 28-inch flexicask was tested in preparation for extracting the THETA test article. The flexicask support plate was modified to accept a strongback-type rigging system that acts as the interface between the flexicask and the B308 crane.
- Maintained alkali metal program support equipment (Building 308 Scrubber, Superheated Steam System, 18-inch & 28-inch Flexi-Casks, Carbonation System, Glovebox and Qualifying Stations)
- Performed the sixth GTA test article extraction using the 18-inch flexicask from Test Vessel 1 to the carbonation vessel
- Performed the sixth GTA cleaning using moist carbon dioxide followed by cleaning with ethanol and water, and by disassembly of the GTA on the 18-inch test stand
- Inserted THETA into Test Vessel 4 (this was the first 28-inch test article that was inserted into METL and Test Vessel 4, so it was accomplished without the flexicask)

- Supported the THETA primary system testing
- Supported the installation of the THETA secondary system
- Extracted THETA from Test Vessel 4 using the 28-inch flexicask system in order to install metal insulation around the THETA test article core and intermediate heat exchanger.
- Performed the first cleaning and disassembly of the THETA test article.
- Performed a re-insertion of the THETA test article into METL Test Vessel 4 using the 28-inch flexicask
- Supported the installation of Test Vessel 6. Most but not all of the piping segments were fabricated and then welded into the piping system. The safety paperwork necessary to perform this work was completed that includes the removal of the differential pressure sensor from the dump tank. This component will need to be removed from the dump tank while the dump tank is hot and molten. Preparations are underway to perform that work in FY24.
- Supported the radiography of the welds on the METL Test Vessel 6 piping installation.
- 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.
- Supported the radiography of the welds on the THETA secondary sodium system
- 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.
- Purchased a replacement B308 scrubber underground storage tank. METL cannot operate without a functional oxide scrubbing system.
- Completed the design of an extension of the METL platform to increase the usable floor space for METL operations and maintenance.
- The legacy steam generator test facility was removed from B308 to open up some space for other test facility installations.
- The METL Experimenters Guide was published for first time after internal and external reviews.
- In January 2023, a break in the ducting of the B308 scrubber system (the part from the cyclone separator to the 30,000cfm exhaust fan) was found. The old carbon steel ducting was replaced with stainless steel ducting.
- The ART Fast Reactor Program review meeting was held the week of December 12, 2022. Tours of the METL facility was provided to meeting participants.
- Attended the Gen-IV Component Design and Balance of Plant meeting at JAEA, in O'arai, Japan 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 April 2023 at JAEA and was the first in-person meeting of the CDBOP since the COVID Pandemic.
- 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:
    - Terrapower
    - Dr. Kathryn Huff, Assistant Secretary for Nuclear Energy and Dr. Brian Bahran, Assistant Director for Nuclear Security, White House Office of Science and Technology Policy, and Dr. Geri Richmond, Under Secretary for Science and Innovation

  - Oklo
  - Nuclear Regulatory Commission personnel
  - Mr. Sal Golub, DOE Deputy NE-4.
  - Sargent & Lundy
  - Ms. Alice Caponiti, DOE, NE-5
  - Staff from Senate Energy and Water Appropriations Subcommittee and DOE's office of the Chief Financial Officer
  - Dr. Yasir Arafat (INL MARVEL project manager) and personnel from Radiant Energy Group and the Aalo Company
  - ASI program personnel
- A presentation on METL activities was presented at the NRIC annual program review meeting.
- Provided 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 FY2024 at METL Phase II

The METL facility will continue its molten sodium operations in FY2024. In FY2024, we expect to be retesting the Gear Test Assembly (7th 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 and the project to install the secondary system will be completed to allow for the rejection of the heat generation by the THETA primary core. The THETA secondary system will be trace heated, instrumented, baked out, and filled with sodium. 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 heath 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. A section of the piping needs to be connected to the dump tank. Following this connection, the piping system will be complete, and the heaters will be installed, followed by installation of instrumentation and insulation. We will be making preparations for the installation of the third test article. If the third test article is ready (Flow Sensor Test Article), we will be supporting the qualification of this test article for insertion into the METL facility. We initiated the design of a west extension to the METL platform to increase the usable space for METL work. This extension will be installed in FY24. We will continue to collaborate with industry (with the expectation of receiving our first industry sponsored test article for testing in METL in FY24) and support the nuclear energy university program calls for experimentation in METL.

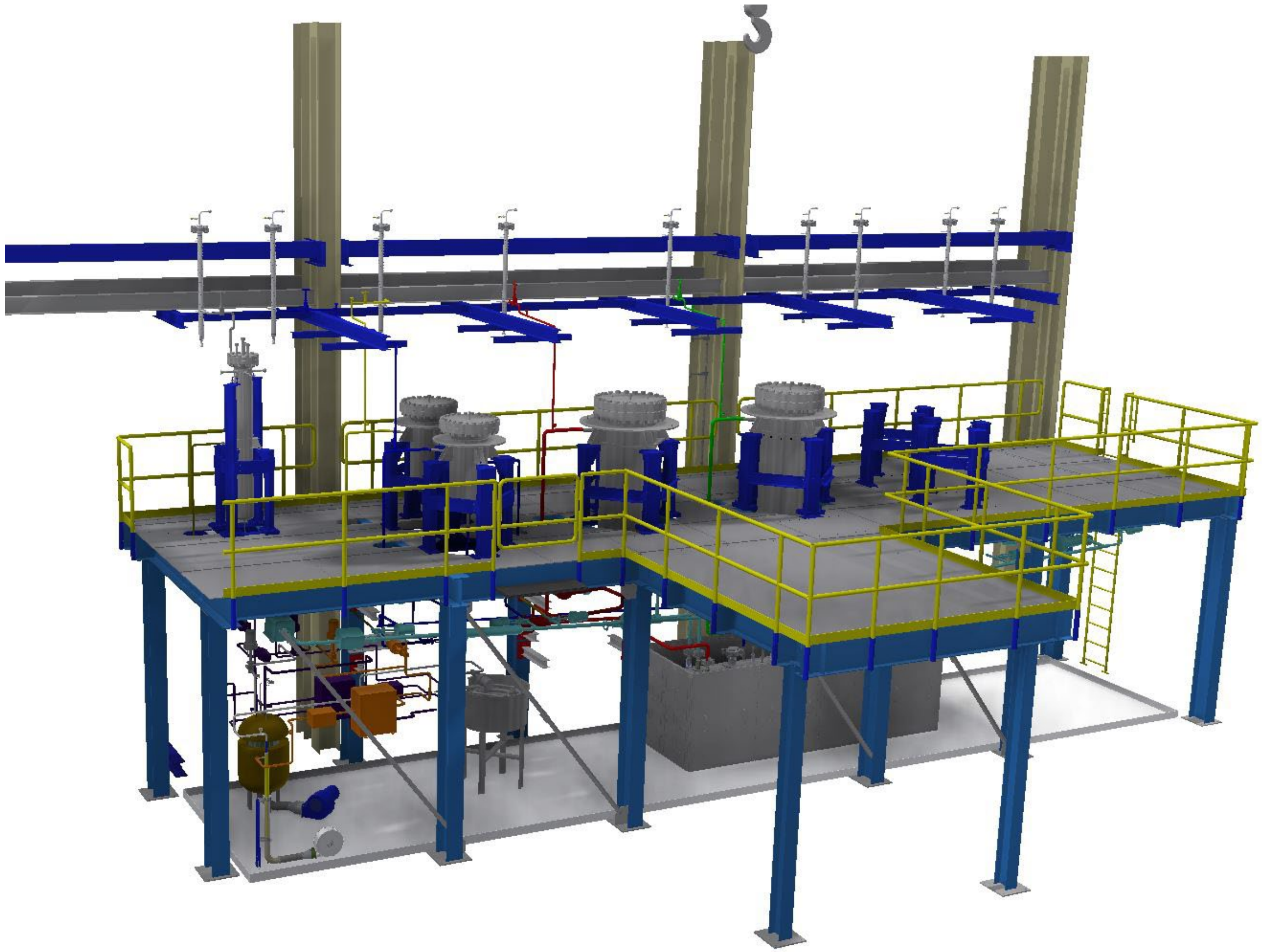

Figure 2 – A 3D model of METL after Phase I was complete.

