Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

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October 30, 2019 **SRNL-L2240-2019-00005**

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INSTRUMENTED LID – FULL INSTRUMENTATION SYSTEM TESTING

I. INTRODUCTION

This report describes full system testing of an instrumentation system for the monitoring of aluminum clad spent nuclear fuel (ASNF). The requirements for this system were laid out in a previous document,[1] with respect to former studies,[2] and the details of project actualization were reported. [3,4,5,6] The reader is directed to these references for more background information. In short, a team composed of personnel from Savannah River National Laboratory (SRNL) and Idaho National Laboratory have been tasked with the design and fabrication of an instrumented assembly for remote sampling, monitoring, and radiation testing (SMART) for demonstration and surveillance of the dry storage environment and conditions of ASNF in a DOE standardized canister.

SRNL proposed the fabrication of two systems to accomplish this goal: 1) an instrumentation system consisting of gas and particle collection, temperature, humidity, pressure, and radiation monitoring; and 2) a lid assembly consisting of a custom-designed lid and hat, together with a custom fuel basket. The corresponding instrumentation system is shown in the piping and instrumentation diagram (**Figure 1**). The individual functionality tests of the instrument system sensor components were performed, and the results were reported in the report "Instrumented Lid

- System Functionality Testing." Savannah River National Laboratory, September 1, 2019.[7] The sensor components of instrumentation system have been mounted and tested in-line with a 6" diameter test canister, and the results are reported in this document.

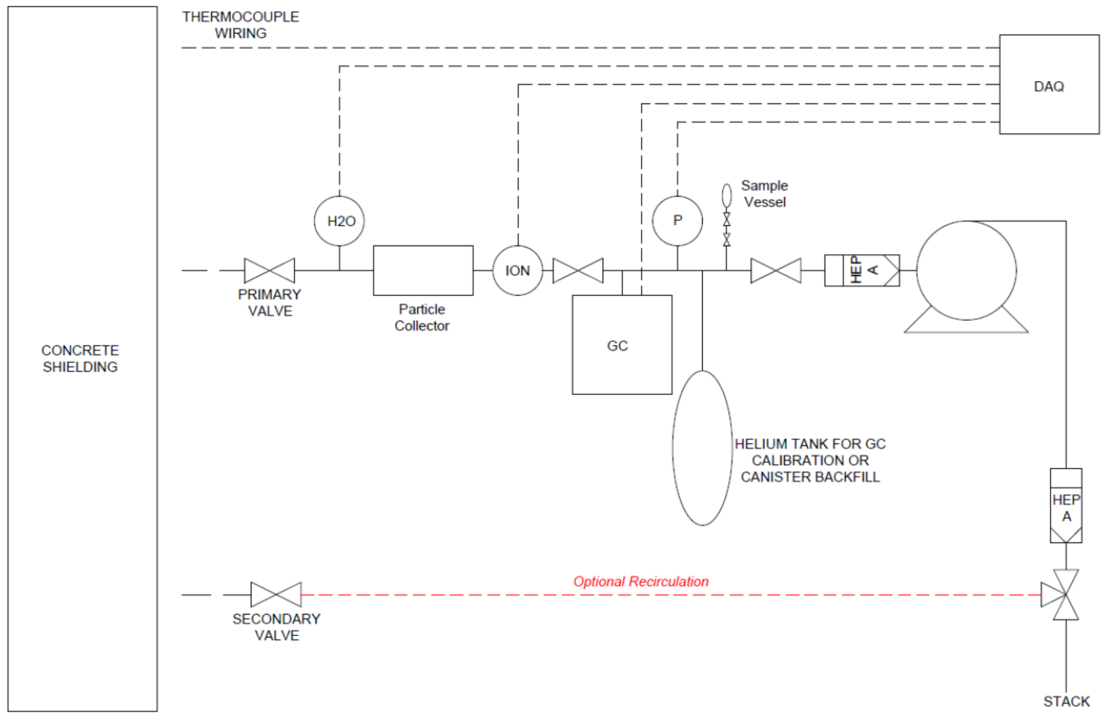

Figure 1: Instrumentation diagram for the sampling and monitoring of ASNF in a DOE standardized canister.

