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SAVANNAH RIVER NATIONAL LABORATORY
OPERATED BY SAVANNAH RIVER NUCLEAR SOLUTIONS

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INSTRUMENTED LID - SYSTEM FINAL DESIGN

ABSTRACT

Work is ongoing to create an instrumented and sampling system for monitoring aluminum clad spent nuclear fuel (ASNF) in dry storage. The anticipated system will be composed of a custom canister assembly and a modular instrument manifold. The conceptual design was first laid out in the Task Technical and Quality Assurance Plan (SRNL-RP-2019-00225). In this document, we outline the project progress to date, and describe the final system design.

INTRODUCTION

Previously at Savannah River National Laboratory (SRNL), two instrumented test canisters (ITC) were designed and built to monitor the ASNF and the storage environment. Each canister contained a single spent nuclear fuel assembly and provided data for temperature, pressure, and concentration of the gaseous corrosion products and hydrogen. The canisters were monitored for 3 years. The test canisters, heat loading, and drying protocol (i.e., to remove chemically-bound waters) were not sufficient to demonstrate the anticipated design for ASNF in a DOE Standard SNF canister. Therefore, a demonstration of the technical basis for dry storage of ASNF in road-ready canisters is still needed.

BACKGROUND

SRNL evaluated the recently published testing on the gas sampling done on the High Burnup Demonstration Cask (SAND2019-2281) as well as the previous testing at SRNL (WSRC-TR-97-00269) to incorporate lessons learned as part of this instrumented lid. Several improvements and recommendations were reviewed and evaluated and will be implemented in the system design and operation. It is imperative that extreme care is taken for optimizing test conditions, such that contamination from water, air, or organic material is minimized. Areas of emphasis will be the preparation of the sample bottles and system tubing to remove adsorbed water, minimizing tubing lengths, leak tightness of the system and thorough testing of components prior to deployment.

INSTRUMENTATION SYSTEM

The gas, temperature, pressure, and particle collection instrumentation will be integrated into a gas manifold and controlled by a PLC and logged on a data acquisition system, as was specified in the Task Technical and Quality Assurance Plan (**SRNL-RP-2019-00225**). The system design will follow the diagram in **Figure 1**, with the caveat that system components could change location along the manifold if during testing it is found to be necessary.

To extract the gas sample, an Edwards dry scroll pump will evacuate the tubing before the primary valve (see Fig. 1) is opened to create a differential pressure of < 2 atm. The volume of the gas sample will depend on the length of the tubing and will be approximately 2 mL per 1 ft. of tubing. In the previous ITC project, gas was sampled at a rate of once per 8 hours for the first week, then once per week for the remainder of the study. We anticipate using a similar sampling approach. After sampling is completed, the remaining gas will be filtered through a HEPA filter and exhausted or recirculated into the canister through the secondary valve. All information from these systems will be collected by the data acquisition system and logged into a computer for further analysis. Gas samples will be drawn from the top of the canister and should be considered representative of the mixture in the canister, so only a single outlet is needed. The option for gas recirculation is being considered. The previous ITC study showed significant issues in maintaining a leak tight system when incorporating recirculation.

An Apex Cascade Impactor will be one of the first pieces of instrumentation after the primary valve. This will serve two purposes: particle scrubbing and particle analysis. The first function will protect other sensitive equipment from harmful particles which may have escaped from the canister as a result of corrosion or oxide spallation. The latter function will provide the means to identify and characterize any corrosion products or particulate matter carried in the gas stream from the canister. We anticipate a very low density of airborne particles, if any, to be less than 10 μm in size, which should not cause clogging or damage to the lines.

