ANL-ART-280

Sample Testing Basket – Design and Capabilities Report

Nuclear Science and Engineering Division

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1 Executive Summary

SFR designs all require integral components that can withstand prolonged submersion in the liquid sodium primary coolant as well as in the gas space of the reactor vessel. Materials are often desired to withstand these conditions for the lifetime of the reactor. The Sample Testing Basket (STB) was designed and fabricated to meet the anticipated need for material exposure testing in prototypic reactor coolant environments; in the liquid sodium primary coolant and the sodium-vapor-laden gas space. Developed at Argonne National Laboratory (ANL), the STB is a piece of equipment designed for use in the Mechanisms Engineering Test Loop (METL) to allow for sodium exposure testing of materials within the METL facility.

Figure 1 shows 3D renderings of the Sample Testing Basket and Figure 2 shows a cross section drawing of the STB inside a METL test vessel. The STB includes two main sections: a lower section designed for materials testing submerged in liquid sodium metal and an upper section designed for materials testing in a sodium vapor environment. Each of the sections can be used individually for testing or can be combined for simultaneous testing in the liquid and vapor spaces. With the two sections of the STB, materials intended for use in the cover gas space of an SFR or submerged in the liquid sodium can be easily tested in a prototypic reactor coolant environment within one of METL's 18-inch test vessels.

The following are some important specifications to keep in mind when considering the STB for material testing:

- The STB is designed to be installed in one of METL's 18-inch test vessels.
- The Maximum testing temperature is 538°C and it is set by the METL vessels.
- Sodium conditions in the STB are static (not flowing).
- Coupons or sample materials are recommended to have physical features, such as a hole, for suspension by wire in the basket.
- Sample materials and coupons must be compatible with reactor grade sodium metal.
- There is 2 ft^3 of sample space in the liquid section.
- There is 1.3 ft^3 of sample space in the vapor section.

The STB is an adaptable piece of equipment providing an environment for diverse material sample testing in METL and expands the capabilities of the METL facility. The report details the design and capabilities of the STB and covers the first installation of the STB in METL as an example of the STB testing procedures. The design of the STB focused on flexibility of use cases for the basket since there is not an individual type or size of sample it was designed to test. Similarly, the design aimed to allow for future expansion of the STB's testing capabilities. The experimental procedures to use the STB in METL include many of the same steps as the larger test articles in METL, however, using the STB is relatively straightforward.

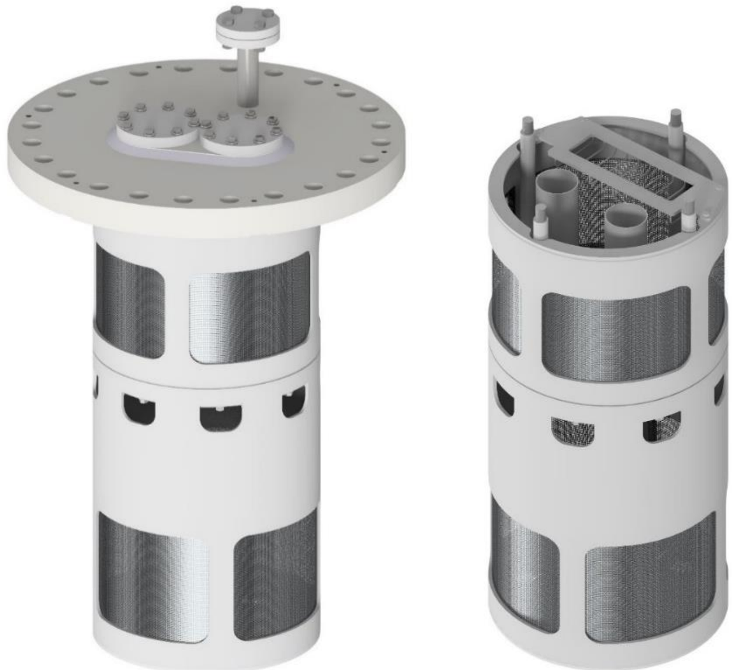

Figure 1 – 3D rendering of the Sample Testing Basket with both the vapor and liquid sections installed with flange for mounting in an 18-inch METL vessel (left), and without the vessel flange (right).

