Report on the completion of long-lead components procurement of new sodium materials test loop

Applied Materials Division

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ABSTRACT

This report provides an update on the completion of long-lead components procurement of new sodium materials test loop. The loop, designated as SMT-3, is a forced-convection sodium loop to be used for the evaluation of sodium compatibility of advanced Alloy 709 with emphasis on long term exposures of tensile, creep, fatigue, creep fatigue, and fracture toughness ASTM-size specimens in support of ASME Code qualification and NRC licensing. The report is a deliverable (Level 4) in FY18 (M4NT-18AN050503013), under the Work Package NT-18AN05050301, “A709 Sodium Compatibility” performed by Argonne National Laboratory (ANL), as part of the Advanced Materials Program for the Advanced Reactor Technology. This work package enables the development of advanced structural materials by providing corrosion, microstructure, and mechanical property data from the standpoint of sodium compatibility of advanced structural alloys.

The first sodium loop (SMT-1) with a single tank was constructed in 2011 at ANL and has been in operation for exposure of subsize sheet specimens of advanced alloys at a single temperature. The second sodium loop with dual tanks (SMT-2) was constructed in 2013 and has been in operation for the exposure of subsize sheet specimens of advanced alloys at two different temperatures. The current loop (SMT-3) has been designed to incorporate sufficient chamber capacity to expose a large number of ASTM-size specimens to evaluate the sodium effects on tensile, creep, fatigue, creep-fatigue, and fracture toughness properties, in support of ASME Code Qualification and USNRC Licensing.

Three major long lead items were identified: 1) Selection and approval of location for the new loop and installation of the necessary infrastructure, such as transformer, power supply panels, and wiring, that is adequate for the long term operation of the loop, 2) Perform a detailed piping analysis that meets the ANL QA and Safety guidelines as well as complying with ASME Code requirements, and 3) Design and fabrication of the specimen exposure vessels that are capable of at least 42 tensile, creep, and fatigue specimens in each vessel and is compliant and compatible with ASME Code and the piping design analysis.

The SMT-3 loop will be located in Building 206 adjacent to the currently operating SMT-2 loop. In addition, we have removed the aged power supply system in Building 206 and installed a new transformer, wiring, and power panels for the new loop. The preliminary loop design was sent to an outside vendor for a detailed piping analysis, to ensure compliance with the ASME Code guidelines. The piping design was completed in FY2017.

The construction of components such as cold trap, economizers, piping arrangement etc. will be performed in the central shops at ANL. About 150 liters of sodium for the loop will be procured in early FY2018. The loop system is designed to circulate sodium through the sample tanks and the associated loop without an operator for an extended period of time.

With the three sodium loops (i.e., single-tank, dual-tank and four-tank), materials can be tested at different sodium temperatures, and large tensile, creep, fatigue, creep-fatigue, and fracture toughness specimens can be exposed to sodium for extended periods of time and generate data on

mechanical properties in support of ASME Code Qualification and USNRC Licensing of advanced Alloy 709 for use as a structural material in SFRs.

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1 Introduction

The Advanced Reactor Technologies campaign has focused on the sodium-cooled fast reactor concept because of its technical maturity. The current needs are for larger, more reliable, more economical reactors suitable for commercial nuclear power generation. Research and development focuses on three areas including advanced materials, innovative components and systems, and computer models and simulation. Inherent in this research and development is the selection and adequate long-term performance of reactor components that are directly exposed to the sodium coolant at elevated temperatures.

In general, structural materials can undergo a variety of interactions upon exposure to liquid sodium. The extent of interaction depends upon the conditions of temperature, temperature gradient, sodium velocity and purity, the materials of construction, and external sources and sinks for the impurities. The interactions can be broadly classified into either metallic or nonmetallic element mass transfer. Metallic element mass transfer usually establishes a go/no-go type of evaluation of an alloy for use in sodium environment, based upon material wastage or component section loss. A classic example of this is the unacceptable performance of vanadium base alloys in sodium of normal reactor purity. Upon selection of an alloy for sodium service, corrosion allowances that account for metallic element transfer can be incorporated into the design of specific components. Nonmetallic elements, such as oxygen, carbon, nitrogen, and hydrogen, are known to migrate in structural material/sodium systems (under both isothermal and non-isothermal conditions) as a result of chemical activity differences.

Transfer of nonmetallic elements also occurs in systems where combinations of materials of different composition are used. By examining the partitioning of nonmetallic elements between the structural alloy and sodium, the extent to which oxygen, carbon, and nitrogen interact in the structural material-sodium systems can be assessed. From the operation of the sodium-fast-reactor standpoint, the oxygen impurity in sodium can be controlled to ≈ 1 ppm which would result in acceptable corrosion of austenitic and ferritic steels and nickel-base alloys at a typical maximum operating temperature of 600°C for the coolant. The solubility of nitrogen in sodium is low in the reactor at anticipated operating temperatures and its effect on the materials performance may not be significant. On the other hand, observations by various investigators indicate that materials of nominally the same composition, but with different degrees of decarburization/carburization in sodium loops operating over similar temperature ranges, have resulted in questions regarding the extrapolation of results obtained in small scale sodium loops to large reactor systems. Since carbon concentration in a given system is established by a dynamic equilibrium between the carbon sources and carbon sinks present in the system, it could vary from system to system as well as over time within a system. It is necessary to establish the acceptable window of performance in terms of service temperature, sodium exposure time, and carbon concentration in sodium, by evaluating the influence of carbon in sodium on the microstructural and mechanical properties of advanced structural materials.

In previous reports [1,2], we addressed the thermodynamics and kinetics of metallic and nonmetallic impurity elements in sodium and their role in the corrosion of structural materials such as austenitic stainless steels and ferritic steels. The reports also presented the available data for the impurity elements, experience on control and maintenance of these impurities in sodium

systems, and the impact of various impurity elements, especially nonmetallic elements, on the corrosion performance of various structural components in sodium-cooled reactors. A single-tank forced convection sodium loop was constructed at Argonne National Laboratory for sodium compatibility studies of advanced materials, and has been operating at the maximum temperature of 650°C for materials testing since early 2011. The second sodium loop with dual tanks (SMT-2) was constructed in 2013 and has been in operation for the exposure of subsize sheet specimens of advanced alloys at two different temperatures.

This report presents an update on the design and construction of a third sodium loop (SMT-3) to be setup at Argonne National Laboratory. This forced convection sodium loop will significantly expand the materials testing capability and will be used for long-term exposure of ASTM-size specimens to evaluate the sodium effects on corrosion, tensile, creep, fatigue, creep-fatigue, and fracture toughness properties of Alloy 709, in support of ASME Code Qualification and USNRC Licensing.

2 Forced Convection Sodium Loops

The first forced convection sodium loop (SMT-1) was constructed in FY2011 at Argonne National Laboratory for exposure of subsize tensile specimens of advanced structural materials. The SMT-1 Loop consists of a single specimen-exposure tank with a heat exchanger, an electromagnetic pump, two electromagnetic flow meters, economizer, and a cold trap. The system was designed to circulate sodium with an argon cover gas through the specimen-exposure tank and the associated loop, for an extended period of time without an operator. The total amount of sodium in the loop is approximately 10 kg. The nominal operating pressure and the temperature for the sample tank in the loop are 3 psig and $<650^{\circ}\text{C}$. The nominal operating pressure and the temperature for the tubing part of the loops are 3 psig and $\sim 300\text{--}400^{\circ}\text{C}$, respectively. The maximum allowable working pressure and temperature are rated at 45 psig and 704°C for the sample tank and 1153 psig and 510°C for the tubing part of the loop, except the cold trap where the maximum pressure rating is 953 psig. The loop assembly including the sample tanks is considered under the coverage of ASME Code for process piping B31.3 and its pressure safety is evaluated based on ASME B31.3. Three specimen ports are available for loading corrosion coupon or sheet-type tensile specimens for sodium compatibility tests.

The second forced convection sodium loop (SMT-2) is a dual-tank sodium loop that has been constructed, in FY2013, for exposure of mechanical test specimens of advanced ferritic-martensitic steels at multiple temperatures [2]. The nominal operating pressure and the temperature for the sample tank in the loop are 3 psig and $<700^{\circ}\text{C}$. The nominal operating pressure and the temperature for the tubing part of the loops are 3 psig and $\sim 300\text{--}400^{\circ}\text{C}$, respectively. The maximum allowable working pressure and the temperature of the loop are 75 psig and 800°C . The total amount of sodium in the loop is approximately 20 kg. The loop assembly including the sample tanks is considered under the coverage of ASME Code for pressure piping B31.3 and its pressure safety is evaluated based on ASME B31.3. The system was designed to circulate sodium through the sample tanks and the associated loop without an operator for an extended period of time.