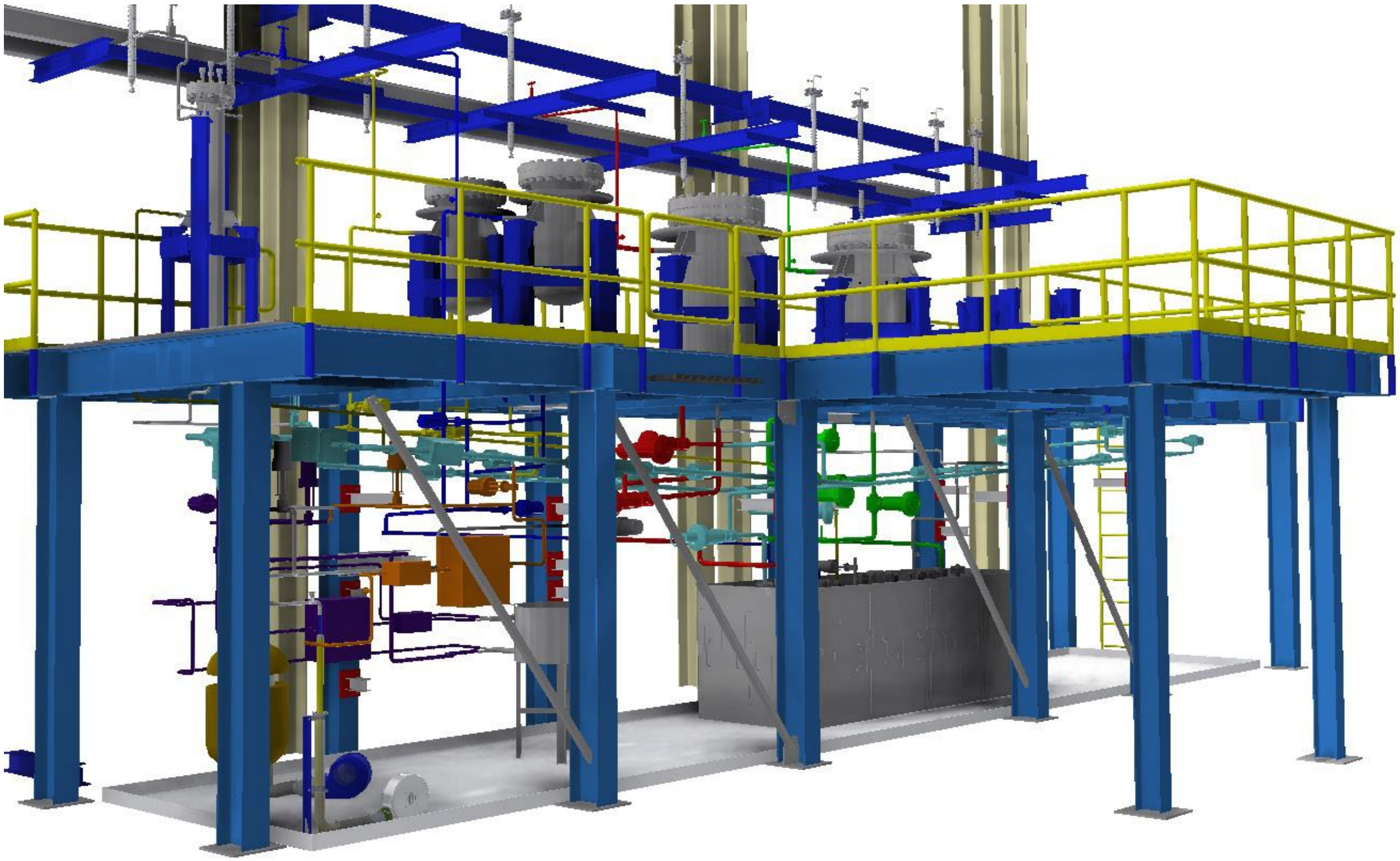

Figure 3 - A 3D model showing the Phase I piping and equipment arrangement underneath the mezzanine.

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 are 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

Following the recovery from a FY22 sodium-oxide plug in the inlet piping to the cold trap, a preventative maintenance work order to run METL's purification system weekly was generated. METL operators pumped sodium through the cold trap at 170°C (≈4.4 Oxygen wppm), a sufficient purity for METL's steady state operating temperature of 300°C. METL's steady state operating temperature is expected to increase in FY24 to accommodate new test articles which will require pumping sodium through the cold trap at 150°C (≈2.2 Oxygen wppm), per their request. In preparation, METL's purification PM was conducted at 150°C. During the purification PM, the pump is fixed at a relative pump speed (PID percentage output) and the cooling air blower varies its' speed to control the cold trap temperature.

Following months of purification PM operations at 150°C, METL operators noticed a gradual decline in sodium flow rate with all other parameters remaining constant. The continued descent in sodium flow rate under constant conditions prompted the METL operators to troubleshoot as conditions were indicative of a sodium-oxide plug forming. A graph illustrating the troubleshooting measures taken on 05/30/2023 are shown below in Figure 4.

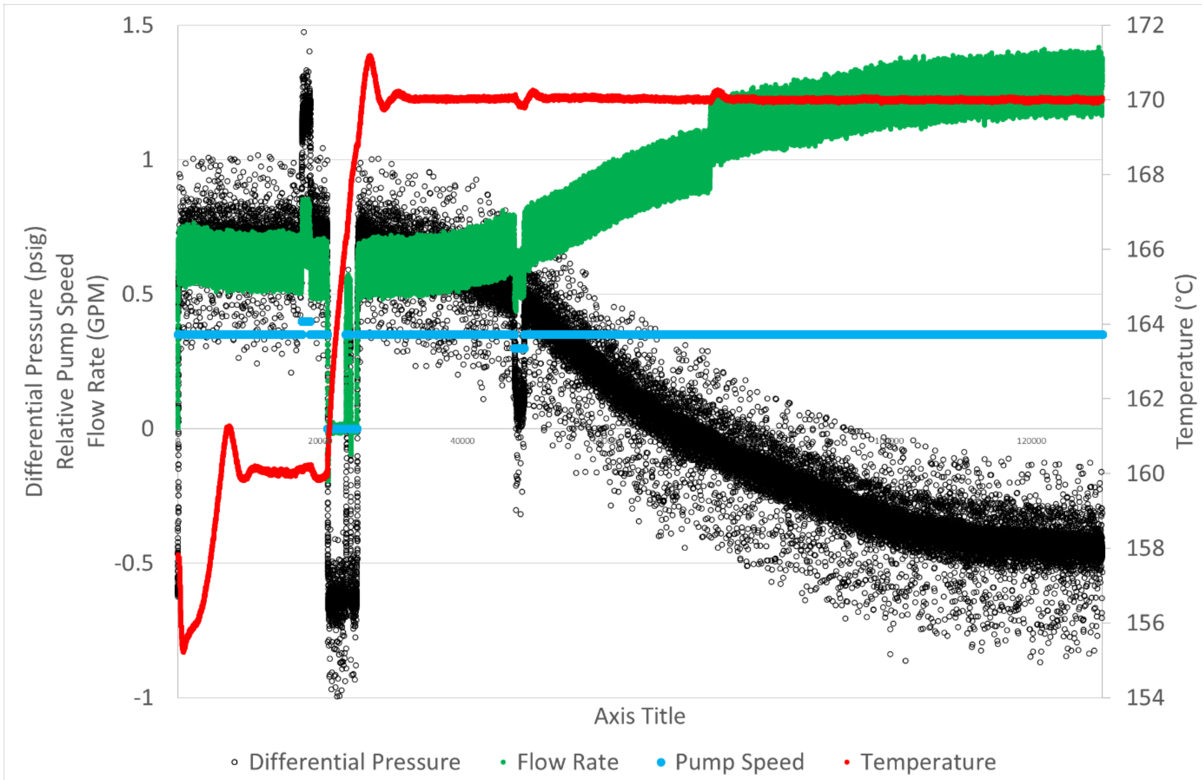

Figure 4. Purification Troubleshooting.

METL operators varied the purification temperature setpoint as well as the relative pump speed to observe the sodium flow rate's response. The issue could be caused by a degrading pump or flow meter signal, but these potential reasons were eliminated by changing the relative pump speed. The sodium flow rate increased with an increase with relative pump speed and vice versa, as expected. It was clear at relatively cooler temperatures; the sodium flow rate has a slightly negative slope while the pump speed is fixed at 0.35 (35%). Operators increased the purification temperature setpoint to its' original 170°C and kept the relative pump speed at a constant. Holding these parameters constant resulted in an increase in sodium flow rate back to historical values and a decay in differential pressure, adding additional evidence of an impending oxide plug.

METL purification PMs were conducted at the original 170°C for a few weeks and then set at the lower 150°C to see if the decline in the observed flow rate could be repeated. Upon a few purification PMs, the decreasing flow rate was observed again, prompting operators to re-return to the 170°C cold trapping temperature. While cold trapping at 170°C, the flow rate increased to expected flow rates (1.1-1.3GPM) for a 0.35 relative pump speed and subsequent METL purification PMs were performed at these conditions. Long term, this issue will have to be addressed, probably with replacement of the cold trap.

3.2 Plugging Meter

The plugging meter is installed in the METL purification and diagnostic system and is used to measure (indirectly) the ppm of oxide and hydride contamination in the METL loop. METL is configured to operate the cold trap and plugging meter in series or parallel as needed. In a series configuration, the cold trap's electromagnetic pump pushes sodium through the cold trap and then the plugging meter. In this purification run, the cold trap's relative pump speed and internal temperature were fixed at 0.3 (30%) and 150°C, respectively. Plugging meter temperatures were oscillated between 115 and 190°C as shown in Figure 5. The differential pressure and flow rate were monitored during this period. Recording the plugging meter's temperature at the flow rates inflection/equilibrium point (flow rate is not decreasing nor increasing) can be used to empirically determine the sodium oxide concentration.