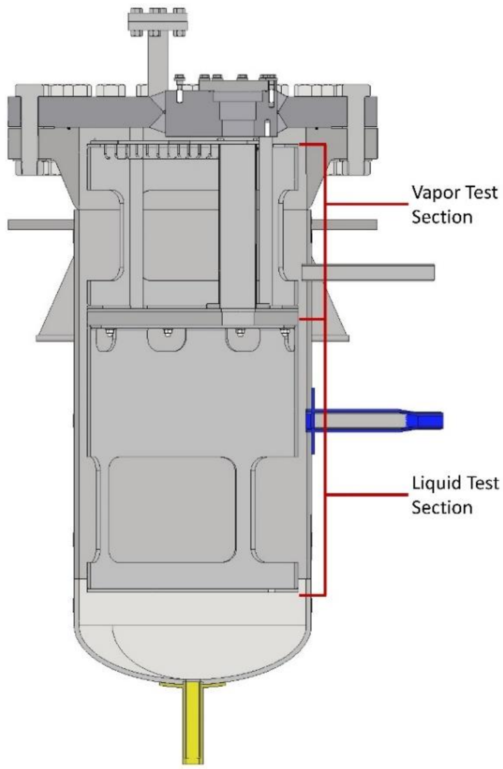

Figure 2 – Cross-sectional drawing of the Sample Testing Basket with both the vapor and liquid sections installed in an 18-inch METL vessel. The sodium inlet and drain lines are shown in blue and yellow respectively.

2 METL Overview

The Mechanisms Engineering Test Loop, or METL, provides reactor-grade liquid sodium metal to various test vessels to provide a prototypic environment to test components for Sodium Fast Reactor (SFR) development. Current resources of the METL facility include 750 gallons of reactor-grade sodium, prototypic reactor temperatures of up to 650°C, 4 test vessels (two 18-inch vessels and two 28-inch vessels), two additional tanks with experimental capabilities, over 1000 sensors, 300 heater zones, and sodium purification and monitoring. Some of the technologies that can be tested in METL include advanced fuel handling systems, self-actuated control and shutdown systems, advanced sensors and instrumentation, inspection and repair technologies, and thermal hydraulic testing. For more information on the METL facility, see the METL Operations and Testing Reports available on the METL website (anl.gov/nse/metl), specifically the *Mechanisms Engineering Test Loop (METL) Operations and Testing Report – FY2019* gives a comprehensive overview of the facility [1].

3 Design of the Sample Testing Basket

The STB was designed in two parts. First, the lower section for liquid sodium testing was designed and fabricated. Then the need for testing in sodium vapor environments was anticipated, prompting the design and fabrication of the vapor testing section to work in conjunction with the liquid section, however, the liquid and vapor sections can operate individually as well. Both sections of the STB were designed with flexibility at the forefront to be able to serve a wide variety of material samples.

The STB is mounted onto standard ANSI flange patterns giving the experimenters flexibility in making design changes to expand testing capabilities of the STB. For example, the flange could be swapped out for a modified flange with ports for additional instrumentation or sensors or motors could be added to the top of the flange to spin samples in the sodium environment or to mix the sodium itself. Modifications only need to be able to mount onto the vessel flange and fit within the space of the METL vessel.

3.1 Design of the Liquid Testing Section

The liquid testing section of the STB, shown in Figure 3, was designed and fabricated before the vapor section, and was based on the catch basket designed for the Gear Test Assembly to prevent debris from falling into the test vessel [2]. There are four key components to the liquid section of the STB: the basket body, support posts, top plate, and screen covers. All main components of the STB are fabricated from 316 or 304 stainless steel except the fasteners, which are a different material to reduce galling potential. Assembly of the STB is very simple: first, the support posts are threaded into the bottom face of the METL vessel flange. Second, the top plate is fastened to the bottom of the support posts. Third, the samples to be tested are loaded into the basket body–it is recommended that samples be secured with stainless steel wire when possible. Finally, the basket body is fastened to the top plate. The Basket body must be attached to the top plate last so that the samples can be loaded into the basket, and because the alignment holes to secure the top plate to the support posts are covered by the basket body when it is fastened to the top plate. Through-holes in the top plate provide access to the liquid test section for possible modifications in the future.