II. FULL INSTRUMENTATION SYSTEM TESTING

In accordance with the drawing in **Figure 1**, a 6-inch diameter test canister has been connected to the instrumentation manifold and tested for system functionality. The entire system is shown in **Figure 3**, and all the instrumentation and system components are labeled. The 6-inch canister was pressure tested to 57 PSIG with a design temperature of 100°C. These parameters were selected so that the 6-inch test canister could be used at a range of test conditions that would simulate the pressure, temperature, and cover gas conditions of a DOE standardized canister filled with Al clad spent nuclear fuel (ASNF) elements. The canister has two gas connections and two thermowells running through the top of the canister, and several gas and temperature ports on the sidewalls to introduce test gases and to verify the internal canister temperature, as can be seen in **Figure 4**. A heater has been installed in the bottom of the canister to simulate the decay heat of the spent fuel. The design for the 6 in. canister was reported in a previous report.[5]

Each of the system components have been verified for sensitivity and response and the results of these tests were reported earlier.[7] For full system functionality testing, all of the components were connected to the gas manifold (as applicable) and the data outputs were connected to the programmable logic controller (PLC). In **Figures 3**, **5**, and **6**, the layout of the system instruments and connections are shown. The PLC demonstrated the ability to read and record each of these outputs. A screen capture displaying an example of the instrument readouts is shown in **Figure 2**. Gas samples can be drawn from the canister through the top gas quick disconnects and through the ½ in. gas line, which is shown in **Figure 3**. The first instrument to see the gas sample is the humidity probe. This was placed first in the series in order to have a more accurate reading of the canister internal humidity levels. The cascade impactor particle collector was placed after the humidity probe to cleanse the gas stream of oxide particles which may be present in a canister filled with ASNF that has been dried. The particle collector can be disassembled, and the collector plates removed for further particle analysis (e.g. scanning electron microscopy, or gravimetric analysis).

In **Figure 6**, the piping from the canister is reduced from a ½ inch line to a ¼ inch line, to reduce the amount of necessary sample gas. The pressure transducer, sample port, and gas chromatograph are connected in parallel to the ¼ inch manifold. The inlet and outlet of the manifold are controlled by valves, and the sample is removed by the dry scroll pump and vented to the atmosphere. All instruments have been demonstrated as an integrated system with the exception of running a sample through the GC with the expected canister helium atmosphere and with minor concentrations of H2, O2, and/or N2 gases. Additionally, each of the components were rigorously tested with sample gases individually, and the results were reported in the previous report.[7] All instruments have been shown to meet the sensitivity requirements.

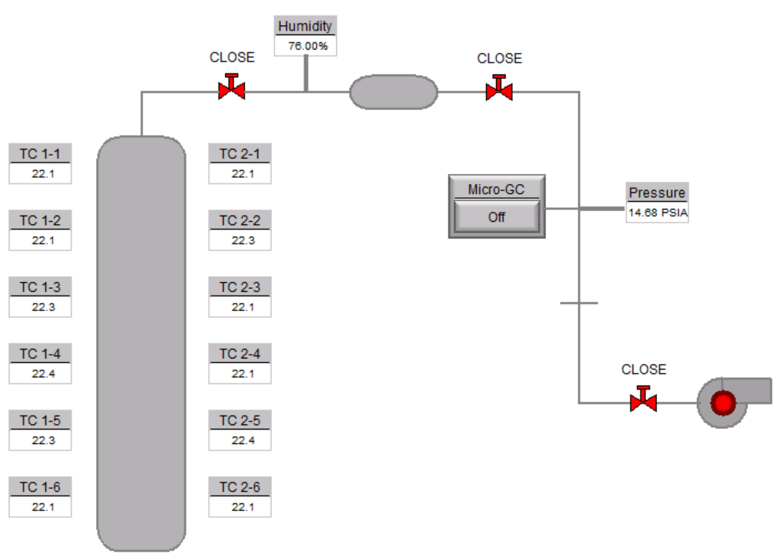

Figure 2: Human machine interface (HMI) display for PLC data acquisition system.