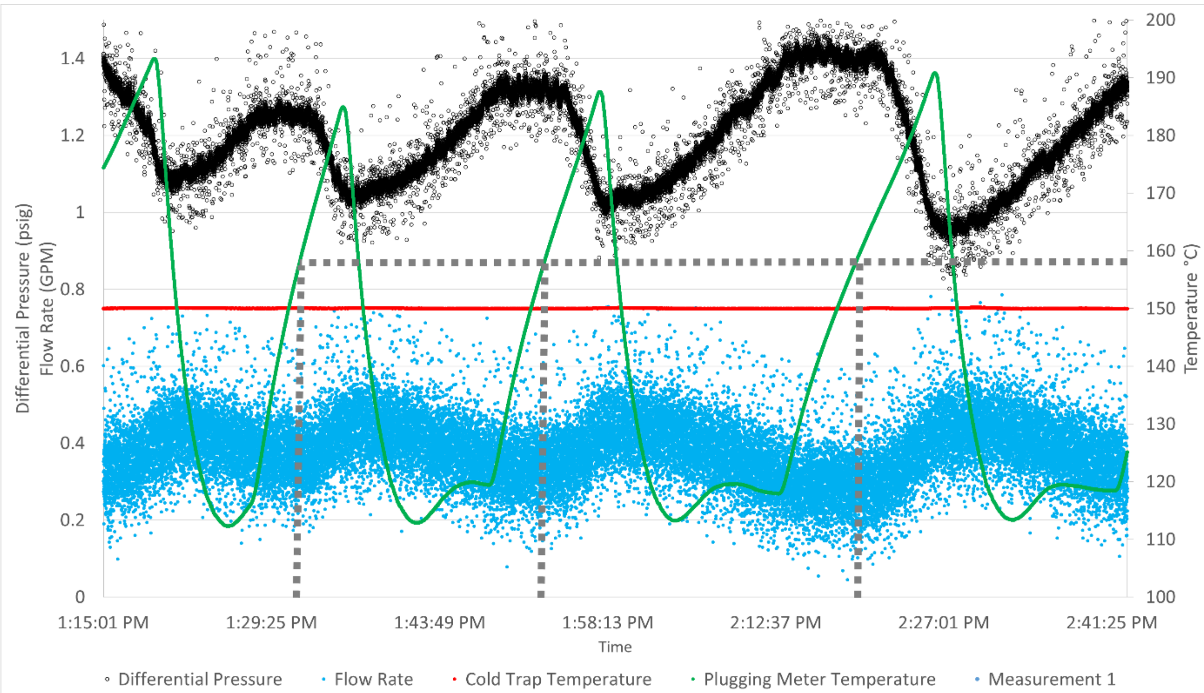

Figure 5. Plugging Meter Results

The flow meter's signal noise introduces difficulties when attempting to precisely identify the inflection point (METL team members are actively pursuing flow meter improvements as described in section 5.3). Inserting a vertical line at the approximate flow inflection point and extending the line until it intersects with the plugging meter temperature indicates the saturation temperature is near 158°C. A theoretically perfect system/operation would have matching saturation and cold trap temperatures, however given the instrumentation uncertainty and scattered flow rate signal, the plugging meter saturation and cold trapping temperatures are within reasonable vicinity of one another.

3.3 Experimental Test Article Support

In FY2023, the METL team supported two active experiments, the Gear Test Assembly (GTA) and the Thermal Hydraulic Experimental Test Apparatus (THETA) in addition to making preparations for future experiments such as the Flow-Sensor Test Article (F-STAr). 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 23.2 million revolutions under various loads equivalent to approximately 37,156 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 #6 and provided periodic sodium purification runs for the GTA. After it was determined that GTA Campaign #6 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 #7 which will be performed in FY24. Using the flexicask, the GTA was inserted into Test Vessel #1 and preparations are being made for testing campaign #7. A full report on GTA FY2023 progress is provided in the reference section (2).

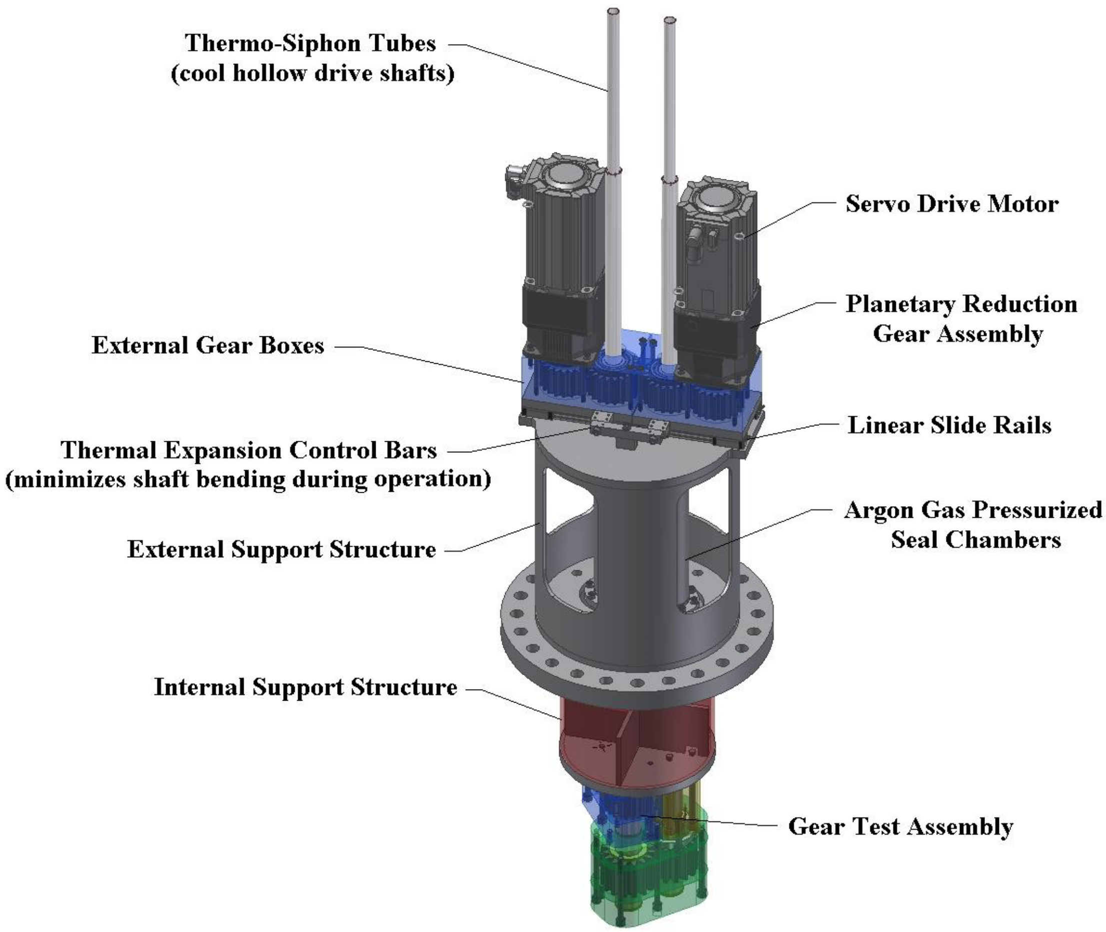

Figure 6 - Overview of the Gear Test Assembly

Figure 7 - Gear Test Assembly - in process of being disassembled following carbonation process. The white power is sodium bicarbonate – the reaction product of the carbonation process.

3.3.2 Thermal Hydraulic Experimental Test Article (THETA) Testing Support

THETA (Figure 9, right) 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 installed in Test Vessel 4 before the test vessel had seen sodium. So, THETA was able to be installed without the use of the flexicask. After THETA was installed in Test Vesel 4, the vessel was heated up to the appropriate temperature for sodium fill. METL team members filled Test Vessel 4 with sodium and proceeded to purify the sodium in preparations for conducting THETA's initial primary system test matrix. During the fiscal year, METL performed periodic sodium purification operations to maintain sodium quality in test vessel 4. Based upon initial primary system testing and some computational analysis, it was determined that THETA needed thermal insulation installed around the electrically-heated core and the intermediate heat exchanger, and thus plans were made for extracting THETA and performing these modifications.

In order to install this thermal insulation, the 28-inch flexicask was used for the first time to extract THETA from a 28-inch test vessel. Test Vessel 4 was drained of sodium and allowed to cool to ambient temperature. The overhead crane and the flexicask was then used to extract THETA and move it over the carbonation tank where the residual sodium on the surface of THETA was reacted to sodium bicarbonate. After about two weeks of sodium cleaning, THETA was then extracted from the carbonation tank and placed on the 28-inch test stand for disassembly.

THETA was disassembled and cleaned of residual sodium. It was an involved process because some of the internal piping had residual sodium. After installation of the thermal insulation, THETA was reassembled and installed in Test Vessel 4. Test Vessel 4 was reheated and filled with sodium. The sodium in Test Vessel 4 was purified using the cold trap down to 150°C and the first test matrix was performed again.

To complete THETA, the intermediate sodium piping system was installed and the piping welds underwent radiography and dye penetrant testing. Most of the welds passed radiography, but two had to be rewelded and recertified. Further details regarding THETA and results from its test matrix are included in its FY23 report (3).