The dimensions of the sample basket are dictated by the inside dimensions of the 18” METL vessels. The STB has a 16-inch outer diameter and 35.5-inch height from the top of the support posts to the bottom of the basket body. Within the liquid section, a submerged internal volume of approximately 2 cubic feet (15.5-inch diameter by 18-inch height) can accommodate samples. Stainless steel wire mesh is spot welded to cover the windows in the sample basket body allowing sodium to fill the liquid section of the basket while keeping samples secure inside. Similarly, drain holes in the bottom of the liquid section of the basket are covered with stainless steel mesh to keep samples secured but still allow sodium to drain from the basket when the vessel is drained.

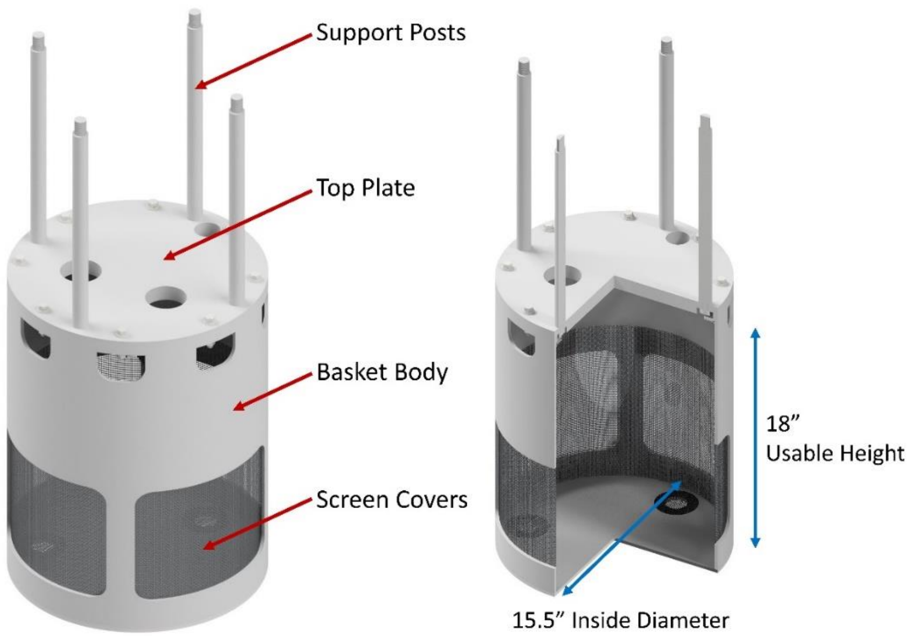

Figure 3 – A 3D render of the liquid testing section of the STB (left) highlighting the main components Quarter-section removed to show internal space (right).

Figure 4 – Fabricated components of the STB liquid section.

3.2 Design of the Vapor Testing Section

The vapor test section of the STB, shown in Figure 5, was developed after the liquid section had been fabricated to provide a space for samples to be exposed to sodium vapors at prototypic reactor temperatures to imitate conditions in the overhead gas space of an SFR. To allow the vapor test section to be used at the same time as the liquid section, the vapor section was designed to sit on top of the liquid section. The vapor section of the STB was designed to maximize the usable space for vapor testing above the liquid section without obstructing the through-holes in the top plate of the liquid section, and without requiring a full redesign of the liquid section. Like the liquid test section, the vapor test section is built off a basket body and has screen covers to keep samples secured inside the basket. The guide pipes keep samples secure by blocking off through-holes in the vapor basket body that allow access to the liquid test section. A sample rack at the top of the vapor section provides easy locations to hang samples with wire. The vapor section of the STB is also fully constructed of 316/304 stainless-steel except for the special non-galling fasteners.

Like the liquid test section, the STB vapor section has a 15.5-inch inner diameter to utilize the maximum volume inside one of the 18-inch METL vessels. The usable height inside the vapor section is approximately 12 inches, giving an internal volume of 1.3 cubic feet. A drain hole in the vapor section allows any sodium to drain out of the basket, however, the amount of sodium condensing in the vapor section will be very small.