One significant difference between SMT-1 system and SMT-2 is that there are 2 tanks each containing enough sodium in SMT-2 to flood another tank if improperly distributed. To address this potential issue, the sodium suction point to feed each tank was located just below the sodium level in each tank to ensure that flooding of any of the tanks will never occur. The volume and the location of suction points were designed such that even if an unexpected flow disturbance or blockage occurs in the loop, only a small portion of the sodium in one tank can flow to another as the sodium level goes down, the suction point comes above the sodium level and no more sodium can flow to another tank.

The third forced convection loop (SMT-3), currently in construction, incorporates four test tanks with capability to expose as many as 42 ASTM-size specimens in each tank at temperatures of 550 and 600°C for as long as 100,000 hours. The current report presents an update on various aspects of SMT-3 design and planned operation scenarios.

3 SMT-3 Forced Convection Sodium Loop

3.1 Loop Specifications

The loop will incorporate four test tanks capable of ASTM-size specimen exposures without an operator for an extended period of time. Each tank has been designed to meet the requirements of Sec. VIII (Div. 1) of the ASME Boiler and Pressure Tank Code and/or ASME B31.3 Process Pipe Code. The technical requirements for each tank include a maximum allowable working temperature of 700°C, a pressure range of full vacuum to 800 kPa gage, operate with working fluids of sodium and cover gas of Argon. Helium leak test of parent material and welds are performed in accordance with the ASME Code Section V Article 10 and its Appendix V. The leak rate limit is $<10^{-9}$ std-cc/sec. The vessels are fabricated with either Type 304 or 316 stainless steel with a carbon content in the range of 0.04-0.08 wt.%, and the tanks design will incorporate a corrosion allowance of 15 $\mu\text{m}/\text{year}$ for 20 years. Figure 1 shows an isometric view of SMT-3.

The tanks will be fabricated from 10" dia. Sch. 80 pipe and will be 16" in height with an end cap welded at the bottom. Each tank will contain ~25 liters of sodium and the loop will have ~125-150 liters of sodium, that includes sodium in cold trap and economizers. The sodium flow rate will be in a range of 0.5-1.0 GPM.

Figure 1. Isometric view of SMT-3 forced convection sodium loop.

The cold trap and economizers will also be constructed from stainless steel pipes. The cold trap will be packed with stainless steel mesh, providing a large surface area. The cold trap will have its own heaters/blower and thermocouples. The temperature of the cold trap will be controlled by means of temperature feedback using a commercially available temperature controller. The economizers will be a tube-in-tube type heat exchanger and will have their own heater and thermocouples. The temperatures of the economizers will be controlled by means of temperature feedback using a commercially available temperature controller. The loop sodium will be partially cooled while exchanging heat with outgoing sodium from the cold trap as it flows through the economizer. The partially cooled sodium will enter the cold trap and will be further cooled. The cold sodium leaving the cold trap will be heated as it flows through the economizer. The cold trap temperature will be maintained in the range of 120-140°C which would result in an oxygen concentration in sodium of ~1-2 ppm, that is typical of SFRs.

To prevent undue stresses in the loop, which may arise due to differential thermal expansion, the loop legs and components will be hung from an Unistrut support frame, or otherwise supported with a support arrangement on the Unistrut frame. Details of the support configuration will be determined based on the results of the piping flexibility analysis.

3.2 Loop Design Specifications

The loop will incorporate the four specimen-exposure tanks in series. Expected operation time will be ~100,000 hours (~12 years). The design temperature (for fabrication and ASME Code purposes) is 650°C. Three of the tanks will be operated at 550°C and the fourth tank at 600°C. There will be a cold trap in the loop to control and maintain the oxygen concentration in the sodium at 1-2 ppm level. An EM pump will circulate the sodium from one of the end tanks through the cold trap back to another end tank. Another EM pump will control the sodium flow distribution between the bypass and the cold trap. Figure 2 shows a schematic of the SMT-3 loop configuration. The major part of the sodium piping will be fabricated using 1/2 in. Sch. 80 pipe of stainless steel. Table 1 lists the various operating scenario, anticipated during the long-term operation of the loop.

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Table 1. Conditions for Various Operating Scenarios for SMT-3 Loop

	Case description	EM Pump 021	EM Pump 221	Temp. zone 1		Temp. zone 2		Economizer 1		Temp. zone 3		Economizer 2	
				Cold trap		Cold trap to economizer 1				Main loop piping			
				Temperature	Pressure	Temperature	Pressure	Temperature	Pressure	Temperature	Pressure	Temperature	Pressure
Scenario 1	Initial-cold	OFF	OFF	-18 °C (0 °F)	0 psig	-18 °C (0 °F)	0 psig	-18 °C (0 °F)	0 psig	-18 °C (0 °F)	0 psig	-18 °C (0 °F)	0 psig
Scenario 2	Initial-hot	OFF	OFF	38 °C (100 °F)	FV to 10 psig	38 °C (100 °F)	FV to 10 psig	38 °C (100 °F)	FV to 10 psig	38 °C (100 °F)	FV to 10 psig	38 °C (100 °F)	FV to 10 psig
Scenario 3	Outgassing	OFF	OFF	300 °C	FV	400 °C	FV	400 °C	FV	500 °C	FV	600 °C	FV
Scenario 4	Sodium filling	ON/OFF	ON/OFF	300 °C	5 psig	300 °C	5 psig	300 °C	5 psig	300 °C	5 psig	300 °C	5 psig
Scenario 5	Nominal operation	ON	ON	Non uniform, linearly from 100 to 145 °C	5 psig	150 °C	5 psig	Non uniform, linearly from 150 to 320 °C	5 psig	335 °C	5 psig	Non uniform, linearly from 350 to 530 °C	5 psig
Scenario 6	High temperature operation	ON	ON	Non uniform, linearly from 100 to 145 °C	5 psig	150 °C	5 psig	Non uniform, linearly from 150 to 320 °C	5 psig	335 °C	5 psig	Non uniform, linearly from 350 to 575 °C	5 psig
Scenario 7	Stand-by-cold	OFF	OFF	-18 °C (0 °F)	5 psig	-18 °C (0 °F)	5 psig	-18 °C (0 °F)	5 psig	-18 °C (0 °F)	5 psig	-18 °C (0 °F)	5 psig
Scenario 8	Stand-by-hot	OFF	OFF	38 °C (100 °F)	5 psig	38 °C (100 °F)	5 psig	38 °C (100 °F)	5 psig	38 °C (100 °F)	5 psig	38 °C (100 °F)	5 psig
Scenario 9	Maximum design condition	ON	ON	500 °C	116 psig	500 °C	116 psig	500 °C	116 psig	500 °C	116 psig	Non uniform, linearly from 500 to 700 °C	116 psig
Scenario 10	Minimum design condition	OFF	OFF	0 °F	FV	0 °F	FV	0 °F	FV	0 °F	FV	0 °F	FV
Temp. zone 4		Temp. zone 5		Economizer 3		Temp. zone 6		Dump tank		Drain piping		Vent piping	
Piping to Tank 1		Tanks 1, 2, 4		Tank 3		Tank 3							
Temperature	Pressure	Temperature	Pressure	Temperature	Pressure	Temperature	Pressure	Temperature	Pressure	Temperature	Pressure	Temperature	Pressure
-18 °C (0 °F)	0 psig	-18 °C (0 °F)	0 psig	-18 °C (0 °F)	0 psig	-18 °C (0 °F)	0 psig	-18 °C (0 °F)	0 psig	-18 °C (0 °F)	0 psig	-18 °C (0 °F)	0 psig
38 °C (100 °F)	FV to 10 psig	38 °C (100 °F)	FV to 10 psig	38 °C (100 °F)	FV to 10 psig	38 °C (100 °F)	FV to 10 psig	38 °C (100 °F)	FV to 10 psig	38 °C (100 °F)	FV to 10 psig	38 °C (100 °F)	FV to 10 psig
650 °C	FV	650 °C	FV	675 °C	FV	700 °C	FV	400 °C	FV	400 °C	FV	Ambient	FV
300 °C	5 psig	300 °C	5 psig	300 °C	5 psig	300 °C	5 psig	300 °C	5 psig	300 °C	5 psig	Ambient	5 psig
Non uniform, linearly from 530 to 550 °C	5 psig	550 °C	5 psig	Non uniform, linearly from 555 to 595 °C	5 psig	600 °C	5 psig	150 °C	5 psig	150 °C	5 psig	Ambient	5 psig
Non uniform, linearly from 575 to 600 °C	5 psig	600 °C	5 psig	Non uniform, linearly from 605 to 645 °C	5 psig	650 °C	5 psig	150 °C	5 psig	150 °C	5 psig	Ambient	5 psig
-18 °C (0 °F)	5 psig	-18 °C (0 °F)	5 psig	-18 °C (0 °F)	5 psig	-18 °C (0 °F)	5 psig	-18 °C (0 °F)	5 psig	-18 °C (0 °F)	5 psig	-18 °C (0 °F)	5 psig
38 °C (100 °F)	5 psig	38 °C (100 °F)	5 psig	38 °C (100 °F)	5 psig	38 °C (100 °F)	5 psig	38 °C (100 °F)	5 psig	38 °C (100 °F)	5 psig	38 °C (100 °F)	5 psig
700 °C	116 psig	700 °C	116 psig	700 °C	116 psig	700 °C	116 psig	500 °C	116 psig	500 °C	116 psig	500 °C	116 psig
0 °F	FV	0 °F	FV	0 °F	FV	0 °F	FV	0 °F	FV	0 °F	FV	0 °F	FV