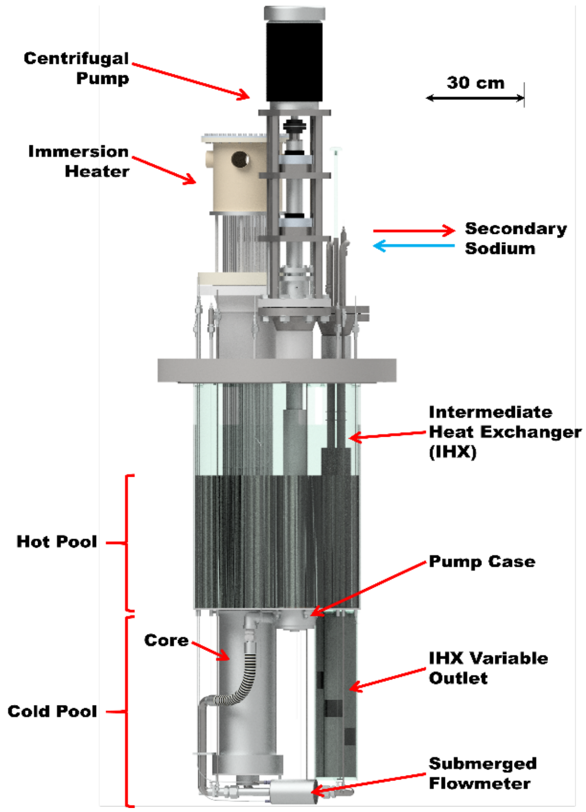

Figure 8 – Thermal Hydraulic Experimental Test Article (THETA)

Figure 9 – THETA Sodium Pool Components in the inerted Flexicask

Figure 10. THETA being inserted into the Carbonation Tank

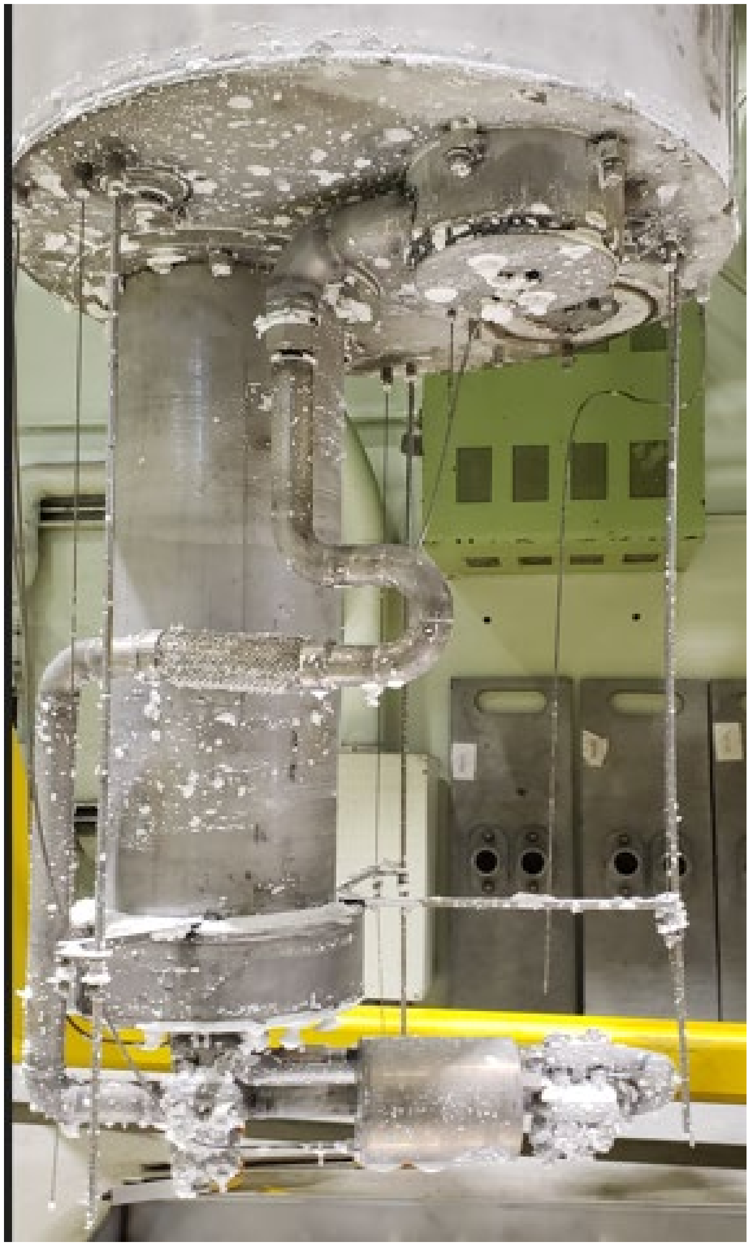

Figure 11 – THETA Following Carbonation Process – the white material is sodium bicarbonate

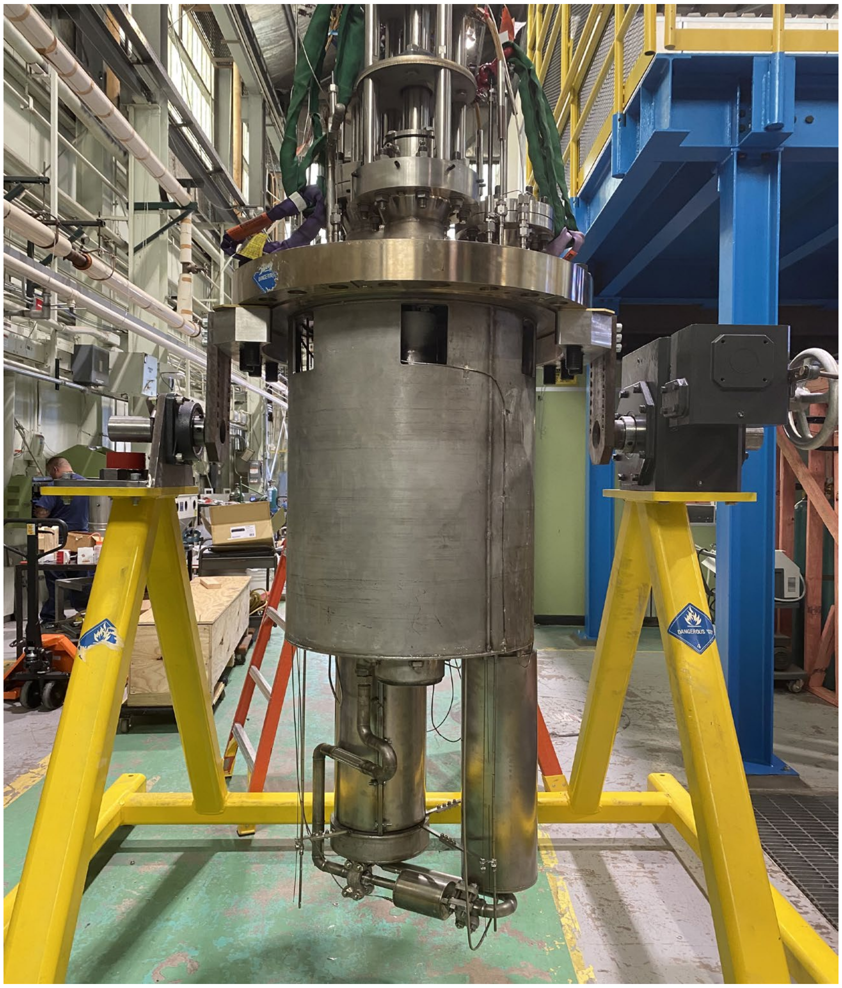

Figure 12 – THETA Following Complete Cleaning and Reassembly on the Test Stand

3.3.3 F-STAr – Making Preparation for Testing

The Flow Sensor Test Article (F-STAr) is a test article currently in the qualifying stage for ultimate insertion in METL. F-STAr was designed to provide high sodium flowrate capabilities for sensor calibration, component testing, and fluid studies. Figure 13 shows F-STAr on its test stand over in B206 where it is being assembled for initial testing and qualification. F-STAr includes a high-capacity pump that can provide a nominal flowrate of 120 GPM; a test section support structure that can accommodate a wide array of sub-test articles and their instrumentation; and finally, a heating and cooling system to aid in controlling the testing environment. Preparations are being made at METL to accept this test article in FY2024 by bringing in power for this test article and configuring locations for installing its control system. The status of F-STAr is reported in the document "Flow Sensor Test Article (F-STAr) – Design and Fabrication Status Report", August 2023. The reference selection provides direction to a report on F-STAr's status as of FY2023. (4)


Figure 13 - F-STAr on a 28-inch Test Stand

3.4 Complementary Support Activities

Repeating earlier discussions, METL's primary mission is hosting experiments to advance SFR development but the facility is also an experiment itself. 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, were co-applicants on numerous NEUP proposals, and provided presentations at industry conferences and forums.

3.4.1 Emerging Technology Proving Ground Support

Many reactor vendors have developed micro-reactor (µR) designs as the miniaturized variant nuclear reactor could be mass produced and predominately built on an assembly line with minimal field construction. µR economics demand an inverse of the operator-to-reactor ratio of large reactors. Utility scale reactors require many operators per reactor whereas a µR will need a group of operators to oversee many reactors for economic feasibility. This operator-to-reactor ratio constraint places a heavy emphasis on operations and maintenance automation and training.

The METL team assisted ANL's Plant Analysis & Control and Sensors Department with the integration of their Parameter-Free Reasoning Operator for Automated Identification and Diagnosis (PRO-AID) with METL's supervisory control and data acquisition system (SCADA). PRO-AID monitored METL during purification operations and METL operators induced faults to showcase PRO-AID's ability to discern sensor faults from component failures. Demonstrations included adding a bias to a temperature sensor and closing a damper on the cold trap cooling circuit. PRO-AID was able to successfully identify which sensor had the bias as well as indicate that the cold trap had a loss of cooling. Technologies, such as PRO-AID, will be crucial for the commercial viability of μRs and in reducing operating and maintenance (O&M) costs of larger plants and facilities. METL's capability and flexibility provides the necessary platform for demonstrating and vetting the emerging technology applicability and functionality.