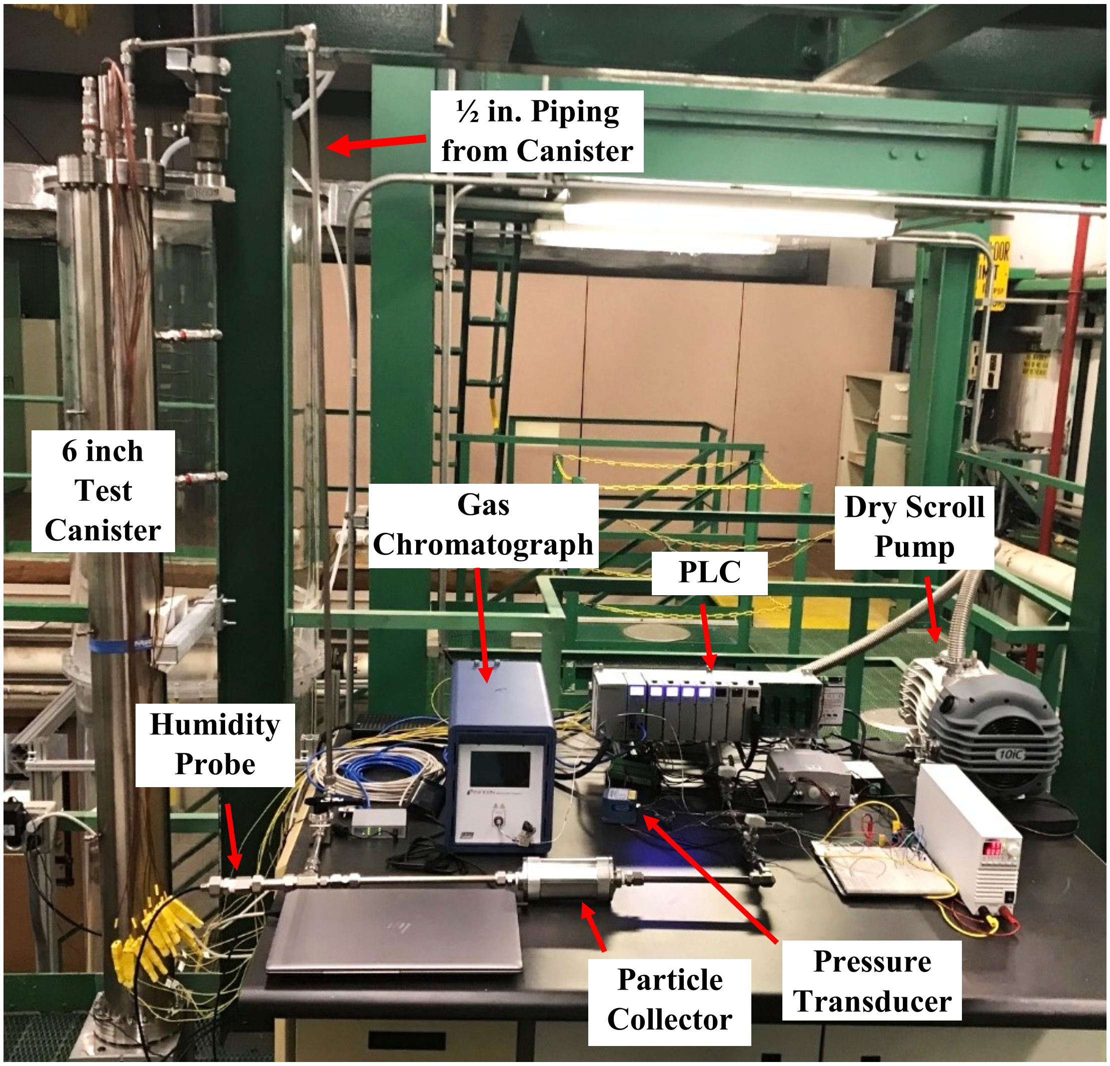

Figure 3: The instrumented lid full setup including 6" canister and instrument manifold. All instruments have been connected and tested for functionality.