Gas composition analysis will be performed with an Inficon Micro gas chromatograph (GC) in a low background location away from the canister. This instrument was selected to allow sensitive measurements of the gases of interest. Humidity measurements will be performed with a Vaisala Humidity and Temperature Probe (HMT330) in a low background area away from the canister. It is very likely that moisture will condense on the sides of the stainless-steel tubing as hot gas samples are drawn through the lines and subsequently are cooled. To avoid condensation, the lines may be coated with the proprietary Silconert 2000 coating, or optionally heated with heater tape. These possible solutions will be investigated. Pressure measurement will be performed using the Paroscientific Series 2000 pressure sensor.

Additional elements of the gas manifold will include any necessary gas tanks, such as He and Ar carrier gasses or calibration gas standards. The He gas will be used to provide carrier gas for the GC and to backfill the ASNF canister if necessary. If gas sampling at an external location is necessary, the modular gas lines will allow a gas sample to be easily isolated and removed from the system for residual gas analysis (RGA) or mass spectrometry. As demonstrated from the Sandia report, the gas sampling bottles must be adequately prepared and treated, so that no residual water or contamination is present prior to filling with a canister gas sample.

Radiation monitoring of the gas can be used to detect fuel cladding failure. An ionization chamber and High Purity Germanium (HPGe) detector are anticipated to be used to monitor the gas environment for beta/gamma radiation and radioactive Kr isotopes to detect a cladding failure. These instruments must be located in a low radiation area for accurate measurements. It was suggested to use an HPGe detector with an electro-mechanical cooling system to provide LN2-free operation. The ionization chamber will be placed after the Apex Cascade Impactor in order to monitor the gas environment and to detect beta radiation. To detect radioactive Kr isotopes, a gas specific absorbent material will be used to concentrate the sample such that the signal is in the range of detection for the HPGe detector.

Components for the instrumented lid system have been ordered and many parts have been received, as can be seen in **Figure 2.** The components of the PLC have been assembled and mounted to a test station alongside the GC. The HP laptop (instrument controller) has also been set up and has communicated and run test samples using an Inficon GC. A technical representative from Inficon demonstrated gas sampling and analysis, and introduced the SRNL technical team to several solutions for integrating GC data collection with the data recorded from the PLC.

CANISTER LID AND DESIGN

All connections near the canister lid must avoid the use of materials susceptible to damage from high radiation fields and high temperatures. These connections must be removable so that the canister can be sealed after the 10-year instrumentation period, interface with lifting components, and meet relevant 10 CFR requirements.

The Instrumented lid set up will be tested in two different configurations. The first will be a 6 in. inner diameter (ID) canister to avoid the requirement of an ASME stamped vessel and provide a cost-effective way of testing component response at pressure. The second configuration will be the full-sized canister system used to demonstrate the layout of instrumentation and connections. This methodology was recommended by the SRNL ASME code subject matter expert.

For the cold testing of gas sampling and particle collection, we are in the process of designing a functional canister which stays below SRNL thresholds for pressure protection requirements (**Figure 3**). This vessel will have an ID of 6 in., wall thickness of 0.083 in., and will be 72 in. long, with conflat flanges at both ends. There will be 4 gas penetrations, 3 thermocouple penetrations, 2 thermowells, and a heater well (as shown in **Fig. 3**). Calibrated gas mixtures will be simultaneously introduced through the side penetrations while the instrumentation manifold monitors and collects data. The functionality and location of each instrument will be tested and calibrated. A pressure relief device will be implemented. This setup will simulate full scale canister conditions for the purpose of testing the response of the system. Testing with this 6 in. vessel will allow for a wider range of temperature and pressures to be used to evaluate the instrumentation in a more economical system.

A second full size canister will be manufactured in parallel to simulate mechanical connections and fittings, including installation of the gas and electrical quick connects and thermocouples. This second canister will be full scale and resemble the final design of the canister as closely as possible without the requirement of Section III certification. The canister will also be tested for disconnection of the quick connects in preparation for the sealing of the canister for shipment and final disposition. The results of the two test stands will be used to confirm the design and operability of the final test lid.

