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INSTRUMENTED LID DETAILED DESIGN

I. INTRODUCTION

This report describes the design of an instrumented lid assembly for remote sampling, monitoring, and radiation testing (SMART) for demonstration and surveillance of the dry storage environment and fuel conditions of aluminum clad spent nuclear fuel (ASNF) in a Department of Energy (DOE) standardized canister. The lid assembly consists of a custom-designed lid and hat, together with a custom fuel basket. The functions and designs of each component of the lid assembly and the general arrangement of the lid assembly are provided in this report. The Piping and Instrumentation Diagram for the corresponding instruments which will be connected to the lid assembly is shown in the appendix. Details of the system to provide characterization are provided in SRNL-L2240-2019-00002, "Instrumented Lid - System Final Design". The detailed drawings of the lid assembly will be prepared following the specification of the demonstration and surveillance system, including canister design, to which the lid will be matched. Individual testing of the lid assembly sensor components will be performed in cold testing. The lid assembly including connection ports for gas sampling and thermowells will be fabricated. The tubing of the lid assembly to which the sensor components will be connected will not be assembled. The final design of the lid assembly connections to instrumentation is dependent on the staging of the demonstration and surveillance canister.

II. BACKGROUND

The request for a system to monitor and analyze the environmental conditions of ASNF in dry storage was given in the document "Design of an Instrumented SNF Canister: Requirements and Assumptions," Josh J. Jarrell, September 2018. The anticipated system would be composed of a custom canister assembly and a modular instrument manifold, to monitor the temperature, humidity, pressure, gas composition, and gas space entrained particle (if any) radioactivity. The conceptual design for the system was laid out in the Task Technical and Quality Assurance Plan (SRNL-RP-2019-00225).

In this present document, the progress to date for the lid assembly design for dry storage demonstration and surveillance monitoring of environment and fuel conditions are described.

III. SMART LID ASSEMBLY

To remotely monitor the environmental conditions inside a DOE standardized canister filled with fuel elements, it is essential to consider the impact from the radiation field and high temperatures surrounding the canister on the instrumentation. Therefore, the technical team designing the SMART lid system have removed all sensitive equipment, which is intolerant to high radiation fields and high temperatures, to outside some concrete containment. The exact locations are still to be determined based on a final location selection for the demonstration by the customer. Near the canister will be radiation and temperature resistant temperature probes and gas sampling lines. To install connections to the canister, we have designed a canister assembly consisting of an instrumented lid, hat with electrical and gas connections, and a custom fuel basket. Below, we describe the overall design functions and features.

a) Hat: Services connections to outside sampling lines and data lines.

The hat of the SMART lid assembly serves as the connection to the outside instrumentation manifold. The hat will have stainless steel tubing and enclosed thermocouple wiring coming out one end and going out to the instrumentation outside the enclosure. The other end will contain the electrical and gas sampling remote connectors, such as Swagelok quick disconnects and remote electrical connections. It will be lowered onto the lid assembly by a crane to avoid radiation exposure to personnel.

b) Lid: Interface between hat and canister. Contains sampling and temperature ports.

For the lid of the canister, modifications were made to the Foster Wheeler assembly to allow for instrumentation. Holes were put in places around the lid to line up directly with the holes defined by the basket, which will be described in further detail in Section III (c). Another goal of instrumentation placement was to ensure that the ability to lift the canister using the lifting ring was not inhibited. A total of four thermowells and two gas sampling tubes will be welded to the domed lid. **Figure 1** shows the top and side views of the lid. **Figure 2** shows how the thermowells (dark blue) and gas sampling tubes (green) are oriented.