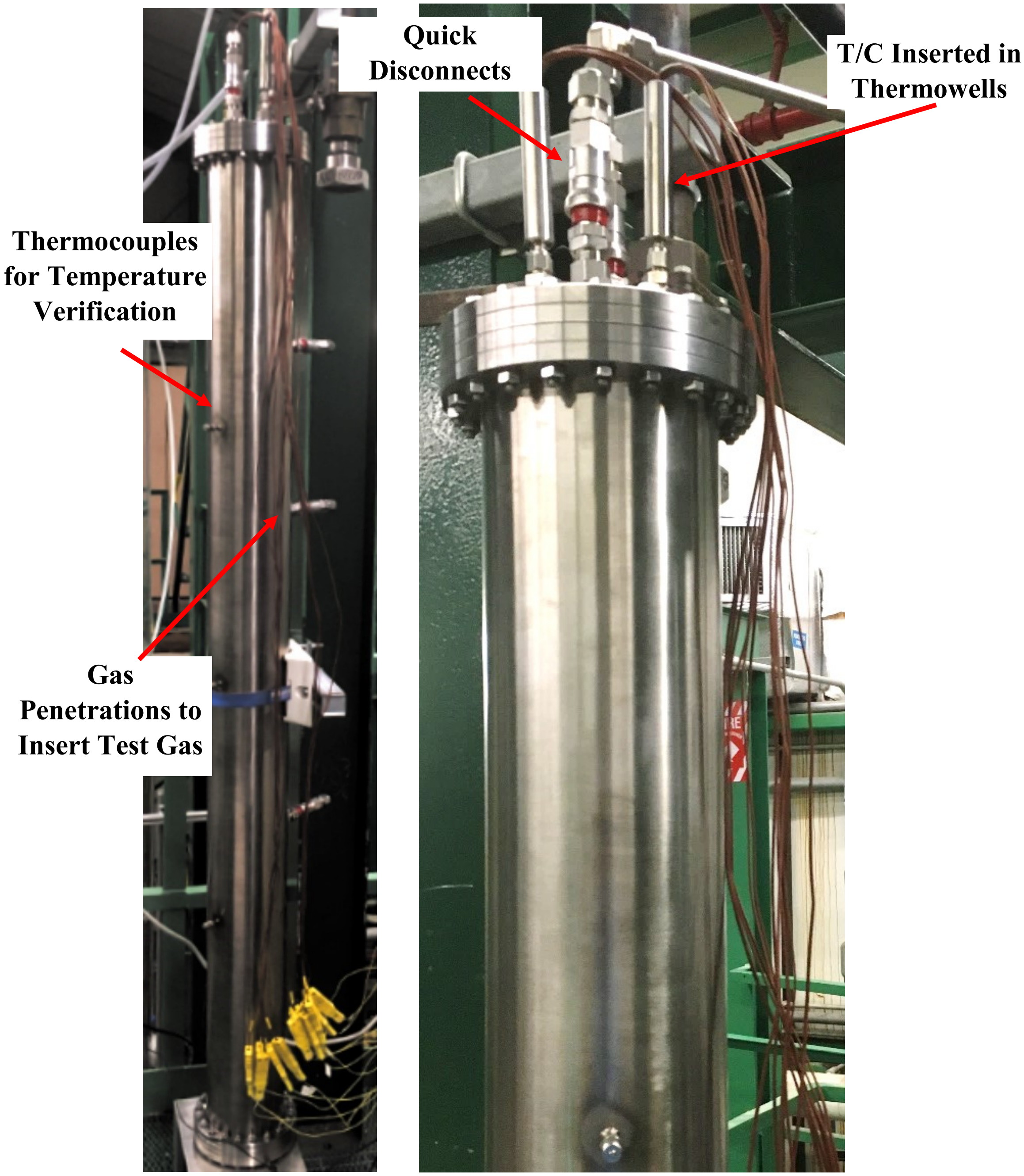

Figure 4: The 6 inch test canister with top and side connections labeled.