Figure 2. A schematic of SMT-3 loop configuration.

3.3 Summary of Piping Analysis

As far as how the elevated temperature fluid service requirements affected the piping design, per the pipe code, all the sodium piping has been designed with the required wall thickness set forth in the code for the sodium service. The only other requirement dictated by the code due to sodium service category was to use creep-based allowable stresses. Per paragraph below from ASME BPV code, sodium piping as well as the vessels design must consider the life of the vessel due to creep, since it will operate in the creep range.

In Section 2 Part D, Mandatory Appendix 1, para 1-100 (b):

At temperatures in the range where creep and stress rupture strength govern the selection of stresses, the maximum allowable stress value for all materials is established by the Committee not to exceed the lowest of the following:

- 100% of the average stress to produce a creep rate of 0.01%/1,000 h
- 100% of the average stress to cause rupture at the end of 100,000 h
- 80% of the minimum stress to cause rupture at the end of 100,000 h. The vendor used this requirement to set the allowable stresses in the analysis.

3.4 Piping System Analysis

We worked with Plant Design Solutions (PDS) to perform a piping analysis required by ASME B31.3 pipe code. After performing the first analysis with the operating condition (operating temperatures and pressures), materials of construction, initial piping layout developed at ANL (designed solely for functionality in terms of flow direction, head balance, heat transfer etc, and not for stress, flexibility etc.), it turned out that it was not possible to make the original design to pass the code requirements with reasonable amount of modifications to the loop itself due to the elevated temperature requirement. In the second iteration, the tanks and special supports were included in the piping layout and the entire system was analyzed to pass the requirements. Details were presented in a report delivered to ANL by PDS.

The piping analysis for the Sodium Loop #3 test facility included four experimental tanks (10" dia. each with two 400-pound flanges on top and a pipe cap serving as the tank bottom. The other components are all made from pipes with pipe caps ends. The dump tank dimension considered is 12 in dia, the cold trap is 6 in dia, and the three economizers are 2 in dia.

The Sodium Loop #3 system is considered as a relatively low pressure (116 psig design pressure) and very high temperature (700°C or 1,292°F design temperature) system with small stainless steel piping (½ in pipe). This temperature for the 316H stainless steel used throughout the system is in fact classified as an "Elevated Temperature Fluid Service," per the ASME B31.3 pipe code. Indeed any temperature above 1,100°F (593°C) is so classified. This classification indicates creep is a factor, and therefore the steel has time-dependent properties.

To define the design and its requirements for the piping system to the vendor, ANL originally provided the vendor with a 3-D model of the roughed-out system layout including piping and equipment in Inventor file. This was used as the basis for the initial pipe stress analysis model. Also provided by ANL was an initial piping specification as well as preliminary drawings for the equipment. Several changes were made after the initial design calculations to be in compliant with the code. Some of the key changes were:

- Piping schedule increased from schedule 40 to schedule 80 - for greater strength
- Material changed from 304 stainless steel to 316H stainless steel - for higher allowable stress at high temperature
- Lighter insulation and band heaters - the original 0.5 psi design was too heavy for the ½-in. pipe at temperature. Weight was reduced to 0.25 psi.
- Pipe routing changed to avoid clashing/interference that original 3-D model allowed.
- Pipe routing changed to include thermal loops to reduce thermal stresses.
- Minimum pressure increased from vacuum to 0 psig - due to pipe code limitations.
- Constant specific gravity used rather than temperature-dependent values - due to software limitation. The specific gravity at 400°C was used throughout the model, irrespective of the actual temperature.
- Included modeling the vessels (not just the piping) in the analysis - added spring supports to several of these vessels to reduce thermal stresses, and snubbers to resist seismic loads (1/2-in. piping is too small and weak to allow off-the-shelf springs, snubbers, or expansion joints to be used).
- Increased vessel nozzle wall thickness to increase allowable loads - because allowable loads for stainless steel at 700°C is only 3.5 ksi, increased the allowable nozzle loads typical of tank nozzles of this size, per API standard 650 Appendix 2.

3.5 Load Cases

The design is detailed in the CAESAR II pipe stress analysis software file that was electronically transmitted to ANL by PDS. The detailed isometric drawings of the revised piping layout with the locations of the pipe support were described in the final report. Since the vessels are much more robust and much larger in diameter, off-the-shelf designs were available to meet the needs of the system. Snubber support locations were also identified. Specifications for the piping supports, including snubbers were also listed. Additionally, ANL worked with the vessel fabricator to increase the robustness of the nozzles to allow the piping system more margin for compliance with allowable loads on the nozzles.

The ANL worksheet document identified ten different operating scenarios that the piping system would have to endure (see Table 1). Using these as the basis, the load cases required to pass the pipe code were developed. The pipe code requires the most taxing scenarios to be analyzed, as well as the normal operating condition. Using the ten operating scenarios in Table 1, the information in Table 2 was created to identify the load cases used in the pipe stress analysis. Table 1 is cross-referenced in Table 2.

Note, the Minimum Design scenario shown in the ANL table was not included in the analysis because vacuum is not a pipe code condition. The minimum pipe code pressure is atmospheric. Thus, the Minimum Design condition was the same as the Initial Cold scenario. The creep analysis in Table 2 analyzes the creep of 100,000 hours of varying operating conditions between Maximum Design and Normal Operation. This served as the basis for the pipe code design.

Table 2. Summary of Load Cases Modeled in CAESAR II

					Temperatures (°C /°F)				
	Operating Case #	ANL Scenario	CAESAR II P Case	System Pressure	CAESAR II T Case	Cold Trap	Exp. Tank #3	Constant T?	Creep Range?
Normal Operating	1	5	P1:	5 psig	T1:	100 / 212	600 / 1112	NO	YES
Maximum Design	2	8	P2:	116 psig	T2:	500 / 932	700 / 1,292	NO	YES
Outgassing	3	3	-	0 psig	T3:	300 / 572	700 / 1,292	NO	YES
Na Filling	4	4	P4:	5 psig	T4:	300 / 572	300 / 572	YES	NO
Initial Cold (Coldest)	5	5	-	0 psig	T5:	-18 / 0	-18 / 0	YES	NO
Seismic	Op 2 + Seismic	8 + Seismic	P2		T2				YES
Creep	Op 2 – Op 1	8 - 5	P2 – P1:	111 psid	T2 – T2				YES
Hydraulic Test	Hydro	125% Op 2*R	HP:	670	Ambient	Ambient	Ambient	YES	NO

3.6 Fabrication of Specimen Exposure Vessels

The fabrication of specimen exposure vessels was contracted to Northland Stainless, a Division of Samuel Pressure Vessel Group who have extensive experience in fabrication of stainless steel components, welding, and testing needed to certify the components for ASME Code compliance. The preliminary drawings of the vessel and top flanges were prepared at ANL to meet the program requirements and the drawings were sent to Northland for discussions on the viability of the system, interface with results of piping design analysis, and code compliance.