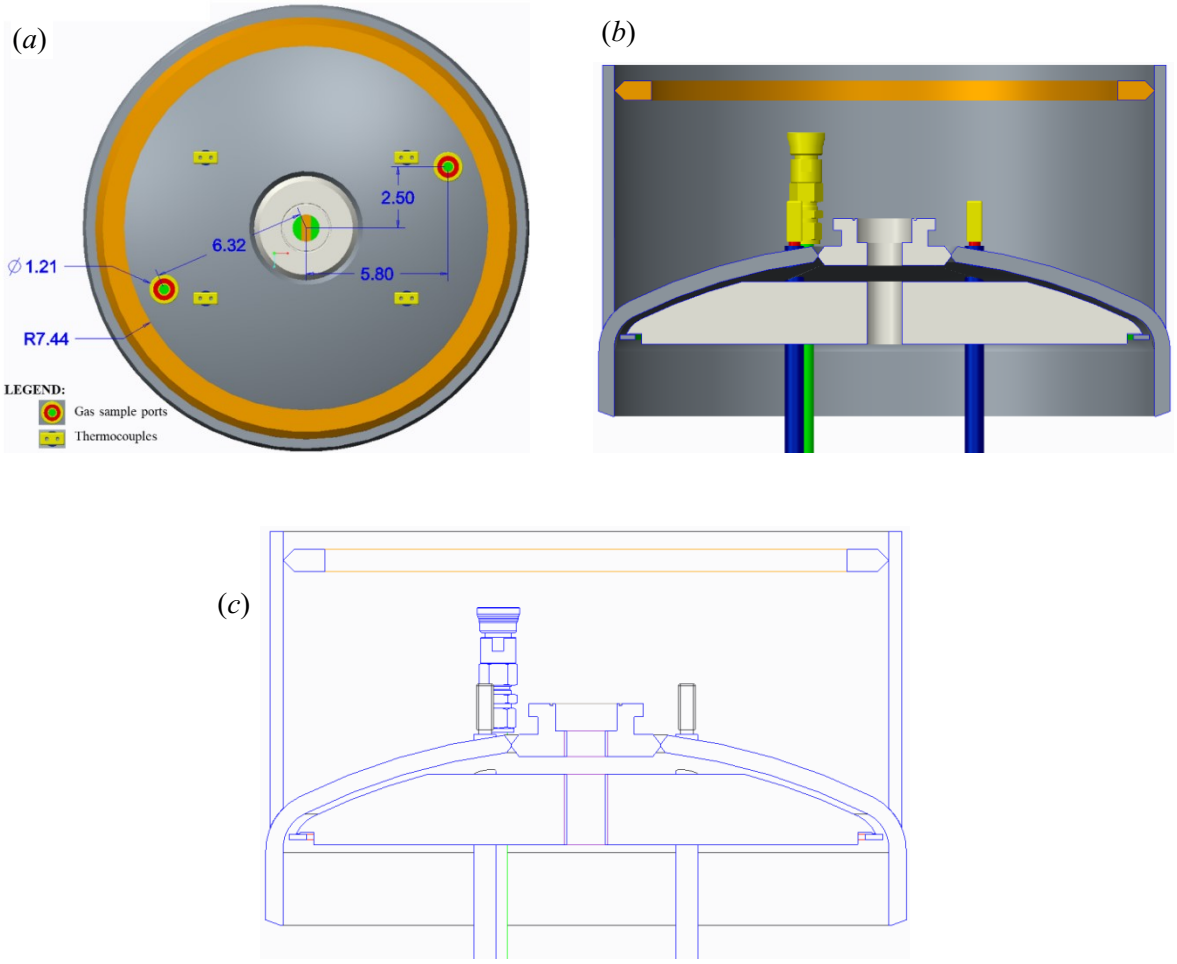

Figure 1: Top view (**a**) and side view (**b**) and (**c**) of canister lid model. The lid will have 4 thermocouple connections and two gas sampling ports with quick disconnects (as pictured). The dimensions in (**a**) are in units of inches.

Each of the thermowells are the same length as it is anticipated that only one length of thermocouple (with a sensing point every 10 in.) will be used for the demonstration. The gas sampling tubes are different lengths because they are also serving as the locator rods that will help line up the lid with the instrument ports in the basket. By being different lengths, once the first locator rod is successfully inserted into the basket, the amount of manipulation needed to orient the lid for the second pin is reduced. This is because the only required motion to place the second rod is rotation rather than additional translation. A detailed view of the gas sampling tube is seen below in **Figure 2(d)**.