SUMMARY AND PATH FORWARD

The instrument gas manifold is being assembled, and calibration gasses are being prepared. Communications between the PLC, computer, and GC are being tested. The implementation of a 6 in. ID canister for initial testing, sampling and monitoring will enable this project to move forward with timely and economical results. A full-scale system will be designed and constructed simultaneously to allow for timely execution of milestones. The design and construction of the full-size canister and lid system will be heavily influenced and informed by the results of the 6 in. canister tests, to ultimately lead to a reduction of unnecessary errors and cost.

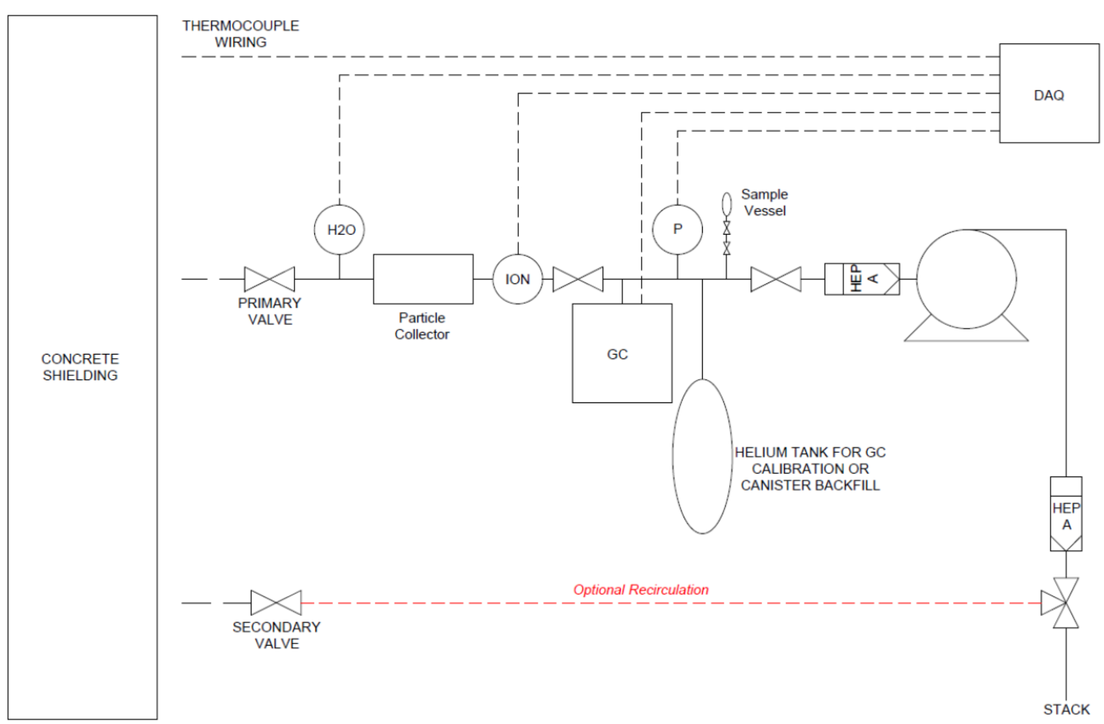

Figure 1: Diagram of anticipated gas manifold for lid instrumentation.

Figure 2: (left) SRNL has received instruments to be used for gas sampling, particle collection, data acquisition, process control, and humidity and pressure monitoring. (right) Laptop configured to communicate with GC and PLC.