Northland was advised of the changes that are needed to vessel design to conform to the piping analysis. For example, for the piping layout to meet the ASME Code requirement, it was necessary to increase the nozzle wall thickness, which made some of the clearances too small and required repositioning some of the nozzles to avoid potential interferences with other structures. The changes were communicated to Northland to make sure the changes would meet the Boiler & Pressure Tank Code with the loading at the nozzles provided from the piping analysis performed by Piping Design Solutions. The vessel dimensional consistency was verified with the piping layout that would meet the piping code requirements.

Figures 3 and 4 show photographs of single and multiple vessels fabricated by Northland and shipped to ANL after extensive testing. Additionally, summary information is presented in this deliverable on the manufacturer's data report, manufacturer's check list, final inspection report, certificate of hydrotest, certification of passivation, certification of cleansing, and helium leak testing certification for all the four vessels.

Figure 3. A photograph of sodium exposure vessel fabricated by Northland for SMT-3 Loop.

Figure 4. A photograph of multiple sodium exposure vessels on the Northland shop floor, fabricated for SMT-3 Loop.

6A-38096
Purchase Order Number

FORM U-1A MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS
(Alternative Form for Single Chamber, Completely Shop or Field Fabricated Vessels Only)
As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1 Page 1 of 2

1. Manufactured and certified by **Northland Stainless, Inc., 1119 Bridge Street, Tomahawk, Wisconsin, 54487**
(Name and address of Manufacturer)

2. Manufactured for **UCHICAGO ARGONNE LLC DBA ARGONNE NATIONAL LABORATORY, Bldg. 201, 9700 S. Cass Ave., Lemont, Illinois, 60439**
(Name and address of Purchaser)

3. Location of Installation **Unknown**
(Name and address)

4. Type **Vertical Tank** **V45867-1-1** **N/A** **90.13613 Rev.F** **6318** **2018**
(Horizontal or vertical, tank) (Manufacturer's serial number) (CRN) (Drawing number) (National Board number) (Year built)

5. ASME Code, Section VIII, Division 1 **2016/ N/A** **N/A** **N/A**
(Edition and Addenda, if applicable (date)) (Code Case numbers) (Special service per UG-120(d))

6. Shell: **SA-312 TP304** **.365"** **0.012"** **10.02" (ID)** **1' 4.376"**
(Material spec. number, grade) (Nominal thickness) (Corr. allow.) (Inner diameter) (Length (overall))

Body Flanges on Shells												
No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
1	Weld Neck Integral	10.02"	17.5"	1.8125	N/A	SA-182 F304	Fig. 2-4(6a)	TOP	(16) - 1"-8 NF	SA193 B8 CL.1, 304	2", 1-1/16", 0.134"	304 SST

7. Seams: **Welded, Sngl. Butt** **Full** **100** **N/A** **N/A** **Welded, Sngl. Butt** **Full** **100** **1**
(Long. (welded, dbl., engl., lap, butt)) (R.T. (spot or full)) (Eff. %) (H.T. temp) (Time, hr) (Girth. (welded, dbl., sngl., lap, butt)) (R.T. (spot or full)) (Eff. %) (No. of courses)

8. Heads: (a) Material **SA240 304 (2.25" nom.)** (b) Material **SA-403 304 (0.365" nom)**
(Spec. no., grade) (Spec. no., grade)

	Location (Top, Bottom, Ends)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)	Top	2.25"	0.012"	N/A	N/A	N/A	N/A	N/A	17.5"	Both
(b)	Bottom	0.320"	0.012"	10.02"	N/A	N/A	N/A	N/A	N/A	Both

Body Flanges on Heads												
	Location	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
(a)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

9. MAWP **117 psi** **FV** at max. temp. **1292 °F** **1292 °F**
(Internal) (External) (Internal) (External)

Min. design metal temp. **-20 °F** at **FV/117 psi** Hydro, pneu., or comb. test pressure **HYDRO at 665 psi**

Proof test **N/A**

10. Nozzles, inspection and safety valve openings:

Purpose (Inlet, Outlet, Drain, etc.)	No.	Diameter or Size	Type	Material		Nozzle Thickness		Reinforcement Material	Attachment Details		Location (Insp. Open.)
				Nozzle	Flange	Nom.	Corr.		Nozzle	Flange	
Process	4	1/2"	Pipe	SA-312 TP304		0.109"			Fig. UW-16.1(d)		
Process	1	1 1/2"	Pipe	SA-312 TP304		0.145"			Fig. UW-16.1(d)		
Process	1	3/4"	Pipe	SA-312 TP304		0.113"			Fig. UW-16.1(d)		
Process	1	1/2"	Pipe	SA-479 304		0.35"	0.012"		Fig. UW-16.1(d)		
Process	1	1/2"	Pipe	SA-479 304		0.35"	0.012"		Fig. UW-16.1(d)		

11. Supports: Skirt **No** Lugs **N/A** Legs **N/A** Other **N/A** Attached **N/A**
(Yes or no) (Number) (Number) (Describe) (Where and how)

12. Remarks: Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors, have been furnished for the following items of the report:
N/A
(Name of part, item number, Manufacturer's name and identifying stamp)

Over pressure protection device supplied by others.
All material noted as alloy 304 SA240, SA182 & SA312 are dual certified 304/304L

FORM U-1A

Page 2 of 2

Manufactured by **Northland Stainless, Inc., 1119 Bridge Street, Tomahawk, Wisconsin, 54487**
Manufacturer's Serial No. **V45867-1-1** CRN **N/A** National Board No. **6318**

CERTIFICATE OF SHOP/FIELD COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. "U" Certificate of Authorization Number **12346**
expires **August 28, 2019**

Date **04/16/2018** Co. name **Northland Stainless, Inc.** Signed **[Signature]**
(Manufacturer) (Representative)

CERTIFICATE OF SHOP/FIELD INSPECTION

Vessel constructed by **Northland Stainless, Inc.** at **1119 Bridge Street, Tomahawk, Wisconsin, 54487**
I, the undersigned, holding a valid commission issued by The National Board of Boiler and Pressure Vessel Inspectors and employed by
OneCIS Insurance Company, of Lynn, MA

have inspected the component described in this Manufacturer's Data Report on **April 17, 2018**
and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME BOILER
AND PRESSURE VESSEL CODE, Section VIII, Division 1. By signing this certificate neither the Inspector nor his/her employer makes any
warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector
nor his/her employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with
this inspection.

Date **04/18/2018** Signed **[Signature]** Commissions **14564, MNC0046514, WI1269509**
(National Board Authorized Inspector Commission number)

3019060

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Form and version: U1A-19

**Northland
Stainless**

a division of **SPVCG**

**Manufacture's Checklist
Exhibit #1**

SPVCG

SPVCG Pressure Vessel Group

Customer: ARGONNE NATIONAL LABS

Work Order: V45867-1

Drawing #: 90.13613

Authorized Inspector Review: **Now**

Serial Number: V45867-1-1

Drawing Rev.: **2-5**

4-10-18

National Board #: 6318

National Board Type: U

Date: **10-21-17**

Manufacture's Checklist

Stage: Manufacturing Step	Req.	Q.A.	Date	Hold Point	A.I.	Date
Drawings & Calculations Review	X	JR	10-2-17	*	Now	10-3-17
Vessel Internal	X	SP	3-28-18	*	RLW	3-28-18
NDE - Type RT-1	X	SP	4-5-18	*	Now	4-17-18
Final Level Check	X	SP	4-5-18		N/A	
Final Dimension Check	X	SP	4-5-18		N/A	
Vessel External	X	SP	3-29-18	*	RLW	3-29-18
Vessel Hydrostatic ⁷⁰⁰ psi Gage #: 219	X	SP	3-29-18	*	RLW	3-29-18
Final Visual	X	SP	3-29-18	*	RLW	3-29-18
Stamping & Marking	X	SP	3-29-18	*	RLW	3-29-18
Material Test Report Review	X	RB	4-6-18	*	Now	4-17-18

All Stages Complete

Authorized Inspector: **[Signature]** Date: **4-17-18**

Quality Assurance: **[Signature]** Date: **4/17/2018**

Internal Inspection Noz G+H prior to Head Attachment **SP 3-23-18** **Now 2-23-18**

Description:

[illegible]

FRM-QA-4
Rev. 2- 5/18/2015

Certification of Hydrotest

Customer: Argonne National Lab
Purchase Order #: 6A-38096
Northland Stainless Work Order #: V45867-1-1

This is to certify that the above vessel was successfully hydro tested in accordance with ASME Section VIII, Division 1.