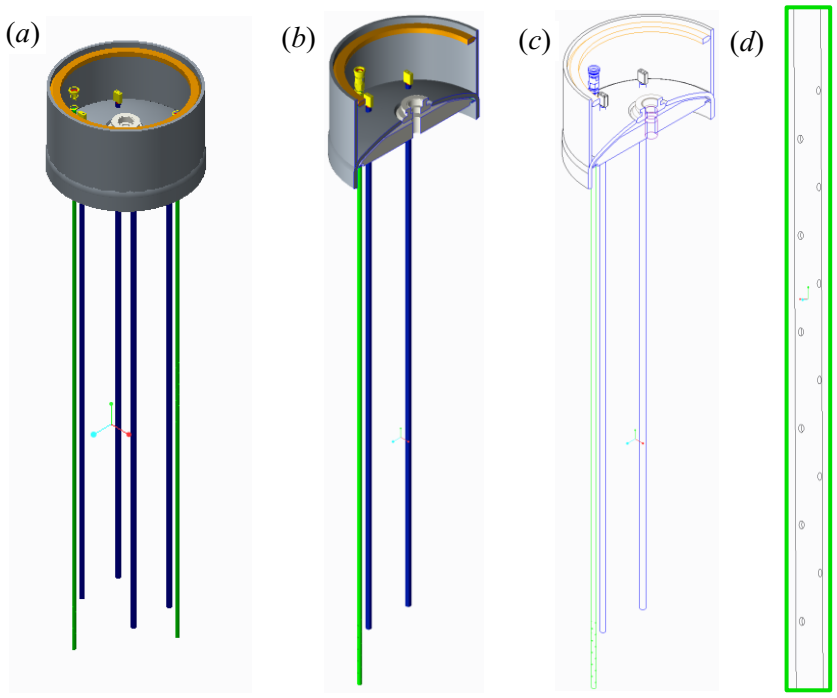

Figure 2: (a) and **(b)** Orientation of gas sampling lines (green) and thermowells (dark blue), and **(c)** isometric view of lid and gas/ temperature lines with quick disconnect pictured. (**d**) Perforation in gas sampling pipe: Section is 8.25 inches long. Diameter of holes: 0.125 in

c) Basket: Holds fuel assemblies. Has slots for gas lines, thermowells, and locator rods.

The basket design is a thin walled cylinder that contains a grid structure that separates fuel assemblies from one another. Currently, the basket that will be used for the demonstration would be able to hold 8 fuel assemblies. The gas sample pipes will be located in the other two grid positions which do not contain fuel assemblies. The grid design inside the basket is a flexible component that could be modified per customer request, but the overarching concepts for incorporating the basket into the system would remain the same.

As shown in **Figure 3 (a)**, between the grid plates are six holes in a rectangular pattern. These holes are used for inserting thermowells into the system when the lid is attached. The thermowells will be welded to the lid and will have a diameter of at least 0.625 in. and be B31.3 certified. To ensure that the thermowells do not experience unnecessary bending, the basket holes will be chamfered at the top, and guide pins will be used. Care must be taken during crane operations to prevent thermowell bending, therefore alignment details are to forthcoming in subsequent designs. Only the four corner holes will contain thermowells at this time, but there are two holes in the center to add flexibility regarding instrumentation placement on the lid. To receive more accurate temperature readings, each hole has four slots down the length of the tube [**Fig. 3(b)**]. Two chamfered holes [**Fig. 3(a)**] located just outside the thermowell insertion points are used to assist in lid placement by guiding locator rods to insert at these points first before the thermowells are lowered.