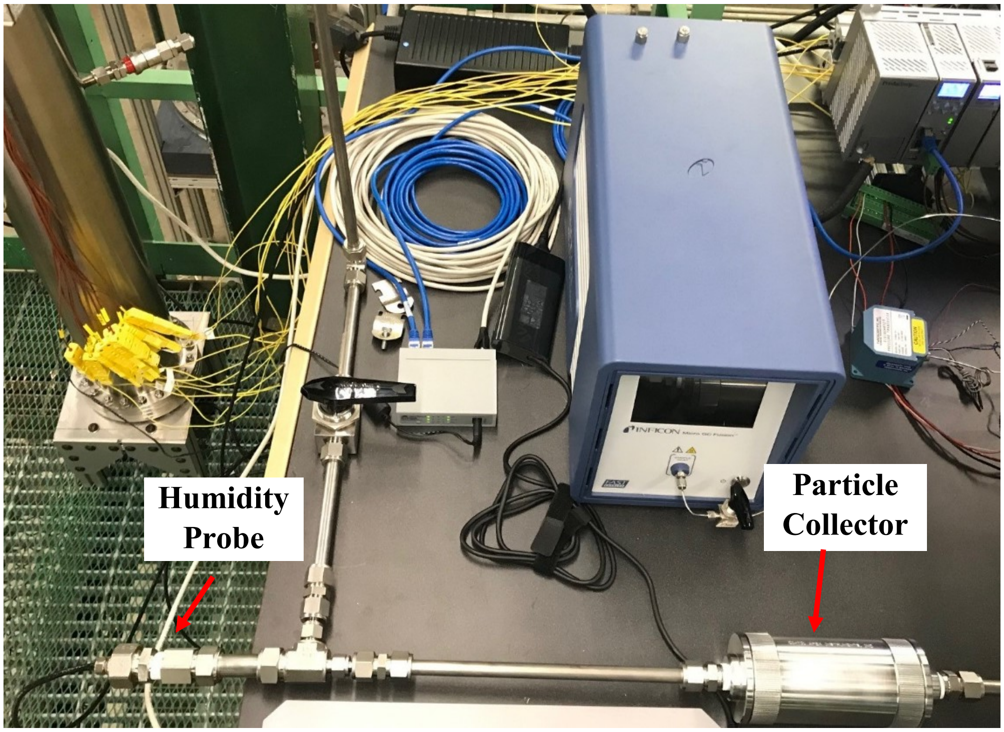

Figure 5: Humidity probe and cascade impactor particle collector

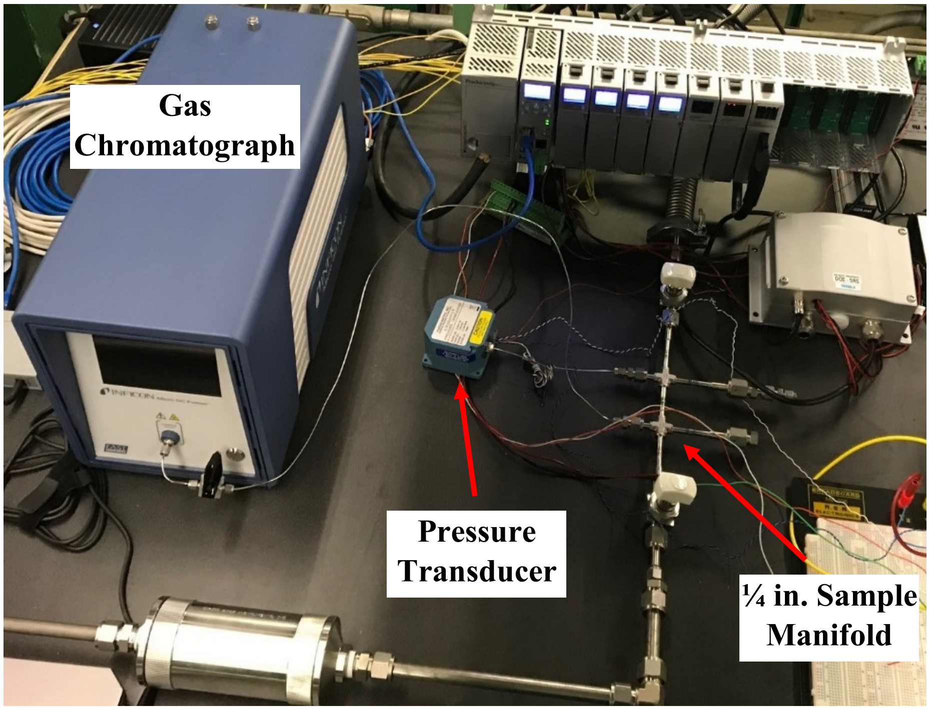

Figure 6: Pressure transducer, gas sampling port, GC and PLC.

III. GAS CHROMATOGRAPH CALIBRATION

Calibration curves were created for the gases of interest, by measuring the response of the system at various levels of known concentrations of the gases. These calibrations were performed for N_2, H_2, and O_2 gas from 10 – 0.01%, 30 – 0.01%, and 21 – 0.004% gas concentrations, respectively. The retention time identifies which gases are present in a sample, as each gas has a characteristic elution time through the columns, and