- Test Pressure – 700 psi
- Test Gage - 219 (calibrated) gauge range 0 - 10,000 psi
-
-

Certified by:

Northland Stainless Inc.
Dated: 03/29/2018

Certification Of Passivation

Customer: Argonne National Lab
Northland Stainless Work Order V45867-1-1
Vessel Description: Specimen Exposure Vessel

This is to certify that the above Vessel(s) was/were successfully passivated
in accordance with Northland Stainless Procedure
SOP-0050 Passivation Scale Clean - HF

Interior: ☐

Exterior: ☒

Interior & Exterior: ☐

Certified by:

Northland Stainless

Date: 9/5/18

**Northland
Stainless**

a division of **CH2M**

Certification of Cleansing

SPVG

Pressure Vessel Group

Customer: Argonne National Lab
Purchase Order # 6A-38096
Northland Stainless Work Order # V45867-1-1

This is to certify that the above Vessel(s) surfaces were successfully cleansed by
Northland Stainless Inc.

Certified by: *Bob Soward*

Northland Stainless Inc.
Date: *4/5/2018*

SRI Pressure Vessel Group

Helium Leak Testing **Certificate of Compliance**

Customer: Argonne National Lab
P.O. Number: 6A-38096
Work Order: V45867-1-1
Drawing Number: 90.13613
Equipment Description: Specimen Exposure Vessel

This letter is to certify the above product meets all requirements of the subject purchase order. This equipment was helium leak tested to -8 Torr and was found to be acceptable.

Signed:

A handwritten signature in black ink, appearing to read "James T. Mills", is written over a horizontal line.

Date:

04-03-2018

6A-38096
Purchase Order Number

FORM U-1A MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS
(Alternative Form for Single Chamber, Completely Shop or Field Fabricated Vessels Only)
As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1 Page 1 of 2

1. Manufactured and certified by **Northland Stainless, Inc., 1119 Bridge Street, Tomahawk, Wisconsin, 54487**
(Name and address of Manufacturer)

2. Manufactured for **UCHICAGO ARGONNE LLC DBA ARGONNE NATIONAL LABORATORY, Bldg. 201, 9700 S. Cass Ave., Lemont, Illinois, 60439**
(Name and address of Purchaser)

3. Location of Installation **Unknown**
(Name and address)

4. Type **Vertical Tank** **V45867-1-2** **N/A** **90.13613 Rev.F** **6319** **2018**
(Horizontal or vertical, tank) (Manufacturer's serial number) (CRN) (Drawing number) (National Board number) (Year built)

5. ASME Code, Section VIII, Division 1 **2016/ N/A** **N/A** **N/A**
(Edition and Addenda, if applicable (date)) (Code Case numbers) [Special service per UG-120(d)]

6. Shell: **SA-312 TP304** **.365"** **0.012"** **10.02" (ID)** **1' 4.375"**
(Material spec. number, grade) (Nominal thickness) (Corr. allow.) (Inner diameter) [Length (overall)]

Body Flanges on Shells												
No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
1	Weld Neck Integral	10.02"	17.5"	1.8125	N/A	SA-182 F304	Fig. 2-4(6a)	TOP	(16) - 1"-8 NF	SA193 B8 CL.1, 304	2", 1-1/16", 0.134"	304 SST

7. Seams: **Welded, Sngl. Butt** **Full** **100** **N/A** **N/A** **Welded, Sngl. Butt** **Full** **100** **1**
[Long. (welded, dbl., sngl., lap, butt)] [R.T. (spot or full)] [Eff., %] (H.T. temp) (Time, hr) [Girth. (welded, dbl., sngl., lap, butt)] [R.T. (spot or full)] [Eff., %] (No. of courses)

8. Heads: (a) Material **SA240 304 (2.25" nom.)** (b) Material **SA-403 304 (0.365" nom.)**
(Spec. no., grade) (Spec. no., grade)

	Location (Top, Bottom, Ends)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)	Top	2.25"	0.012"	N/A	N/A	N/A	N/A	N/A	17.5"	Both
(b)	Bottom	0.320"	0.012"	10.02"	N/A	N/A	N/A	N/A	N/A	Both

Body Flanges on Heads												
	Location	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
(a)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A	N/A	N/A

9. MAWP **117 psi** **FV** at max. temp. **1292 °F** **1292 °F**
(Internal) (External) (Internal) (External)

Min. design metal temp. **-20 °F** at **FV/117 psi** Hydro, pneu., or comb. test pressure **HYDRO at 665 psi**

Proof test **N/A**

10. Nozzles, inspection and safety valve openings:

Purpose (Inlet, Outlet, Drain, etc.)	No.	Diameter or Size	Type	Material		Nozzle Thickness		Reinforcement Material	Attachment Details		Location (Insp. Open.)
				Nozzle	Flange	Nom.	Corr.		Nozzle	Flange	
Process	4	1/2"	Pipe	SA-312 TP304		0.109"			Fig. UW-16.1(d)		
Process	1	1 1/2"	Pipe	SA-312 TP304		0.145"			Fig. UW-16.1(d)		
Process	1	3/4"	Pipe	SA-312 TP304		0.113"			Fig. UW-16.1(d)		
Process	1	1/2"	Pipe	SA-479 304		0.35"	0.012"		Fig. UW-16.1(d)		
Process	1	1/2"	Pipe	SA-479 304		0.35"	0.012"		Fig. UW-16.1(d)		

11. Supports: Skirt **No** Lugs **N/A** Legs **N/A** Other **N/A** Attached **N/A**
(Yes or no) (Number) (Number) (Describe) (Where and how)

12. Remarks: Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors, have been furnished for the following items of the report:
N/A
(Name of part, item number, Manufacturer's name and identifying stamp)

Over pressure protection device supplied by others.
All material noted as alloy 304 SA240, SA182 & SA312 are dual certified 304/304L.

FORM U-1A

Page 2 of 2

Manufactured by Northland Stainless, Inc., 1119 Bridge Street, Tomahawk, Wisconsin, 54487
Manufacturer's Serial No. V45867-1-2 CRN N/A National Board No. 6319

CERTIFICATE OF SHOP/FIELD COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. "U" Certificate of Authorization Number 12346

expires August 28, 2019

Date 04/16/2018 Co. name Northland Stainless, Inc. Signed [Signature]
(Manufacturer) (Representative)

CERTIFICATE OF SHOP/FIELD INSPECTION

Vessel constructed by Northland Stainless, Inc. at 1119 Bridge Street, Tomahawk, Wisconsin, 54487

I, the undersigned, holding a valid commission issued by The National Board of Boiler and Pressure Vessel Inspectors and employed by

OneCIS Insurance Company, of Lynn, MA

have inspected the component described in this Manufacturer's Data Report on April 17, 2018, and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. By signing this certificate neither the Inspector nor his/her employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his/her employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 04/18/2018 Signed [Signature] Commissions 14564, MNCO046514, W11269509
(National Board Authorized Inspector Commission number)

3026932

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Form and version: U1A-19

**Northland
Stainless**

A Division of **SPVCG**

Manufacture's Checklist
Exhibit #1

SPVCG
Pressure Vessel Group

Customer: ARGONNE NATIONAL LABS

Work Order: V45867-1

Drawing #: 90.13613

Authorized Inspector Review: [Signature]

Serial Number: V45867-1-2

Drawing Rev.: 6.0 E-11.5-2.5

Rev 10-4-13

National Board #: 6319

National Board Type: U

Date: 10-3-17

Manufacture's Checklist

Stage: Manufacturing Step	Req.	Q.A.	Date	Hold Point	A.I.	Date
Drawings & Calculations Review	X	AR	10-2-17	*	NW	10-3-17
Vessel Internal	X	SPM	3-28-18	*	RW	3/28/18
NDE - Type RT-1	X	SPM	4-5-18	*	NW	4-17-18
Final Level Check	X	SPM	4-5-18		N/A	
Final Dimension Check	X	SPM	4-5-18		N/A	
Vessel External	X	SPM	3-28-18	*	RW	3/28/18
Vessel Hydrostatic <u>685</u> PSI psi Gage #: <u>219</u>	X	SPM	3-28-18	*	RW	3/28/18
Final Visual	X	SPM	3-28-18	*	RW	3/28/18
Stamping & Marking	X	SPM	3-28-18	*	RW	3/28/18
Material Test Report Review	X	QAB	4-16-18	*	NW	4-17-18

All Stages Complete

Authorized Inspector: [Signature] Date: 4-17-18

Quality Assurance: [Signature] Date: 4/17/2018

Internal Inspection Noz G+H prior to Head Attachment SPM 2-23-18 NW 2-23-18

NSI Final Inspection Report

Customer: Argonne National Lab Job#: V45867-1-2 DRW#: 90.13613 Date: < Select >

Description: _____

Place your initials in the highlighted areas below. If a nonconformance is discovered please make notes in the designed area.