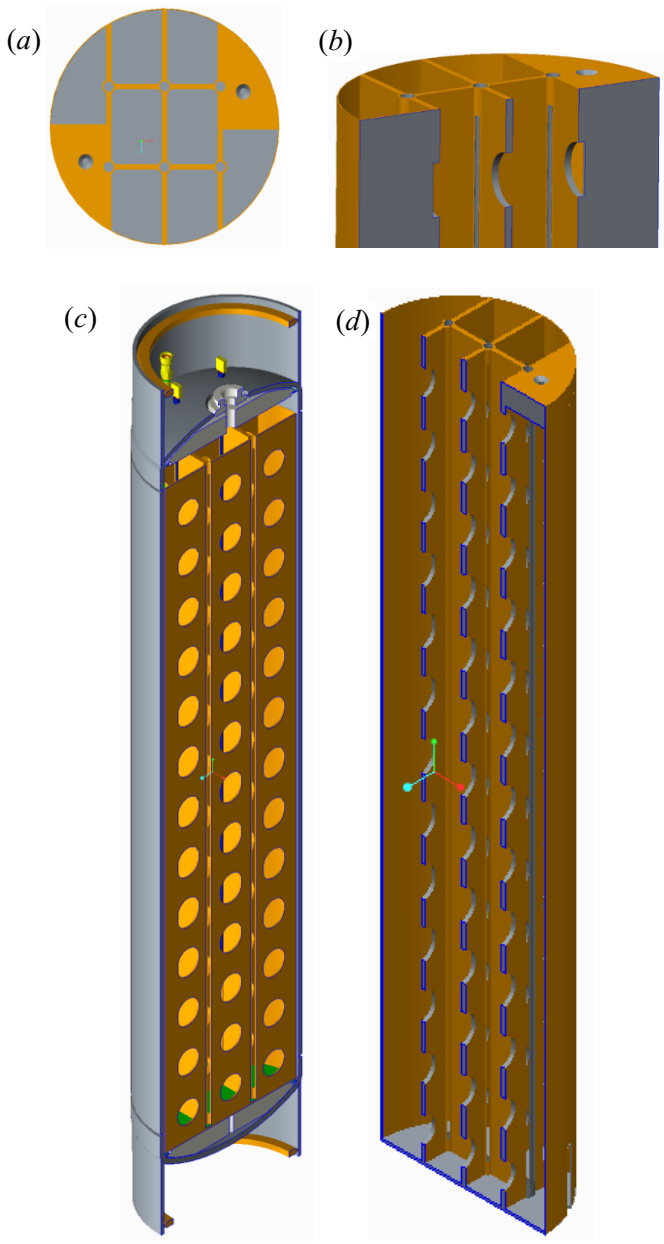

Figure 3: (**a**) Basket grid layout. (**b**) Slots along instrumentation tubes. (**c**) and (**d**) Isometric cross-section view of internal basket in SMART lid assembly.

Lastly, to make sure that when the basket is dropped into the canister it is placed in the same orientation, a slot was cut in the bottom of the basket. This slot aligns with a locator pin on the inside of the canister. The basket will not properly sit in canister unless the pin lines up with the slot. The full locator pin and slot assembly can be seen in **Figures 4 (a)** and **(b)**. The basket will be aligned to the canister with the slot, and the lid (with gas lines and thermowells) are aligned to the basket using guide pins and chamfered holes. These modifications will only be for the testing system.

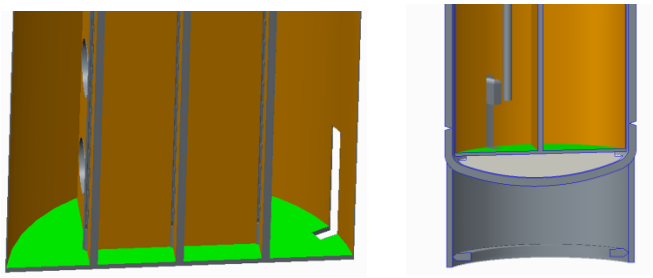

Figure 4: (**a**) Locator slot for basket alignment in canister. (**b**) Locator pin on canister wall assembled with basket.

d) 18 in. Canister

Dimensions of the outer canister are based off Foster Wheeler Environmental Corporation's 18" O.D. Spent Nuclear Fuel (SNF) Canister. The main components of the canister are: end cap structure with lifting ring attached, vent plug for lid, domed canister head (top and bottom), upper and lower impact plates, and main canister body. This test 18 in. canister will be open ended and will be used primarily to test alignment and mechanical and electrical connections. The integration of the DOE standardized canister with the SMART lid assembly must be accounted for by the contractor and taken into consideration for the final implantation. Such considerations include how the guide pins will affect the standardized design and the effects of the penetrations in the upper impact plate.