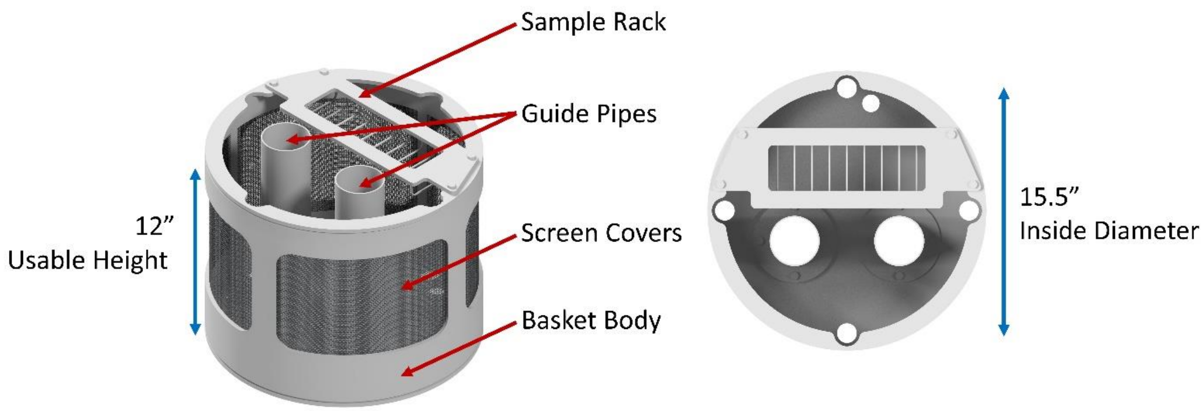

Figure 5 – A 3D render of the vapor test section of the STB (left) highlighting the main components. Top-down view (right).

Figure 6 – Fabricated components of the STB (left). Close-up of the vapor testing section (right).

4 STB First Installation in METL

The STB was assembled and installed in the METL facility for the first time in the fall of 2023. To test samples in the STB the process includes assembling the STB with samples secured inside, installing the STB into an 18-inch METL test vessel, operation, and disassembly/cleaning. The first installation of the STB in METL provides a good example of these processes. For the first installation, the samples were intended for exposure to liquid sodium so only the liquid section of the STB was assembled and installed. For more information on the procedures involved in conducting research in the METL facility–including topics such as assembly, the flexicask system, design constraints, removal, and cleaning–see the METL Experimenter’s Guide [3].

4.1 Assembly

The STB was assembled in Building 308 at ANL on one of the 18-inch test stands for assembly and disassembly of METL test articles. During assembly, the standard 18-inch ANSI flange of the STB was mounted directly to the assembly test stand as shown on the left in Figure 7. As mentioned before, the assembly process is very simple for the STB. First, the support posts were threaded into the bottom face of the METL vessel flange. Next, the top plate was fastened to the bottom of the support posts. Then the samples to be tested were secured to the assembly–in this case they were hung by stainless-steel wires from the holes in the top plate, but samples can be anchored throughout the entire basket. To secure the samples further, the stainless-steel wire was spot welded to the top plate. Finally, the basket body was raised up using the red lift table cart shown in the figure and was fastened to the top plate.

Figure 7 – Assembly of the STB liquid section on the assembly stand (left). Samples inside the STB secured with stainless steel wire (right).

4.2 Installation

After assembly of the STB on the assembly test stand, the STB was installed in a METL 18-inch vessel using the overhead crane in the METL facility. The STB was picked up directly from the stand, where it was assembled, using the flexicask system and overhead crane as shown in Figure 8. The flexicask is a custom system that minimizes air ingress to the METL piping during installation and removal of assemblies from the METL vessels by enclosing the assembly in a large bag which can be purged with argon. The STB was moved directly from the assembly stand to METL test vessel 1 with the flexicask system and was installed with no issues. Following installation of the STB, final preparations for the test vessel were made. First the vessel bolts were torqued down following a standard torque sequence. Then flange heaters were installed on the vessel flange and the vessel was insulated. Before moving on, the vessel is leak checked.

Figure 8 – Assembled STB being lifted from the assembly test stand with the flexicask system (left). The STB installation in vessel 1 using the flexicask system (right).

4.3 Operation

After installation in METL test vessel 1 was completed, the vessel temperature was increased to transfer sodium into the test vessel. The vessel heating followed a rate of 0.1°C/min up to a temperature of 300°C. At 300°C sodium was transferred into the vessel, filling the vessel above the level of the hanging samples. After filling, test vessel 1 was isolated from the rest of METL. To accelerate the wetting rate of the sodium the vessel temperature was raised to 350°C for the duration of the sample exposure. The duration of this first sample exposure using the STB was 3 weeks. During that time, vessel temperature was monitored using the METL temperature monitoring systems. Once the 3-week planned exposure time had passed, sodium was drained from the vessel and the vessel was slowly cooled down to room temperature.