Table 1 Equipment Received and under Procurement

Received:	**In process:**
Inficon Fusion Micro GC	Swagelok QC with rad resistant O-rings
PLC Controller	INL Thermocouples x4
HP Laptop	Gas cylinders
VAT Valves	Gas regulators
Edwards Vacuum pump and HEPA filters	Piping, other swagelok parts and valves
Vaisala Humidity sensor	
Paroscientific pressure transducer	
Apex Cascade Impactor	

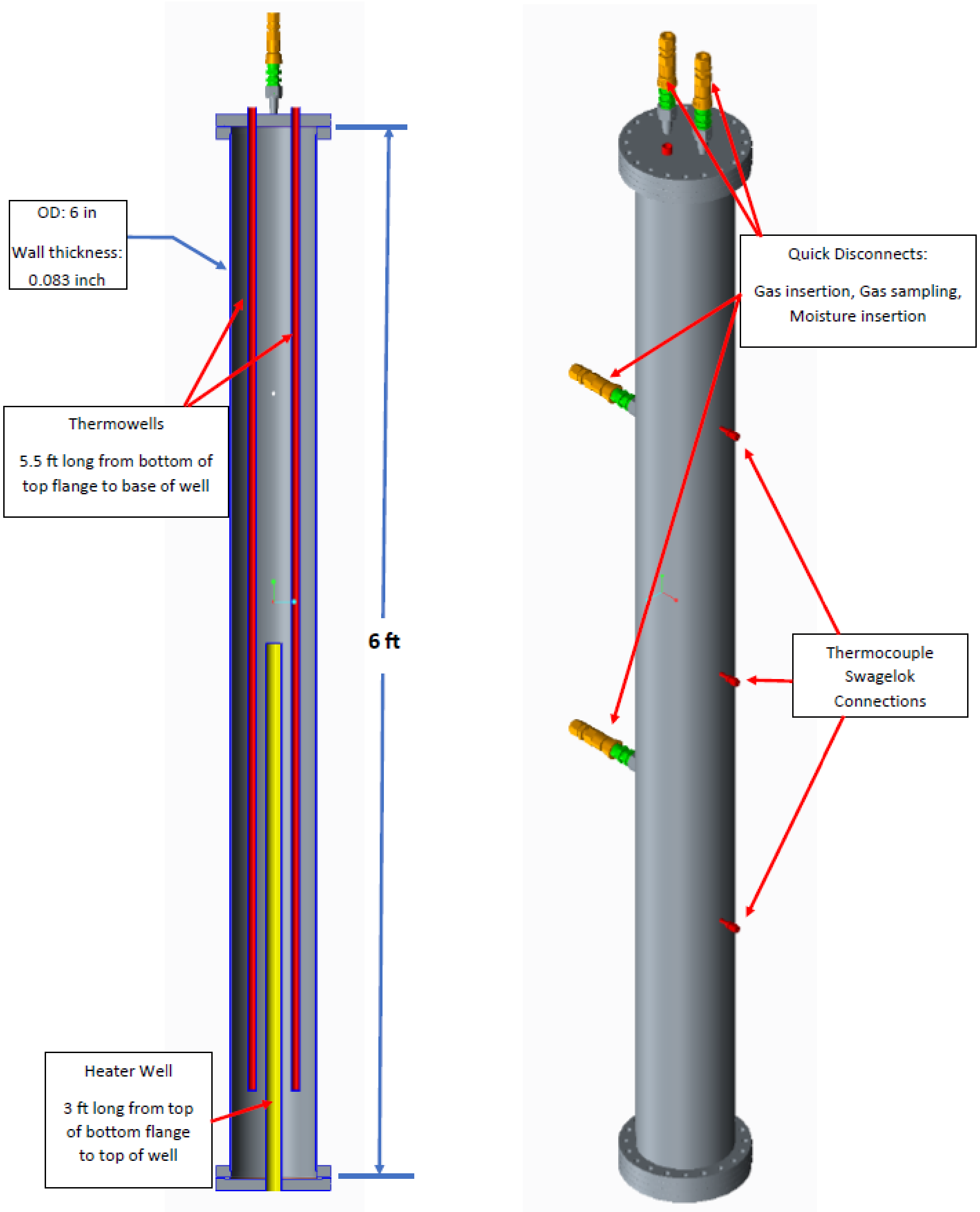

Figure 3: Diagram and 3D rendering of small sample canister with anticipated penetrations, gas sampling ports, temperature connections, and heater elements.