Figure 5: Demonstration canister model.

e) Demonstrations and Test Components

For this work, SRNL personnel will test the instrumentation response to the system, and design and fabricate a lid assembly to monitor ASNF inside a DOE standardized canister. To do this, we estimate that 3 types of demonstrations and tests will be conducted by SRNL and INL personnel. For the initial cold test of the instrumentation system, we anticipate using a pipe less than 6" diameter with connections for temperature and gas control. This system does not need custom fabricated hat, lid, and basket assemblies since its purpose is to test the instrumentation. For a cold test demonstration of the 18 in. lid assembly, the custom hat, lid, and basket assemblies will be fabricated and tested by SRNL personnel to test mechanical and electrical connections. For the hot test of the 18 in. lid assembly, SRNL will design and build the custom hat, lid, basket assembly. INL will fabricate the canister. INL will be responsible for completing the assembly according to Section III requirements, since the welding of the final lid to the canister will be completed after the fuel system is loaded and is anticipated to be subject to ASME code requirements. A summary of the components to be fabricated by SRNL for the instrumented lid task is outlined in **Table 1**.

Table 1: A summary of the components SRNL will fabricate for the 3 demonstration tests.

	Hat	**Lid**	**Basket**	**Canister**
Cold Test 6"	No*	No*	No*	6 in. pipe
Cold Test 18"	Yes	Yes	Yes	18 in. pipe open bottom
Hot Test 18"	Yes	Yes	Yes	No**

*Not needed for 6 in. cold test.
** INL fabricates DOE Standardized canister.

IV. TEST ASSEMBLIES AND DEMONSTRATION OF LID CAPABILITIES

A total of 3 types of lid assemblies are necessary to adequately test the capabilities of our system: a 6" pipe and instrumentation test; an 18" cold test of lid assembly; and an 18" hot test of the lid assembly with standardized canister.

a) 6" Cold Test

A 6-inch inner diameter (ID) canister and lid assembly will be assembled to test the capabilities of the system and to avoid the requirement of an ASME stamped vessel. This provides a cost-effective way of testing the component responses. A model of the 6" demo canister is shown below in **Figure 6**, as was described in the SRNL Instrumented Lid - System Detail Design report. [SRNL-L2240-2019-00002]. This vessel will have an ID of 6 in., wall thickness of 0.083 in., and will be 72 inches 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. 6**). 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 as required per SRNL Conduct

of Research & Development protocols. This setup will simulate full scale canister conditions to test the response of the system. Testing with the 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. We will run tests on Swagelok quick disconnects to measure the hydrogen leak rate at elevated temperatures and to test the durability and reliability of fittings.