4.4 Disassembly

After the test vessel was cooled, the insulation, flange heaters, and flange bolts were removed to prepare the STB for removal. Once again, the flexicask system was used with the overhead crane to remove the STB from METL test vessel 1. During removal, it was immediately apparent that sodium had drained effectively from the STB and there was minimal sodium on the surfaces of the basket. The STB was moved directly from vessel 1 to the METL carbonation system, where it went through the carbonation process for approximately 6 days to passivate any sodium on the surface of the STB. After carbonation, the STB was moved back to the assembly stand for disassembly.

Disassembly of the STB was very straightforward. Essentially all the sodium on surfaces of the basket had been passivated during the carbonation process and turned into sodium bicarbonate, as shown in Figure 9. Components were cleaned with ethanol as they were removed from the assembly, followed by a rinse with deionized water. Some components required additional soaking in water or ethanol to completely clean, but overall disassembly and cleaning went very well. See Figure 10 for a picture of a sample following the sodium exposure and cleaning process.

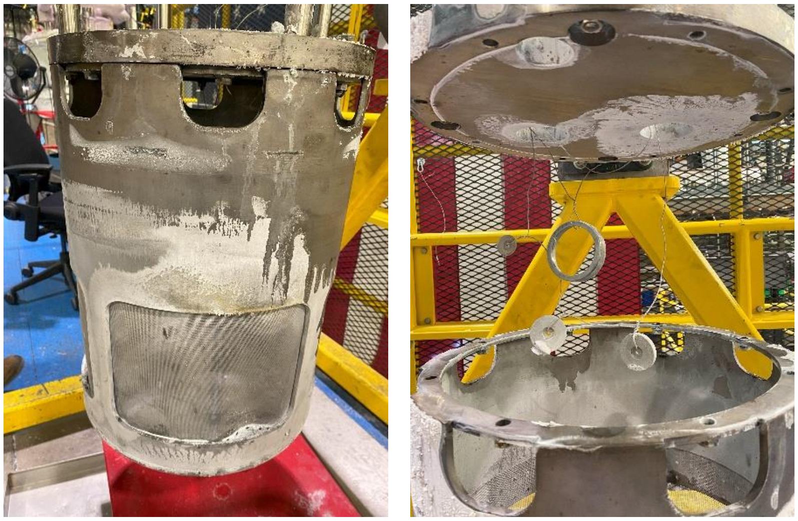

Figure 9 – The STB directly after removal from the carbonation process (left). Disassembly of the STB showing the samples hanging from the top plate after carbonation (right).

Figure 10 – Cleaned sample following sodium exposure and carbonation.

5 Summary of STB capabilities and Testing Procedure

- The STB is a versatile experimental assembly accommodating material exposure testing in prototypic SFR environments.
  - Capabilities for testing in liquid sodium and the overhead gas space for sodium-vapor exposure.
  - Maximum temperature of 538°C.
  - 2 ft^3 of sample space in the liquid section.
  - 1.3 ft^3 of sample space in the vapor section.
  - The liquid section and vapor section can be installed together in one vessel or one at a time.
- Testing procedure includes assembly, installation, operation, and disassembly.
  - The sample basket is assembled in the METL high bay using an 18” METL flange as the base (samples are loaded and secured during assembly).
  - The STB is moved from the assembly stand and installed in an 18” METL test vessel using the overhead crane and flexicask system.
  - Final preparations are made to the test vessel, such as installing flange heaters, insulating, torquing bolts, and leak checking.
  - The test vessel is slowly heated to the decided upon filling temperature and is subsequently filled with sodium.

- Vessel temperature is increased to the decided upon soaking temperature for the samples and the exposure test proceeds for the necessary duration.
- After exposure testing, the test vessel is drained and cooled.
- Once cooled, the vessel is prepared for removal of the STB and the STB is transferred to the carbonation system for passivation.
- After being in the carbonation system for ~1 week, the STB is moved back to the assembly stand for disassembly.
- Parts are cleaned with ethanol and deionized water during disassembly.

6 Acknowledgements

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