the area under the curve can be used to quantify the original concentration of gas in the sample, if the peaks are clearly resolved and do not need deconvolution. The following data in **Figures 7 – 9** show that the GC is capable of resolving gas concentrations of H_2, N_2, and O_2 down to at least 100ppm, which is well below the required sensitivity limit of 500 ppm. Future measurements of unknown quantities can be compared with the following calibrations curves to provide the concentration of gas in each sample.

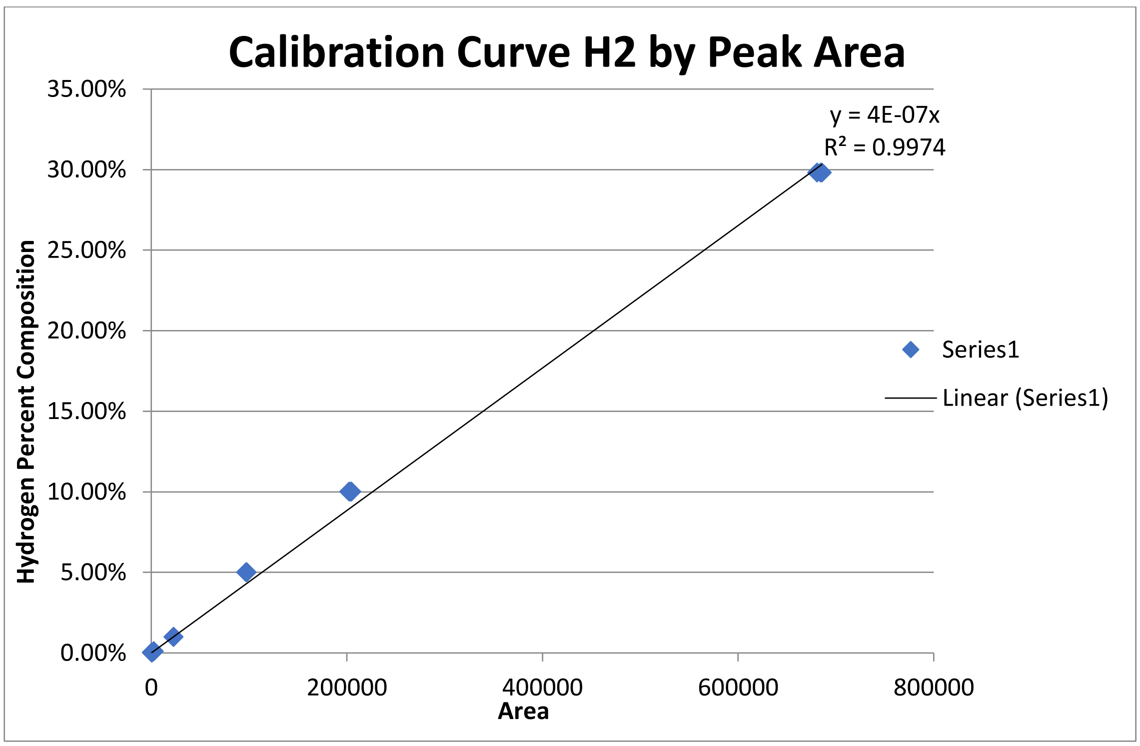

Figure 7: Calibration curve for H_2 gas, where known quantities of 30 – 0.01% H_2 gas were injected into the column.