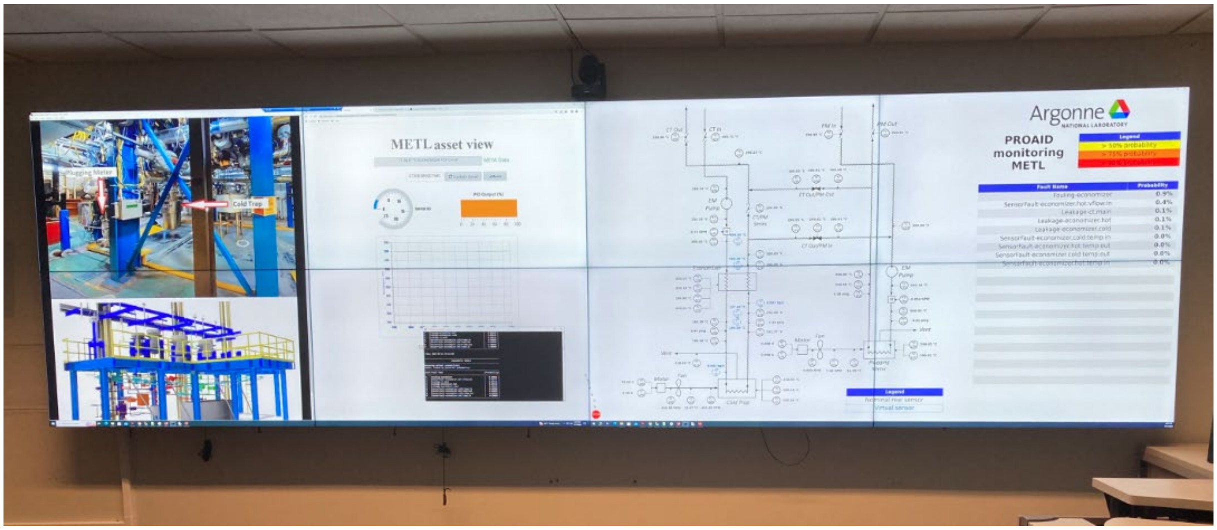

Figure 14. Advanced Monitoring & Diagnostics Center in B208 Room R201.

The contemporary climate for nuclear energy in the U.S. is at a historically positive level but the industry faces labor and supply chain challenges. Regardless of reactor size, adding an additional nuclear power plant will be a large-scale project that requires a skilled workforce. The METL team investigated using Extended Reality (XR) to support attracting, increasing knowledge/skills and in retaining the next generation of nuclear industry workers (5).

The application and utility of XR was investigated for multiple technical disciplines covering construction, operations, maintenance, and design. A Mixed Reality (MR) example using the GTA is shown below in Figure 14. Equipping a user with an MR headset allows them to see an augmented CAD model of the GTA at the METL installation site. Real-time vibration data is displayed in the gauge on the left and the user can interact with the digital projection by manipulating digital buttons. The specific example here shows that upon pressing the button, the gear and bearing housings, support structures, and hardware are made transparent, revealing the device under test (gears). The entire model is animated, true to actual existing installed conditions, based on the live data feed so the shafts and the gears rotate in the proper direction. This XR example provided in the report is one of many use cases but the highlights the importance of utilizing visualization technologies with live data for communicating a machines design and function to an operator. This technology is especially useful in visualizing advanced reactor operations, especially considering some advanced reactor designs utilize an optically opaque coolant.

Figure 15. Mixed Reality of GTA Prior (Top) and Subsequent (Bottom) after 'Pushing' 3D Button "Show Gears".

3.4.2 Support for Nuclear Energy University Projects

In FY23, METL team members supported various clientele. METL team members served on numerous Nuclear Energy University Project (NEUP) teams and facilitated their research activities to ensure their ultimate milestone of deploying their technology to METL remained on schedule. A fiber optic-based flow meter NEUP project was demonstrated in FY2022, and preparations were made in FY2023 to support three additional NEUP projects, all of which are aimed at providing online structural health monitoring.

3.4.3 Support to Industry

The METL teams' alkali metal expertise was leveraged for Small Business Innovation Research (SBIR) proposals and grants. METL consultation on SBIR projects assisted with increasing their devices' technology readiness level and assuring METL's ecosystem could accommodate future testing.

Periodic meeting (every two weeks) and some design reviews were conducted with industry collaborators who are actively pursuing the construction of dedicated test articles for insertion to one of METLs' test vessels.

3.4.4 Outreach Efforts

METLs growing recognition as a world-class test facility has translated into increased visitation and tours. METL guests in FY2023 included Department of Energy officials, U.S. Senate subcommittees, foreign government representatives, nuclear and A&E industry members, media content generators, other national laboratory personnel, and academia.

On a roughly triennial basis, Argonne opens its' gates to the public for researchers to showcase their work. METL team members volunteered to create displays and staff tables presenting METL and its' associated experiments to convey the importance of nuclear technology and METLs critical role in advancing nuclear technology to the U.S. public.

METL team continued advocating for the fourth generation (Gen-IV) reactors by participating in Gen-IV community events such as a Generation IV International Forum (GIF) webinar where, a presentation which highlighted METL's ecosystem and capabilities (hardware and personnel) was given along with a virtual tour (6). In addition, the METL facility and its work is the main U.S. contribution to the Generation IV Component Design and Balance of Plant (Gen-IV CDBOP) of the GIF SFR System Activity.

Figure 16 - METL Related Exhibit at Argonne Open House

3.4.5 METL Experimenters Guide

The METL team created a draft of the METL experimenter's guide in FY2022 and continued revising it throughout FY2023. This document was reviewed internally and by industry. This document was issued for the very first time in December 2022 (7). The experimenter's guide is expected to accelerate test article development for external clients as it informs potential clients on best practices for sodium service designs, generalized acceptance criteria, available infrastructure/services, and an overview of a typical project lifecycle of an experimental campaign. Likewise, schematics, constraints, and specifications (example in Table 1) on the METL ecosystem are also incorporated into the guide.

Table 1. Excerpt from METL's Experimenter's Guide.

System / Topic / Parameter	Value
R-Grade Sodium Inventory	Current inventory = 750 [gal] (as of Aug. 2021) Dump tank capacity = 840 [gal] Catch pan capacity = approx. 1000 [gal]
Electric Power	~ 1 [MW]
Sodium Purity	~ <=5 [wppm] oxygen
Main Loop Flow Rate	0-10 [gpm]
18" Vessel	18" nominal vessel with a minimum wall thickness of 0.328" Height = approx. 34.25" Internal Capacity = approx. 40 [gal] Static operation = Room Temp – 1000 [°F] Dynamic operation = 250 - 1000 [°F] Rated pressure = 100 [psig] @ 1000 [°F]
28" Vessel	28" nominal vessel with a minimum wall thickness of 0.615" Height = approx. 62 5/16" Internal Capacity = approx. 170 [gal] Static operation = Room Temp – 1200 [°F] Dynamic operation = 250 - 1000 [°F] Rated pressure = 100 [psig] @ 1200 [°F]
Expansion Tank	Inner diam. = approx. 8.5" Height = approx. 80" Internal Capacity = approx. 20 [gal] Static operation = Room Temp – 1000 [°F] Dynamic operation = 250 - 1000 [°F] Rated pressure = 100 [psig] @ 1200 [°F]
Dump Tank	Inner diam. = approx. 41" Length = approx. 151" Internal Capacity = approx. 840 [gal] Static operation = Room Temp – 1000 [°F] Dynamic operation = 250 - 1000 [°F] Rated pressure = 200 [psig] @ 1000 [°F]
Crane Access (Bldg. 308 hi-bay)	20 [ton] w/ 5 [ton] auxiliary. The height of the inside of the 5-ton crane hook to the top of each vessel (vessel with no flange) is 189-190 inches. This crane hook height value is the same for both the 18 and 28 inch vessels.
Notes & Conversions	1000 [°F] ≈ 538 [°C] 1200 [°F] ≈ 650 [°C] 100 [psi] ≈ 6.89 [bar] 1 [gal] ≈ 3.78 [liter]

3.4.6 METL's External Web Page

Continuing the theme of ensuring METL's information is readily accessible, METL's external web page is routinely updated with pertinent alkali metal and facility information. The URL is provided below, in the bibliography (8), and is generally the first result when requesting "Argonne METL" from a search engine.

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

This site contains background information on METL, liquid metal technology in general, and has links to related facilities and research initiatives. In addition, it includes the reports that are generated from the testing and operations conducted at METL as well as a virtual tour of the facility and highlight reels.

4. ADDITION OF TEST VESSELS TO METL

GTA and THETA are installed in an 18" and 28" test vessel, respectively, which represents two of the available four test vessels at METL. In FY24, the remaining two test vessels are expected to be occupied starting in FY24 for a number of years as more test articles are developed by Industry and DOE's Advanced Reactor Technology Development program.

METL was designed to accommodate eight test vessels; the original four test vessel installed during Phase 1 and four additional 18-inch test vessels. Effort to expand METLs testing capacity has been incrementally underway since FY21. 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.

4.1 Test Vessels

METL has two 18" and two 28" test vessels installed with plans to incorporate an additional three 18" test vessels. THETA's balance-of-plant will require the footprint originally intended for Test Vessel 5, so expansion plans proceeded with Test Vessel 6 (V6). V6 has the same architecture as the other 18" test vessels and is piped in parallel to METL's primary loop (Figure 17).