Q.A.		Q.A.			
1. Fittings Projection:	<u>SP</u>	15. Leg Straightness	<u>NA</u>	Passivated	Yes ☒ No ☐
2. Fitting Orientation:	<u>SP</u>	16. Leg Pads	<u>NA</u>	ASME	Yes ☒ No ☐
3. Fitting Straightness	<u>SP</u>	17. Repad Gusset Ring	<u>NA</u>	X-Ray	Yes ☒ No ☐
4. Fitting Type	<u>SP</u>	18. Weep Holes	<u>NA</u>	Tank Test	<u>685 psi</u>
5. Manway	<u>NA</u>	19. Cleanness/ corrosion	<u>SP</u>	JKT Test	<u>NA</u>
6. Weld Appearance	<u>SP</u>	Heating Cooling Jackets		Initial	<u>SP</u>
7. Overall Appearance	<u>SP</u>	20. Material Spec.	<u>NA</u>	Job Bin Empty	Yes ☒ No ☐
8. Material Spec.	<u>SP</u>	21. Appearance	<u>I</u>	Initial	<u>SP</u>
9. Finish	<u>SP</u>	22. Welds	<u>I</u>	Ready for skidding Sign & Date	
10. Tank Dimensions	<u>SP</u>	Insulation Jacket		<u>James R. Miller</u> <u>4/5/18</u>	
11. Fitting to Floor	<u>NA</u>	23. Appearance	<u>NA</u>	O.K. for shipping Sign & Date	
12. Tank Drainage	<u>NA</u>	24. Vapor Test	<u>I</u>	<u>James R. Miller</u> <u>4/5/18</u>	
13. Nameplate	<u>SP</u>	25. Material Spec.	<u>I</u>		
14. Leg Orientation:	<u>NA</u>				
Discrepancy Codes					
1. Defective Weld	4. Defective Material	8. Training Issues	Other:		
2. Drawing Error	5. Material Handling	9. Production Issues			
3. Defective Finish	6. Fabrication Damage	10. Defective Finish			
	7. ASME Issue				
Discrepancy		ENG OK	FAB CL#	QA OK	Code #

Northland Stainless
1119A Bridge St
Tomahawk, WI 54487
(715) 453-5326
Fax (715) 453-5357
Email: info@northlandstainless.com
Website: www.northlandstainless.com

FRM-QA-4
Rev. 2- 5/18/2015

Certification of Hydrotest

Customer: Argonne National Lab
Purchase Order #: 6A-38096
Northland Stainless Work Order #: V45867-1-2

This is to certify that the above vessel was successfully hydro tested in accordance with ASME Section VIII, Division 1.

- Test Pressure – 685 psi
- Test Gage - 219 (calibrated) gauge range 0-10,000 psi
-
-

Certified by:

A handwritten signature in black ink, appearing to read 'Justin C. Miller'.

Northland Stainless Inc.
Dated: 03/28/2018

Certification Of Passivation

Customer: Argonne National Lab
Northland Stainless Work Order V45867-1-2
Vessel Description: Specimen Exposure Vessel

This is to certify that the above Vessel(s) was/were successfully passivated
in accordance with Northland Stainless Procedure
SOP-0050 Passivation Scale Clean - HF

Interior: ☐

Exterior: ☒

Interior & Exterior: ☐

Certified by:

Northland Stainless

Date: 4/9/18

Certification of Cleansing

Customer: Argonne National Lab
Purchase Order # 6A-38096
Northland Stainless Work Order # V45867-1-2

This is to certify that the above Vessel(s) surfaces were successfully cleansed by Northland Stainless Inc.

Certified by:

Northland Stainless Inc.
Date: 04/05/2018

Helium Leak Testing **Certificate of Compliance**

Customer: Argonne National Lab
P.O. Number: 6A-38096
Work Order: V45867-1-2
Drawing Number: 90.13613
Equipment Description: Specimen Exposure Vessel

This letter is to certify the above product meets all requirements of the subject purchase order. This equipment was helium leak tested to $\sim 8 \times 10^{-8}$ Torr and was found to be acceptable.

Signed: *Allen Klein*
Paul K. Miller

Date: *3-29-18*

6A-38096
Purchase Order Number

FORM U-1A MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS
(Alternative Form for Single Chamber, Completely Shop or Field Fabricated Vessels Only)
As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1 Page 1 of 2

1. Manufactured and certified by **Northland Stainless, Inc., 1119 Bridge Street, Tomahawk, Wisconsin, 54487**
(Name and address of Manufacturer)

2. Manufactured for **UCHICAGO ARGONNE LLC DBA ARGONNE NATIONAL LABORATORY, Bldg. 201, 9700 S. Cass Ave., Lemont, Illinois, 60439**
(Name and address of Purchaser)

3. Location of Installation **Unknown**
(Name and address)

4. Type **Vertical Tank** **V45867-1-3** **N/A** **90.13613 Rev.F** **6320** **2018**
(Horizontal or vertical, tank) (Manufacturer's serial number) (CRN) (Drawing number) (National Board number) (Year built)

5. ASME Code, Section VIII, Division 1 **2015/ N/A** **N/A** **N/A**
(Edition and Addenda, if applicable (delete)) (Code Case numbers) (Special service per UG-120(d))

6. Shell: **SA-312 TP304** **.365"** **0.012"** **10.02" (ID)** **1' 4.375"**
(Material spec. number, grade) (Nominal thickness) (Corr. allow.) (Inner diameter) (Length overall)

Body Flanges on Shells												
No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
1	Weld Neck Integral	10.02"	17.5"	1.8125	N/A	SA-182 F304	Fig. 2-4(6a)	TOP	(16) - 1"-8 NF	SA193 B8 CL.1, 304	2", 1-1/16", 0.134"	304 SST

7. Seams: **Welded, Sngl. Butt** **Full** **100** **N/A** **N/A** **Welded, Sngl. Butt** **Full** **100** **1**
(Long, welded, dbl., engl., lap, butt) [R.T. (spot or full)] (Eff. %) (H.T. temp) (Time, hr) (Girth, welded, dbl., engl., lap, butt) [R.T. (spot or full)] (Eff. %) (No. of courses)

8. Heads: (a) Material **SA240 304 (2.25" nom.)** (b) Material **SA-403 304 (0.365" nom.)**
(Spec. no., grade) (Spec. no., grade)

	Location (Top, Bottom, Ends)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)	Top	2.25"	0.012"	N/A	N/A	N/A	N/A	N/A	17.5"	Both
(b)	Bottom	0.320"	0.012"	10.02"	N/A	N/A	N/A	N/A	N/A	Both

Body Flanges on Heads												
	Location	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
(a)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

9. MAWP **117 psi** **FV** at max. temp. **1292 °F** **1292 °F**
(Internal) (External) (Internal) (External)

Min. design metal temp. **-20 °F** at **FV/117 psi** Hydro, pneu., or comb. test pressure **HYDRO at 665 psi**

Proof test **N/A**

10. Nozzles, inspection and safety valve openings:

Purpose (Inlet, Outlet, Drain, etc.)	No.	Diameter or Size	Type	Material		Nozzle Thickness		Reinforcement Material	Attachment Details		Location (Insp. Open.)
				Nozzle	Flange	Nom.	Corr.		Nozzle	Flange	
Process	4	1/2"	Pipe	SA-312 TP304		0.109"			Fig. UW-16.1(d)		
Process	1	1 1/2"	Pipe	SA-312 TP304		0.145"			Fig. UW-16.1(d)		
Process	1	3/4"	Pipe	SA-312 TP304		0.113"			Fig. UW-16.1(d)		
Process	1	1/2"	Pipe	SA-479 304		0.35"	0.012"		Fig. UW-16.1(d)		
Process	1	1/2"	Pipe	SA-479 304		0.35"	0.012"		Fig. UW-16.1(d)		

11. Supports: Skirt **No** Lugs **N/A** Legs **N/A** Other **N/A** Attached **N/A**
(Yes or no) (Number) (Number) (Describe) (Where and how)

12. Remarks: Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors, have been furnished for the following items of the report:
N/A
(Name of part, item number, Manufacturer's name and identifying stamp)