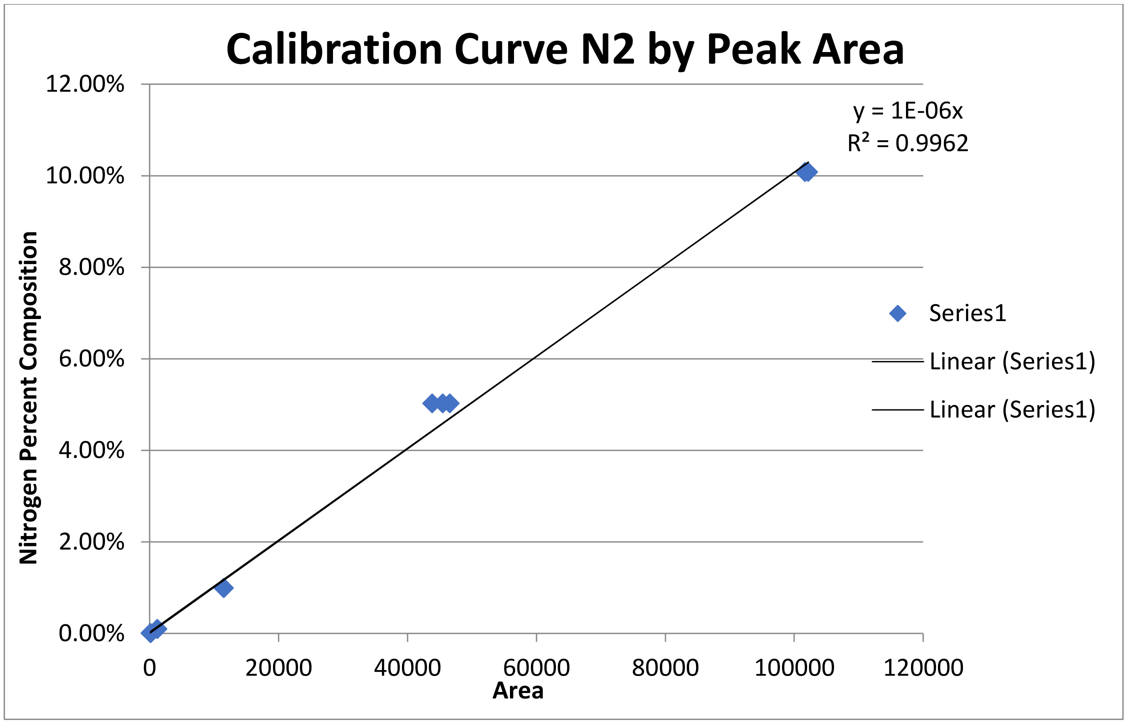

Figure 8: Calibration curve for N_2 gas, where known quantities of 10 – 0.01% N_2 gas were injected into the column.