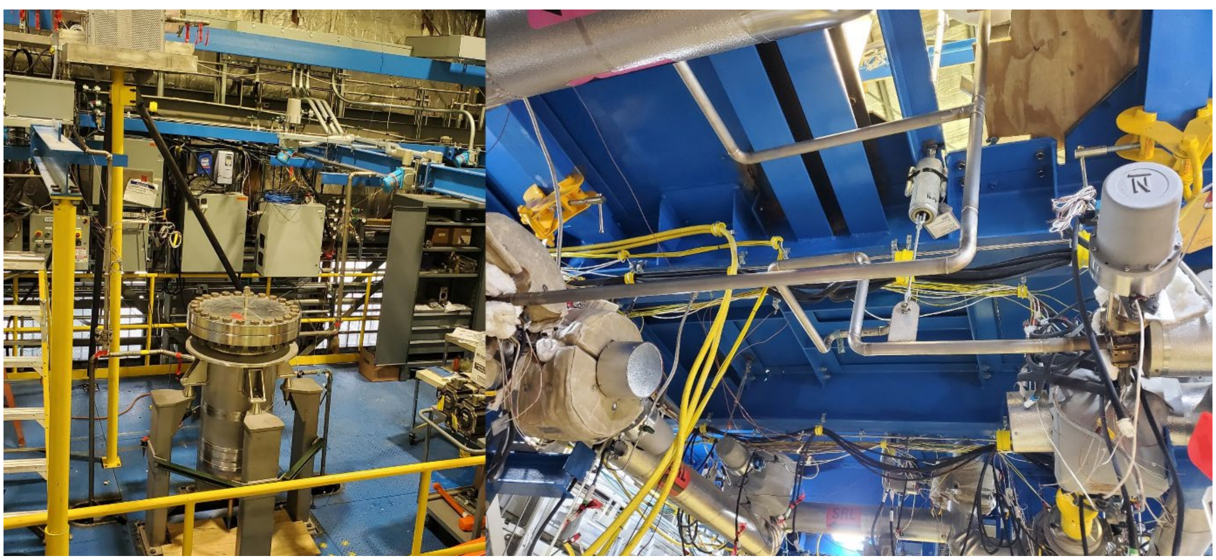

Figure 17. Test Vessel 6 (left) and Installed Subassemblies (left & right).

V6 installation is unique compared to the other test vessels as it was equipped with structural health monitoring (SHM) instrumentation. SHM is an attractive technology for next generation nuclear power plants because it may provide confidence to regulatory agencies to grant longer inspection and/or refueling intervals which is expected to decrease the plant's levelized cost of electricity. A commercially available SHM technology, an acoustic emission system, was installed on V6's piping network as illustrated by the screenshot in Figure 17, where a numbered gray box indicates where an acoustic emission sensor is installed. The status of SHM work and support of corresponding SHM NEUP projects at METL is provided in a separate report (8).

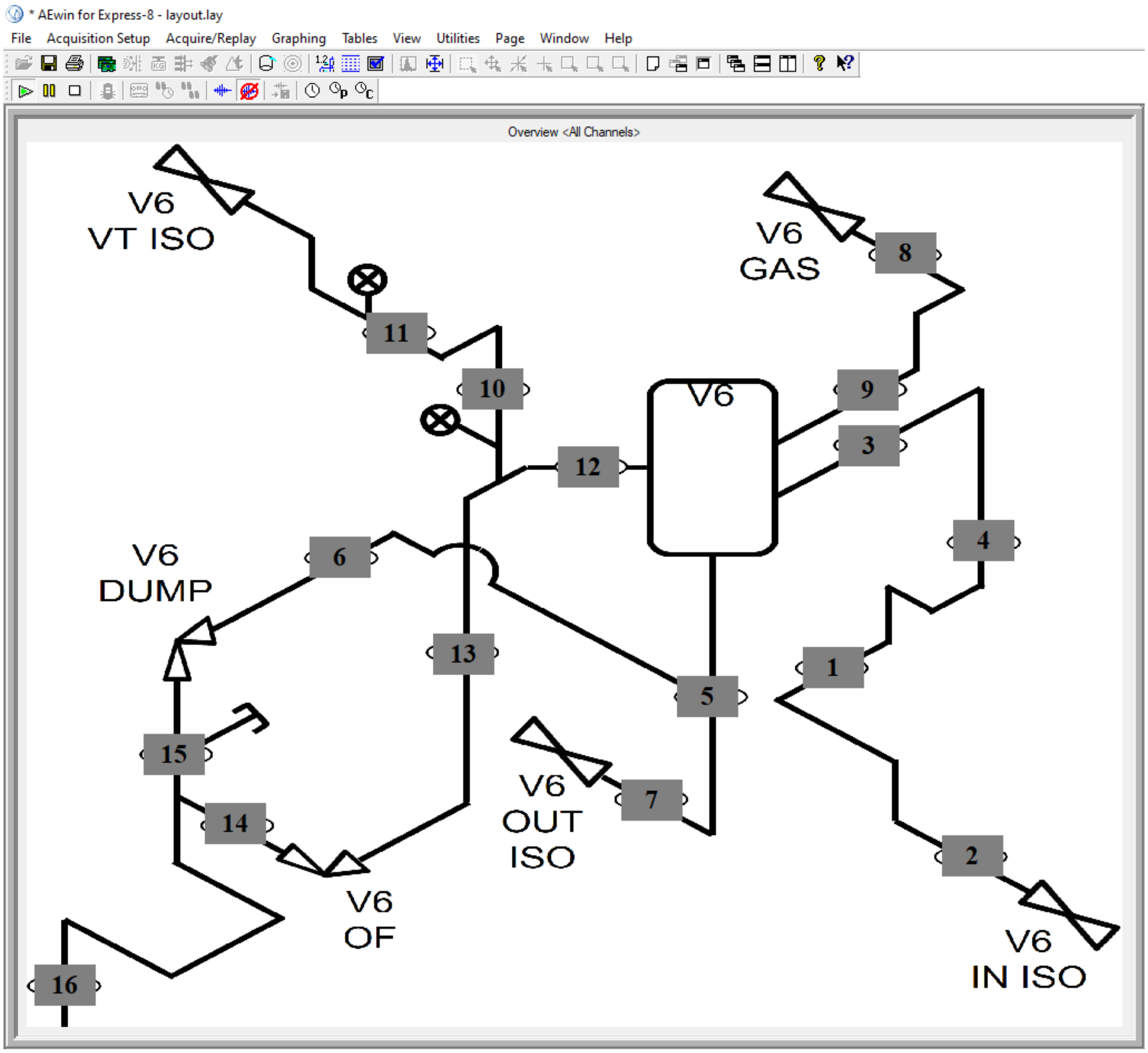

Figure 18. Overview of V6 Acoustic Emission Sensor Installation.

The additional two test vessels, with plans for installation in FY25 and FY26, are Test Vessels 7 and 8 (V7 & V8). Following METLs original design, V7 & V8 are replicas of the existing 18" test vessels but have a slight configuration alteration. Every one of METLs test vessels have their supply nozzles oriented in the northeast direction whereas V7 & V8 face the northwest (V7 & V8 are rotated 90° CCW with respect to the other vessels). This vessel orientation configuration, along with securing two of the stanchions to raised bracing system, is illustrated in Figure 18. By design, the non-uniformity of V7 & V8's installation is to accommodate the 3° slope of METLs primary loop (facilitates sodium piping system draining by gravity). The slope in combination with the fact V7 & V8 are at the far east end of METLs primary loop results in a shorter distance between the vessels nozzles and the primary loop tie-in points when compared to the other test vessels. In summary, the heterogeneity of V7 & V8's installation ensures the vessels remained on the mezzanine and within the footprint of METLs catch pan while complying with ASME process piping code. Installation of V8 is predicated on moving the carbonation system equipment.

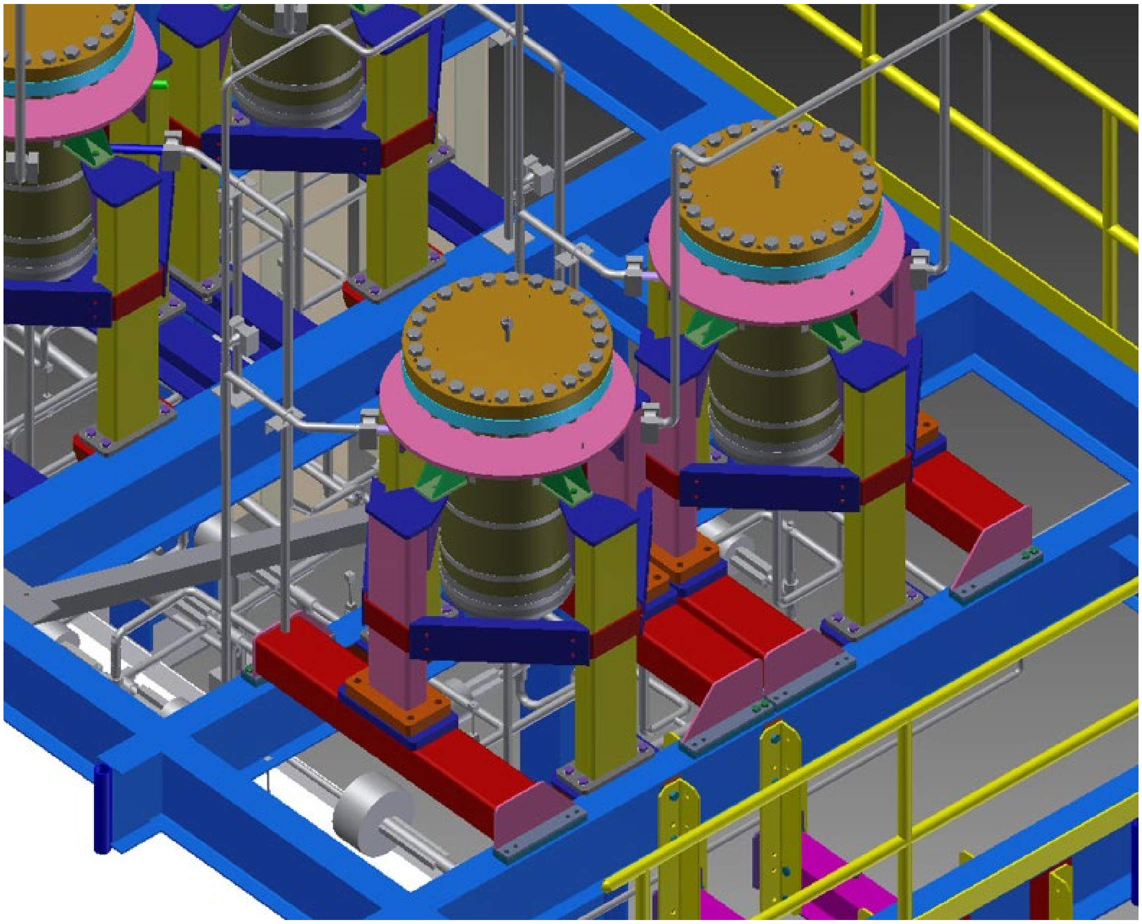

Figure 19. CAD of Test Vessels 7 & 8 Installation.