Over pressure protection device supplied by others.
All material noted as alloy 304 SA240, SA182 & SA312 are dual certified 304/304L

FORM U-1A

Page 2 of 2

Manufactured by **Northland Stainless, Inc., 1119 Bridge Street, Tomahawk, Wisconsin, 54487**
Manufacturer's Serial No. **V45867-1-3** CRN **N/A** National Board No. **6320**

CERTIFICATE OF SHOP/FIELD COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. "U" Certificate of Authorization Number **12346**
expires **August 28, 2019**

Date **04/16/2018** Co. name **Northland Stainless, Inc.** Signed **[Signature]**
(Manufacturer) (Representative)

CERTIFICATE OF SHOP/FIELD INSPECTION

Vessel constructed by **Northland Stainless, Inc.** at **1119 Bridge Street, Tomahawk, Wisconsin, 54487**
I, the undersigned, holding a valid commission issued by The National Board of Boiler and Pressure Vessel Inspectors and employed by

OneCIS Insurance Company, of Lynn, MA
have inspected the component described in this Manufacturer's Data Report on **April 17, 2018**
and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. By signing this certificate neither the Inspector nor his/her employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his/her employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date **04/18/2018** Signed **[Signature]** Commissions **14564, MNC0046514, WI1269509**
(National Board Authorized Inspector Commission number)

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Form and version: U1A-19

**Northland
Stainless**
a division of **SPVCG**

Manufacturer's Checklist
Exhibit #1

Customer: ARGONNE NATIONAL LABS

F KR 3-9-18

Work Order: V45867-1

Serial Number: V45867-1-3

National Board #: 6320

Drawing #: 90.13613

Drawing Rev.: ~~2-5~~

National Board Type: U

Authorized Inspector Review: **[Signature]**

10-4-13

Date: **10-3-17**

Manufacturer's Checklist

Stage: Manufacturing Step	Req.	Q.A.	Date	Hold Point	A.I.	Date
Drawings & Calculations Review	X	[Signature]	10-2-17	*	[Signature]	10-3-17
Vessel Internal	X	[Signature]	3-28-18	*	[Signature]	3-28-18
NDE - Type RT-1	X	[Signature]	4-17-18	*	[Signature]	4-17-18
Final Level Check	X	[Signature]	4-5-18		N/A	
Final Dimension Check	X	[Signature]	4-5-18		N/A	
Vessel External	X	[Signature]	3-29-18	*	[Signature]	3-29-18
Vessel Hydrostatic 693 665 PSI psi Gage #: 219	X	[Signature]	3-29-18	*	[Signature]	3-29-18
Final Visual	X	[Signature]	3-29-18	*	[Signature]	3-29-18
Stamping & Marking	X	[Signature]	3-29-18	*	[Signature]	3-29-18
Material Test Report Review	X	[Signature]	4-16-18	*	[Signature]	4-17-18

All Stages Complete

Authorized Inspector: **[Signature]** Date: **4/17/18**

Quality Assurance: **[Signature]** Date: **4/19/2018**

Internal Inspection Nov 6+H prior to ^{Hand} attachment **[Signature]** 2-23-18 **[Signature]** 2-23-18

Place your initials in the highlighted areas below. If a nonconformance is discovered please make notes in the designed area.

Northland Stainless
1119A Bridge St.
Tomahawk, WI 54487
(715) 453-5326
Fax (715) 453-5357
Email: info@northlandstainless.com
Website: www.northlandstainless.com

Certification of Hydrotest

Customer: Argonne National Lab
Purchase Order #: 6A-38096
Northland Stainless Work Order #: V45867-1-3

This is to certify that the above vessel was successfully hydro tested in accordance with ASME Section VIII, Division 1.

- Test Pressure – 643 psi
- Test Gage - 217 (calibrated) gauge range 0-10,000 psi
-
-

Certified by:

Northland Stainless Inc.
Dated: 03/29/2018

Certification Of Passivation

Customer: Argonne National Lab
Northland Stainless Work Order V45867-1-3
Vessel Description: Specimen Exposure Vessel

This is to certify that the above Vessel(s) was/were successfully passivated
in accordance with Northland Stainless Procedure
SOP-0050 Passivation Scale Clean - HF

Interior: ☐

Exterior: ☒

Interior & Exterior: ☐

Certified by:

Northland Stainless

Date: 8/15/18

Helium Leak Testing
Certificate of Compliance

Customer: Argonne National Lab
P.O. Number: 6A-38096
Work Order: V45867-1-3
Drawing Number: 90.13613
Equipment Description: Specimen Exposure Vessel

This letter is to certify the above product meets all requirements of the subject purchase order. This equipment was helium leak tested to -8×10^{-8} Torr and was found to be acceptable.

Signed:

James T. Mills

Date:

04-03-2018

6A-38096
Purchase Order Number

FORM U-1A MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS
(Alternative Form for Single Chamber, Completely Shop or Field Fabricated Vessels Only)
As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1 Page 1 of 2

1. Manufactured and certified by **Northland Stainless, Inc., 1119 Bridge Street, Tomahawk, Wisconsin, 54487**
(Name and address of Manufacturer)

2. Manufactured for **UCHICAGO ARGONNE LLC DBA ARGONNE NATIONAL LABORATORY, Bldg. 201, 9700 S. Cass Ave., Lemont, Illinois, 60439**
(Name and address of Purchaser)

3. Location of Installation **Unknown**
(Name and address)

4. Type **Vertical Tank** **V45867-1-4** **N/A** **90.13613 Rev.F** **6321** **2018**
(Horizontal or vertical, tank) (Manufacturer's serial number) (CRN) (Drawing number) (National Board number) (Year built)

5. ASME Code, Section VIII, Division 1 **2016/ N/A** **N/A** **N/A**
(Edition and Addenda, if applicable (date)) (Code Case numbers) [Special service per UG-120(d)]

6. Shell: **SA-312 TP304** **.365"** **0.012"** **10.02" (ID)** **1' 4.375"**
(Material spec. number, grade) (Nominal thickness) (Corr. allow.) (Inner diameter) [Length (overall)]

Body Flanges on Shells												
No.	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Location	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
1	Weld Neck Integral	10.02"	17.5"	1.8125	N/A	SA-182 F304	Fig. 2-4(6a)	TOP	(16) - 1"-8 NF	SA193 B8 CL 1, 304	2", 1-1/16", 0.134"	304 SST

7. Seams: **Welded, Sngl. Butt** **Full** **100** **N/A** **N/A** **Welded, Sngl. Butt** **Full** **100** **1**
[Long. (welded, dbl., sngl., lap, butt)] [R.T. (spot or full)] (Eff. %) (H.T. temp) (Time, hr) [Girth. (welded, dbl., sngl., lap, butt)] [R.T. (spot or full)] (Eff. %) (No. of courses)

8. Heads: (a) Material **SA240 304 (2.25" nom.)** (b) Material **SA-403 304 (0.365" nom.)**
(Spec. no., grade) (Spec. no., grade)

	Location (Top, Bottom, Ends)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)	Top	2.25"	0.012"	N/A	N/A	N/A	N/A	N/A	17.5"	Both
(b)	Bottom	0.320"	0.012"	10.02"	N/A	N/A	N/A	N/A	N/A	Both

Body Flanges on Heads												
	Location	Type	ID	OD	Flange Thk	Min Hub Thk	Material	How Attached	Bolting			
									Num & Size	Bolting Material	Washer (OD, ID, thk)	Washer Material
(a)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		N/A	N/A	N/A

9. MAWP **117 psi** **FV** at max. temp. **1292 °F** **1292 °F**
(Internal) (External) (Internal) (External)

Min. design metal temp. **-20 °F** at **FV/117 psi** Hydro, pneu., or comb. test pressure **HYDRO at 665 psi**

Proof test **N/A**

10. Nozzles, inspection and safety valve openings:

Purpose (Inlet, Outlet, Drain, etc.)	No.	Diameter or Size	Type	Material		Nozzle Thickness		Reinforcement Material	Attachment Details		Location (Insp. Open.)
				Nozzle	Flange	Nom.	Corr.		Nozzle	Flange	
Process	4	1/2"	Pipe	SA-312 TP304		0.109"			Fig. UW-16.1(d)		
Process	1	1 1/2"	Pipe	SA-312 TP304		0.145"			Fig. UW-16.1(d)		
Process	1	3/4"	Pipe	SA-312 TP304		0.113"			Fig. UW-16.1(d)		
Process	1	1/2"	Pipe	SA-479 304		0.35"	0.012"		Fig. UW-16.1(d)		
Process	1	1/2"	Pipe	SA-479 304		0.35"	0.012"		Fig. UW-16.1(d)		