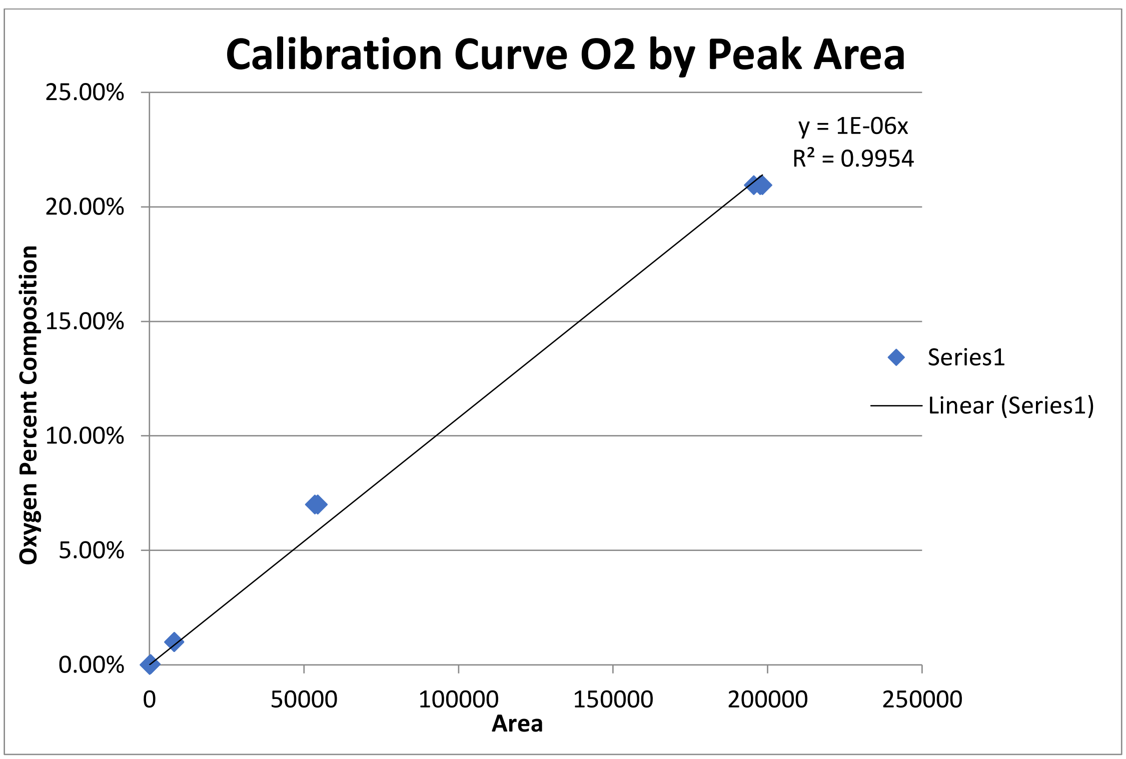

Figure 9: Calibration curve for O_2 gas, where known quantities of 21 – 0.004% O_2 gas were injected into the column.

IV. PATH FORWARD

Full system testing and integration will continue through the first quarter of FY20. Specialized gas samples (e,g, H2 at 500 ppm in He) will be introduced into the canister to test the response of the system. Heating and moisture will also be simulated inside canister. Additional testing of the instrumentation system in FY20 is being planned. The system will be connected a chamber in a gamma irradiator to monitor predicted H2 evolution from plates of aluminum with oxide layers that represent ASNF before and after a drying treatment(s).

ACRONYMS:

ASNF: Aluminum clad spent nuclear fuel

DOE: Department of Energy

FY: fiscal year

GC: Gas Chromatograph

PLC: programmable logic controller

SMART: sampling, monitoring, and radiation testing

SRNL: Savannah River National Laboratory

T/C: Thermocouple

REFERENCES:

[1] J. J. Jarrell, "Design of an Instrumented SNF Canister: Requirements and Assumptions", September 2018.

[2] R. L. Sindelar, D. J. Pak, P. J. French, R. F. Eakle, W. S, Large, K. Chen, "Instrumented, Shielded Test Canister System for Evaluation of Spent Nuclear Fuel in Dry Storage," WSRC-TR-97-00269, September 1997.

[3] J. D. McNamara, D. T. Herman, "Task Technical and Quality Assurance Plan for Development of the Instrumented Lid for Dry Storage of Aluminum Spent Nuclear Fuel", March 2019, SRNL-RP-2019-00225.

[4] J. D. McNamara, B. C. Randall, "Instrumented Lid – System Final Design, SRNL-L2240-2019-00002, May 2019.

[5] J. D. McNamara, A. McNight, "Instrumented lid Detailed Design", SRNL-L2240-2019-00003, June 2019.

[6] J. D. McNamara, B. C. Randall, "Instrumented Lid – Assemble System Components" SRNL-L2200-2019-00024, August 2019.

[7] J. D. McNamara, B. C. Randall, "Instrumented Lid – System Functionality Testing" SRNL-L2240-2019-00004, September 2019.