4.2 Assembly Location for Test Articles

Due to space constraints in B308, B206 serves as a useful location for the assembly of METL experimental test articles and it is located near METL's qualifying station. Building 206 (B206) is a building like B308 on ANL's main campus but is slightly smaller, relatively newer and its' alkali metal decontamination equipment is suitable for radioactive alkali metals. The qualifying station was established in FY19, and its' utility has been increased incrementally. A number of medium voltage fused disconnects and switch-rated receptacles were installed on B206's western high bay wall to support the initial testing of test articles destined for testing in METL. The disconnects are fed from bus ducts on the same wall and are rated for 100A.

In FY2023, the qualifying station was equipped with a 28" qualifying vessel (the vessel was purchased in FY2021) that is identical to those installed in the METL test facility. Aside from high temperatures, this allows an experiment to be demonstrated in-situ prior to insertion into METL. Using replica hardware also provides the opportunity for the entire component or device lifecycle (i.e., assembly/disassembly, operation, insertion/extraction) to be demonstrated. For example, the commissioning of the 28" flexi-cask was performed in this location as shown in Figure 19 prior to its initial use extracting THETA from Test Vessel 4.

Figure 20. 28" Qualifying Vessel and 28" Flexi-Cask.

The 28" flexi-cask was assembled in B308 and then moved to B206 for testing at the qualifying station. The ports for gloves were sealed shut and the glovebag (cask) was inflated with compressed air and extended. The gates which isolate the lower and upper assemblies were removed/installed to verify its' functionality. During this commissioning work, it was found that the steel gates were bulky and heavy. Gates made from a high-density plastic material were fabricated using the same design as the steel gates, and their sealing capability was demonstrated as part of this commissioning process. Post-commissioning, the 28" flexi-cask was moved back to B308 where it was used to extract and insert THETA as previously shown in Figure 9.

4.3 Test Article Cleaning

A carbonation system is used to remove residual sodium from a device under test (DUT) once extracted from the facility. The process delivers humidified carbon dioxide to a reaction chamber housing the DUT. The reaction between the humid carbon dioxide and residual sodium results in sodium bicarbonate with trace hydrogen generation. METL's carbonation system is effective and benign from a workplace safety standpoint and DUT preservation perspective but requires prolonged operation for thorough cleaning and there are issues with compaction of the sodium bicarbonate in locations where it is not free to expand.

The potential bottleneck in test article cleaning (METL has the potential for 8 test vessels but only 1 cleaning station) is the prime motivation for investigating an additional cleaning process using wet vapor nitrogen to increase throughput. The wet vapor nitrogen process has similar characteristics to the carbonation process (low energetic reactions and non-destructive) but on an accelerated timescale. This process was used back in the 1970's for the cleaning of residual sodium off components. Other processes were used, such as alcohol washes (at EBR-II sodium components maintenance shop). In FY2023, a wet vapor nitrogen (WVN) system was designed as illustrated by its' process and instrumentation diagram (P&ID) in Figure 20. Replacing carbon dioxide with nitrogen should increase water carry-over and thus the reaction rate, with reaction products that include sodium hydroxide and hydrogen. As shown in the P&ID below, the WVN has the flexibility to revert back to a carbonation process if needed.

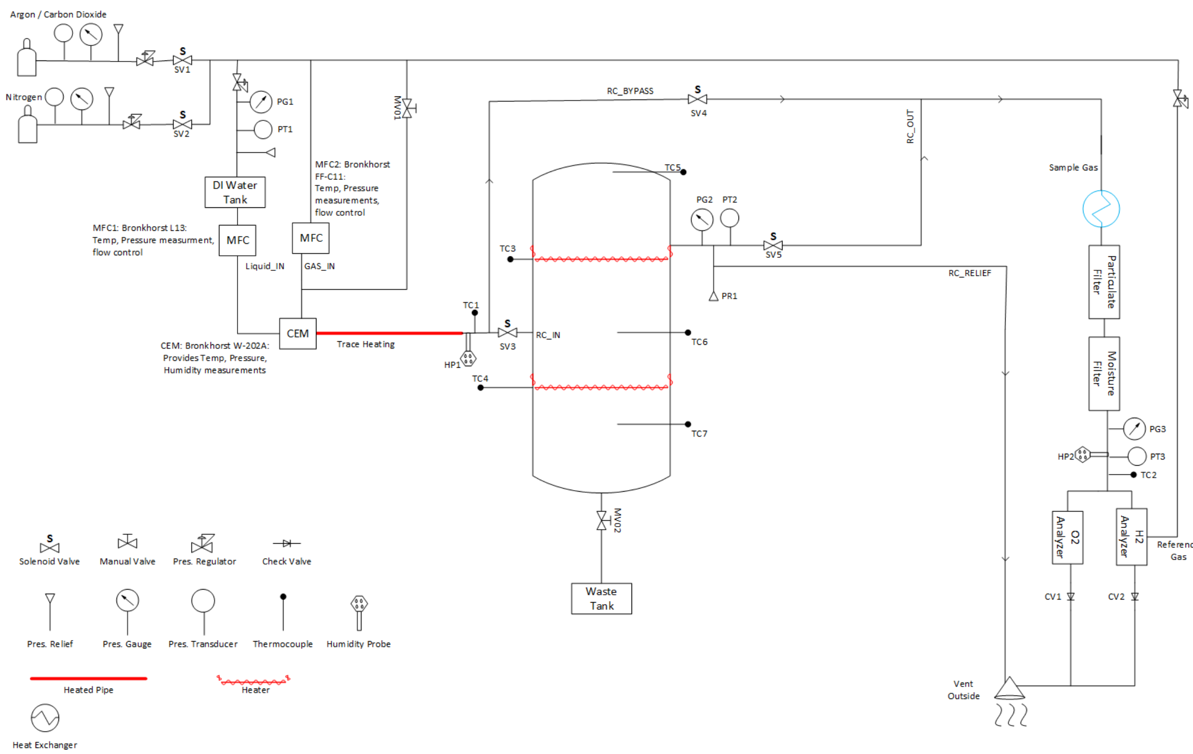

Figure 21. WVN P&ID.

4.4 Mezzanine

Integrating additional experimental apparatus into METL and its' associated infrastructure has consumed much of the original mezzanine deck space. In FY2023, southern extension with two support columns was bolted to the existing mezzanine to increase METLs effective square footage (Figure 21). Similar to the original southern portion of the mezzanine, the handrails have a vertical addition that allows workers to use ladders while prepping their experimental test articles. These handrail additions can also be removed to provide additional clearance when placing equipment on/off the mezzanine with the overhead crane.

Prior to the installation of the southern mezzanine, the METL ecosystem had a useable area deficit. The METL team is presently reviewing a design to expand the mezzanine on the western end of the high bay to recover dead space in the highbay that is useful to METL testing and support.

4.5 Client Infrastructure

Integrating an additional three, potentially four vessels requires the necessary supporting infrastructure and services. METL provides 100A of 1Φ 240VAC from a panelboard in room B162 and a ½" argon "tap" from its' 1000L micro-bulk system to each test vessel. Each test vessel has a switch-rated 100A receptacle to provide a disconnect means and power experiments as well as, a ½" quarter turn plug valve to feed argon to various components. Shown in Figure 23, these services are secured to blue cantilever arms on METLs flagship facility to keep the floor plan in vicinity of the test vessel unobstructed and available for a DUT or its' supporting components.

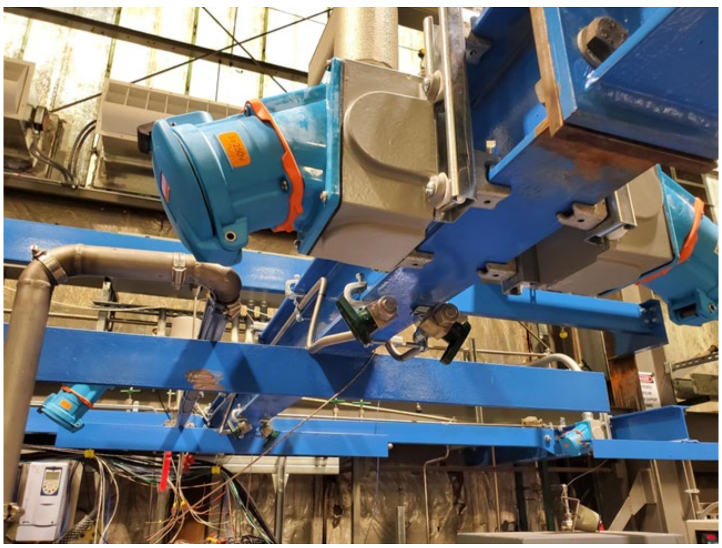

Figure 22. Power and Argon Services for Test Vessels 5-8.

5. CONTINUOUS IMPROVEMENT

METLs success throughout the years has demanded the facility perpetually investigate and pursue projects to maintain its' relevancy, flexibility, reliability, and accessibility. Many reactor designs are fluid, translating to evolving requirements and accompanying experimental demonstrations. METLs ability to adapt and house a myriad of test articles demands METLs ecosystem is also under perpetual development.