11. Supports: Skirt **No** Lugs **N/A** Legs **N/A** Other **N/A** Attached **N/A**
(Yes or no) (Number) (Number) (Describe) (Where and how)

12. Remarks: Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors, have been furnished for the following items of the report:
N/A
(Name of part, item number, Manufacturer's name and identifying stamp)

Over pressure protection device supplied by others.
All material noted as alloy 304 SA240, SA182 & SA312 are dual certified 304/304L

FORM U-1A

Page 2 of 2

Manufactured by	Northland Stainless, Inc., 1119 Bridge Street, Tomahawk, Wisconsin, 54487		
Manufacturer's Serial No.	V45867-1-4	CRN	N/A
		National Board No.	6321

CERTIFICATE OF SHOP/FIELD COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME BOILER AND PRESSURE VESSEL CODE, Section VIII, Division 1. "U" Certificate of Authorization Number **12346**

expires **August 28, 2019**

Date **04/16/2018** Co. name **Northland Stainless, Inc.** Signed *[Signature]*
(Manufacturer) (Representative)

CERTIFICATE OF SHOP/FIELD INSPECTION

Vessel constructed by **Northland Stainless, Inc.** at **1119 Bridge Street, Tomahawk, Wisconsin, 54487**
I, the undersigned, holding a valid commission issued by The National Board of Boiler and Pressure Vessel Inspectors and employed by
OneCIS Insurance Company, of Lynn, MA

have inspected the component described in this Manufacturer's Data Report on **April 17, 2018**,
and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME BOILER
AND PRESSURE VESSEL CODE, Section VIII, Division 1. By signing this certificate neither the Inspector nor his/her employer makes any
warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector
nor his/her employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with
this inspection.

Date **04/18/2018** Signed *[Signature]* Commissions **14564, MNCO046514, WI1269509**
(National Board Authorized Inspector) (National Board Authorized Inspector Commission number)

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Form and version: U1A-19

Certification of Cleansing

Customer: Argonne National Lab
Purchase Order # 6A-38096
Northland Stainless Work Order # V45867-1-3

This is to certify that the above Vessel(s) surfaces were successfully cleansed by
Northland Stainless Inc.

Certified by:

[Signature]

Northland Stainless Inc.

Date: **4/15/2018**

**Northland
Stainless**

a division of **BEI**

Manufacture's Checklist

Exhibit #1

SPVG

Pressure Vessel Group

Customer: ARGONNE NATIONAL LABS

Work Order: V45867-1

Drawing #: 90.13613

Authorized Inspector Review: Now

F JKR 39-18

Serial Number: V45867-1-4

Drawing Rev.: 8.1 E-110 2-5

10-4-17

National Board #: 6321

National Board Type: U

Date: 10-3-17

Manufacture's Checklist						
Stage: Manufacturing Step	Req.	Q.A.	Date	Hold Point	A.I.	Date
Drawings & Calculations Review	X	JR	10-2-17	*	Now	10-3-17
Vessel Internal	X	SP	3-28-18	*	Now	3-28-18
NDE - Type RT-1	X	SP	4-5-18	*	Now	4-17-18
Final Level Check	X	SP	4-5-18		N/A	
Final Dimension Check	X	SP	4-5-18		N/A	
Vessel External	X	SP	4-2-18	*	Now	4-2-18
Vessel Hydrostatic ⁶⁷² 665 PSI psi Gage #: 219	X	SP	4-2-18	*	Now	4-2-18
Final Visual	X	SP	4-2-18	*	Now	4-2-18
Stamping & Marking	X	SP	4-2-18	*	Now	4-2-18
Material Test Report Review	X	JB	4-16-18	*	Now	4-16-18

All Stages Complete

Authorized Inspector: Now Date: 4-17-18

Quality Assurance: Now Date: 4/17/2018

Internal inspection Noz G, H prior to head attachment SP 2-23-18 4/2/18

Place your initials in the highlighted areas below. If a nonconformance is discovered please make notes in the designed area.

Northland Stainless
1119A Bridge St.
Tomahawk, WI 54487
(715) 453-5326
Fax (715) 453-5357
Email: info@northlandstainless.com
Website: www.northlandstainless.com

Certification of Hydrotest

Customer: Argonne National Lab
Purchase Order #: 6A-38096
Northland Stainless Work Order #: V45867-1-4

This is to certify that the above vessel was successfully hydro tested in accordance with ASME Section VIII, Division 1.

- Test Pressure – 672 psi
- Test Gage - 219 (calibrated) gauge range 0-10,000 psi
-
-

Certified by:

Northland Stainless Inc.
Dated: 4/2/2018

Certification Of Passivation

Customer: Argonne National Lab
Northland Stainless Work Order V45867-1-4
Vessel Description: Specimen Exposure Vessel

This is to certify that the above Vessel(s) was/were successfully passivated
in accordance with Northland Stainless Procedure
SOP-0050 Passivation Scale Clean - HF

Interior: ☐

Exterior: ☒

Interior & Exterior: ☐

Certified by:

Northland Stainless

Date: 9/15/18

Certification of Cleansing

Customer: Argonne National Lab
Purchase Order # 6A-38096
Northland Stainless Work Order # V45867-1-4

This is to certify that the above Vessel(s) surfaces were successfully cleansed by Northland Stainless Inc.

Certified by: *Bob Soward*

Northland Stainless Inc.

Date: *4/4/2018*

SPVG

SMUEL Pressure Vessel Group

Helium Leak Testing **Certificate of Compliance**

Customer: Argonne National Lab
P.O. Number: 6A-38096
Work Order: V45867-1-4
Drawing Number: 90.13613
Equipment Description: Specimen Exposure Vessel

This letter is to certify the above product meets all requirements of the subject purchase order. This equipment was helium leak tested to -8 Torr and was found to be acceptable.

Signed:

Date:

4-3-18

4 Summary

This report provides update of the progress made in FY 2018 in the design and fabrication of long lead components for the new sodium loop SMT-3 at Argonne National Laboratory. The loop will be used for the studies on sodium effects on the advanced Alloy 709 with emphasis on corrosion, tensile, creep, fatigue, creep fatigue, and fracture toughness properties. The loop will

have four test tanks that can accommodate as many as 42 ASTM-size specimens in each tank. This system is a forced convection sodium loop in which the oxygen concentration in sodium will be controlled and maintained at 1-2 wppm by a cold trap, during the long-term exposures of mechanical test specimens.

During the current year effort concentrated on three distinct areas with three different vendors. The first is the infrastructure for the loop that includes the selection of location for the loop, installation of the transformer and electrical wiring that is adequate for the long term operation of the loop and electrical panel for the eventual connection of the loop to the alkali metal scrubber system. The second is the detailed piping analysis to be in compliance with ASME piping code. The third is the design and fabrication of four specimen exposure vessels that is in compliance with the ASME Code as well as meet the program objectives and goals.

With the three sodium loops (with single-tank, dual-tank and four-tanks), materials can be tested at different sodium temperatures, and large tensile, creep, fatigue, creep-fatigue, and fracture toughness specimens can be exposed to sodium for extended periods of time and generate data on mechanical properties in support of ASME Code Qualification and USNRC Licensing of advanced Alloy 709 for use as a structural material in SFRs.

Acknowledgement

The research was sponsored by the U.S. Department of Energy, under Contract No. DE-AC02-06CH11357 with Argonne National Laboratory, managed and operated by UChicago Argonne LLC. Programmatic direction was provided by the Office of Nuclear Energy.

The authors gratefully acknowledge the support provided by Alice Caponiti, Director, Office of Advanced Reactor Technologies (ART), Sue Lesica, Federal Manager, ART Advanced Materials Program, Robert Hill of ANL, National Technical Director, ART Fast Reactors Campaign, and Sam Sham of ANL, ART Technology Area Lead on Advanced Materials.

The authors acknowledge the assistance of D. L. Rink, E. Listwan, and R. Kmak for the design approaches, drawings preparation, and vendor interaction for accomplishing the goals of the project.

References

[1] Natesan, K., M. Li, Y. Momozaki, and D. L. Rink, ANL-AFCI-276, Argonne National Laboratory, September 2009.

[2] Natesan, K., Y. Momozaki, M. Li, and D. L. Rink, ANL-GenIV-163, Argonne National Laboratory, September 2010.

Applied Materials Division

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