5.1 Emergency Power to METL Controls

During FY2022, Argonne replaced the original emergency diesel generator and emergency bus for the B308 area. This afforded the ability to tap METL's control room into this new emergency bus via an automatic transfer switch providing a redundant power supply (grid and diesel generator). This alternate power source increases the safety and reliability of METL in being able to control the facility in case of a loss of power. Building upon this infrastructure, an uninterruptible power supply (UPS) was installed in FY2023.

5.2 Information Technology (IT)

Reliably and effectively supporting emerging digital technologies such as those in section 3.4.1 requires enterprise grade IT. Non-critical operational computing is performed by a single desktop server which was originally manufactured in 2009. In FY23, two new rackmount servers (Figure 24) were received, installed in the main industrial control enclosure and configured. These servers will replace METLs original outdated server and ensure robust operation of advanced/future capabilities such as extended reality, machine learning/artificial intelligence (digital twins) and improve client accessibility to their experiments.

METL IT added three virtual machines (VM) on ANLs cluster in FY23, each with a dedicated function. METL-Comms VM acts as a universal gateway for data exchange, providing access for 3rd party applications (e.g., PRO-AID and THETA's control program) to METLs live and historical operational data. METL-Intranet hosts an internal website for METL operators and users. The METL intranet site has live data pages for viewing on mobile devices, an asset page and a document page for frequently accessed information. METL-utility VM is used to perform maintenance of METLs IT equipment, test/debug new programs, and troubleshoot existing controllers/hardware.

Figure 23. Servers Installed in Main Industrial Control Enclosure (2nd and 3rd Rack Mounted Devices form the Bottom).

5.3 Electromagnetic Flowmeters

A new design for the METL Electromagnetic Flowmeters (METL EMFM MK-II) was developed to improve on the original converted design. Recall that the CT and PM flowmeters were originally upgraded in August of 2021 and calibrated in March of 2022. However, the main loop flowmeter was left as is. During the original conversion of the CT and PM flowmeters, there were several lessons learned for future implementation. First, the operating temperature of the magnet was found to be higher than expected. It was assumed the insulation would keep the magnets around a maximum temperature of 30 C. However, actual temperature measurement showed that the magnets' operating temperature were around 40 C, and in some places, higher. Unfortunately, the neodymium magnets selected are rated to 80 C and it is therefore likely the magnets are being "cooked" and have lost some of their initial magnetism. Consequently, higher temperature rated magnets were required to be a better choice for this application.

Secondly, the flowmeter was made using recycled parts from the original installation. While this allowed the project to start quickly, it resulted in many design constraints. Two major constraints were the magnet spacing and thickness. These constraints resulted in choosing a neodymium magnet with a lower maximum temperature and a spacing that was much closer to the conduit than anticipated. Additionally, during installation, it was found another spacer needed to be added to the PM yoke. Overall, it was identified that making a flowmeter design from scratch would result in a product that would better meet METL's needs.

Since the main loop flowmeter was left as-is, it was planned to eventually upgrade it like the CT and PM flowmeters. However, a small project was developed to replace all the flowmeters with a common and consistent design. This enhanced design uses higher temperature neodymium magnets rated to 250 C. Additionally, the yoke was custom designed to allow for adjustable spacing. Finally, the wiring connections were also custom designed to meet the needs of the updated flowmeter, which includes power, shielded signal wire, and four thermocouples.

Figure 25 shows an overview of the newly developed design. As noted earlier, this will be a common design across the ML, CT, and PM, with the ML flowmeter requiring a slightly different piping support. At the time of this report, the design has been completed and reviewed, with a drawing package and specification document developed. This package was sent out for quote. We received one quote and another no-quote on the project. The quote was accepted and a purchase order setup. After an initial kick-off meeting was held to answer questions and outline expectations, construction of the METL EMFM Mk-II began. The expected completion of the flowmeters is late October or early November. The goal is to obtain reliable measurements of sodium flow for the cold trap, plugging meter, and main flow loops.

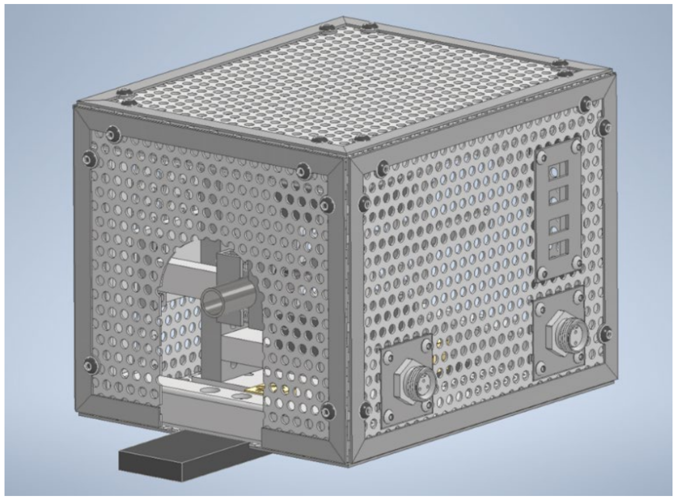

Figure 24. Model of upgraded METL Main Loop, Cold Trap Leg (CT), and Plugging Meter Leg (PM). The CT and PM flowmeters were originally upgraded in August of 2021 and calibrated in March of 2022. However, several lessons were learned from the initial implementation that were incorporated into the revised design.

6. BUILDING 308 INVESTMENTS

Constructed in the late 1950s, Building 308 (B308) was built to conduct alkali metal research and it continues to support this mission today. 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. During FY2023, B308 again received some additional investments by ANL. Investments included historical equipment removal and disposal and continued alkali metal scrubber renovations.

6.1 Space Reclamation

Maintaining METL's standing as a valuable asset within the nuclear energy community has compelled plans for ongoing expansion. Building and areas capable of supporting alkali metal research are scarce and at a premium. Apart from cost, time, real-estate, and DOE guidelines; there are hurdles to constructing new buildings for alkali metal research as traditional fire suppression systems cannot be used. In FY23, the METL team increased B308 high bay's available capacity by recovering areas that housed legacy liquid metal experiments.

6.1.1 Steam Generator Test Facility (SGTF)

The Steam Generator Test Facility (SGTF) is a four-story structure located in the high bay of B308. Its original mission was to conduct critical heat flux tests on sodium-water heat exchangers for use in the Clinch River Breeder Reactor project and follow-on large scale demonstration projects. SGTF consumed about 25% of the high bay area, hardware was beyond its' useful-life and/or was composed of hazardous materials (asbestos, lead, mercury, etc.), prevented the overhead crane from reaching the western portion of the high bay, remained dormant for decades and was already partially deconstructed to accommodate METLs present footprint. These compounding factors led to the demolition of the SGTF in FY23.

Figure 25. Dormant SGTF (left) and SGTF Remains (right).

A before and after picture was taken and are shown above in Figure 26. The orange structure was reduced by a level to increase overhead crane access and the technical equipment was removed. An important aspect of SGTF demolition is its' removal now provides access to a 12' deep pit and a 20' deep well within that pit, presenting the possibility of constructing a significantly taller test facility within B308.

6.1.2 Original Alkali Metal Scrubber

The use of an Alkali Metal Scrubber dates back to the original construction of the building in the 1950s. In the late 1970s, a larger 30,000 CFM system replaced the original which was abandoned-in-place in room C141 of B308. A burn stall and superheated steam system are routinely used in room C141 to passive alkali metal contaminated components. Similar rationale behind the demolition of the SGTF, the original B308 scrubber was also removed in FY23.

The legacy scrubber was housed inside of room C141 next to the burn stall and has been abandoned in-place since circa 1980s. Removal of the original blower and cyclone separator cleared approximately 110 ft^2 in a prime area. Equipment dedicated to alkali metal passivation was stored in place of the legacy scrubber. Equipment consists of a hoist for placing materials into the burn stall, a large hacksaw for cutting large vessels/pipes filled with sodium and a mobile chest with tools and replacement parts.

Figure 26. Room C141 Before (left) and After (right) Legacy Scrubber Removal.

6.2 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 an essential part of the safety posture for the METL facility. In FY22, a new underground water storage tank, 350HP electric motor, water pump and motor were received. The replacement blower and inlet vanes arrived on-site in FY23, completing the acquisition of equipment with very extended lead times.

Figure 27. New 30,000 CFM Blower for B308 Alkali Metal Scrubber.

The outdoor installation of the B308 scrubber poses environmental challenges as its' steel construction is exposed to the elements. In FY21, the scrubber's water and steam lines were replaced with stainless steel piping as the original carbon steel corroded until failure. A similar failure occurred to the inlet ducting of the scrubber blower (Figure 29). The partial shearing of the inlet duct forced the scrubber to be placed in an emergency mode state (only operate if there is a breach in METL) as it was still able to achieve a negative pressure on the building. Upon further inspection of the ducting there were also support brackets which fractured and impending fractures at other inlet duct sections.

Figure 28. Original Corten Ducting (left) and Sheared Riser (right).

The inlet duct section connecting the cyclone separator to the blower inlet was removed and replaced with new stainless-steel ducting as shown in Figure 30. The expansion joint which dampens vibrations and accounts for thermal expansion between the ducting and blower was also replaced with a new "U-belt" and mating flanges. The replacement expansion joint improved upon the original as it is equipped with an inlet flow liner that prevents debris from being pulled into the blower if there is a break in the U-belt.

Figure 29. Ducting Removal (right) and New Stainless-Steel Ducting Installed (right).

7. SUMMARY

This fiscal year report provided a summary for the status of the METL facility as of September 2023. 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.

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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