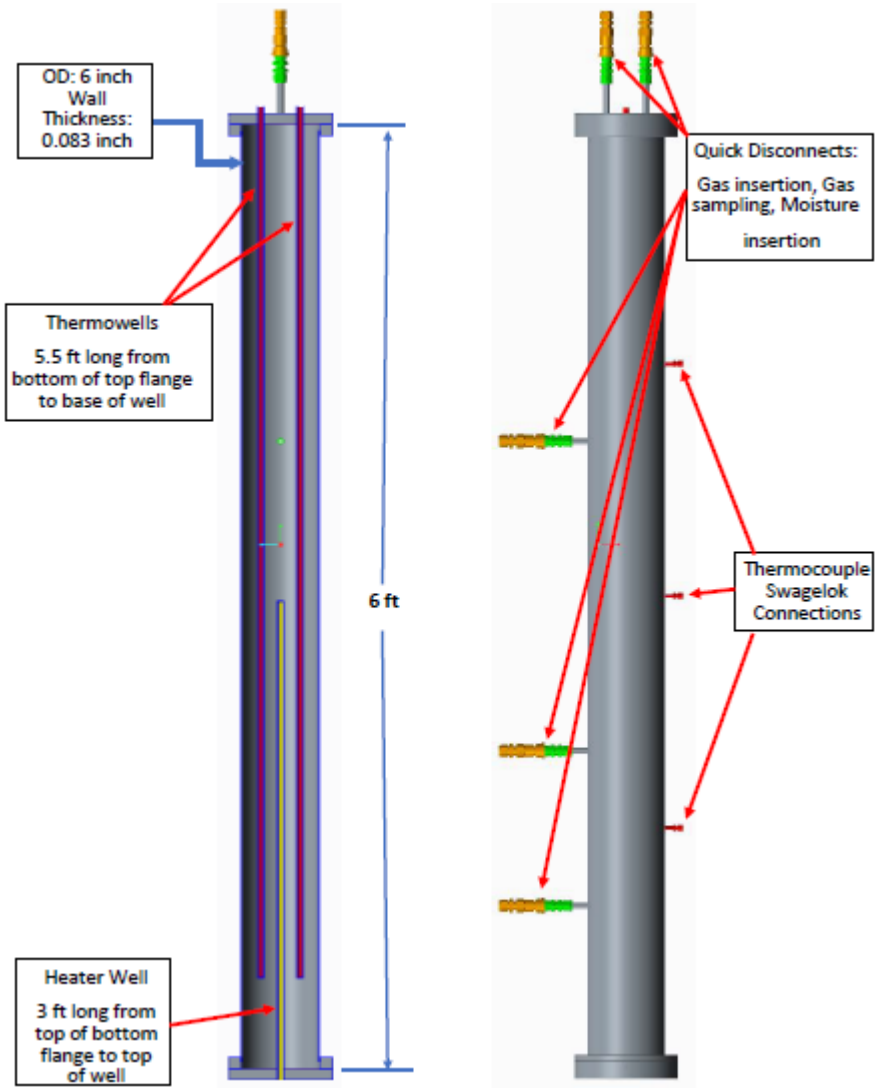

Figure 6: Diagram and 3D rendering of small sample canister with anticipated penetrations, gas sampling ports, temperature connections, and heater elements.

b) 18” Cold Test

The second configuration will be the full-sized canister system used to demonstrate the layout of instrumentation and connections and should resemble the final design of the canister as closely as possible without the requirement of Section III certification. This system will demonstrate the mechanical connections and fittings, including installation of the gas and electrical quick disconnects and thermocouples. The canister will also be tested for disconnection of components in preparation for the sealing of the canister for shipment and final disposition. The results of these two cold tests will be used to confirm the design and operability of the final test lid.

c) 18” Hot Demonstration

SRNL will design and fabricate the full-size lid, hat, and basket assembly to be used in a hot demonstration of monitoring the ASNF fuel in a DOE standardized canister. This fabrication will need to be informed by code experts as to which guidelines fabrication must adhere. Ultimately, the system together with the standardized canister (made by INL) must meet requirements of ASME Section III code, as well as 10 CFR 71 stipulations. SRNL and INL personnel will fabricate the 18” cold test assembly in a manner such that Section XI repairs can be performed to make the final product Section III compliant.

V. CODES AND STANDARDS

This section describes the strategy to meet the requirement that the “canister is assumed to be compatible with storage, transportation, and disposal packaging to meet DOE and NRC regulations without having to open the canister and re-package the ASNF”.

The DOE standardized canister is anticipated to be fabricated as an ASME Section III vessel. The design of the lid would be such that the final canister/lid would meet the ASME code. The mounting of the instrumented lid to the canister body and the controls to meet the ASME code requirements is the responsibility of the contractor at the site where the demonstration project would be loaded. During testing the system will meet B31.3 pipe code.

The intent of the lid design is to be able to meet the Section III requirements at the end of the demonstration. At the end of the test period the instruments will be removed, and the penetrations will have to be made Section III compliant. This will require the sealing of the penetrations required for the gas sampling and other instrumentation. The design of the lid will include Section III acceptable nozzles at the penetrations. These nozzles will be the Section III boundaries for the final canister. The connections and piping/tubing during the demonstration will be connected to these nozzles. At the completion of the demonstration, the instrumentation and the connections will be removed at the nozzles and the nozzles will be sealed to meet the code requirements. The process is expected to be similar to the sealing of the standard can vent plug. It is anticipated that this will be completed as “repairs” per ASME Section XI. Note that this work will be performed at the demonstration location and will be the responsibility of the contractor at the site where the demonstration project would be staged.

VI. SUMMARY AND PATH FORWARD

This report outlined the detailed design for the testing and demonstration of an instrumented SMART lid assembly. We are proposing fabricating components for custom hat, lid, and basket assemblies for cold and hot demonstrations. Initially, instrumentation will be tested with a < 6" pipe, and heat and gas conditions will be simulated. To test the 18" assembly, cold testing will be performed with a custom 18" hat, lid, and basket assembly, and electrical and mechanical connections between the lid and canister will be tested. Finally, an 18" assembly designed for hot demonstrations will be fabricated and tested. At this point in time, SRNL is not committing to fabricating an assembly which meets Section III requirements, but to one that has the potential to meet Section III requirements via Section XI repairs or similar.

VII. APPENDIX

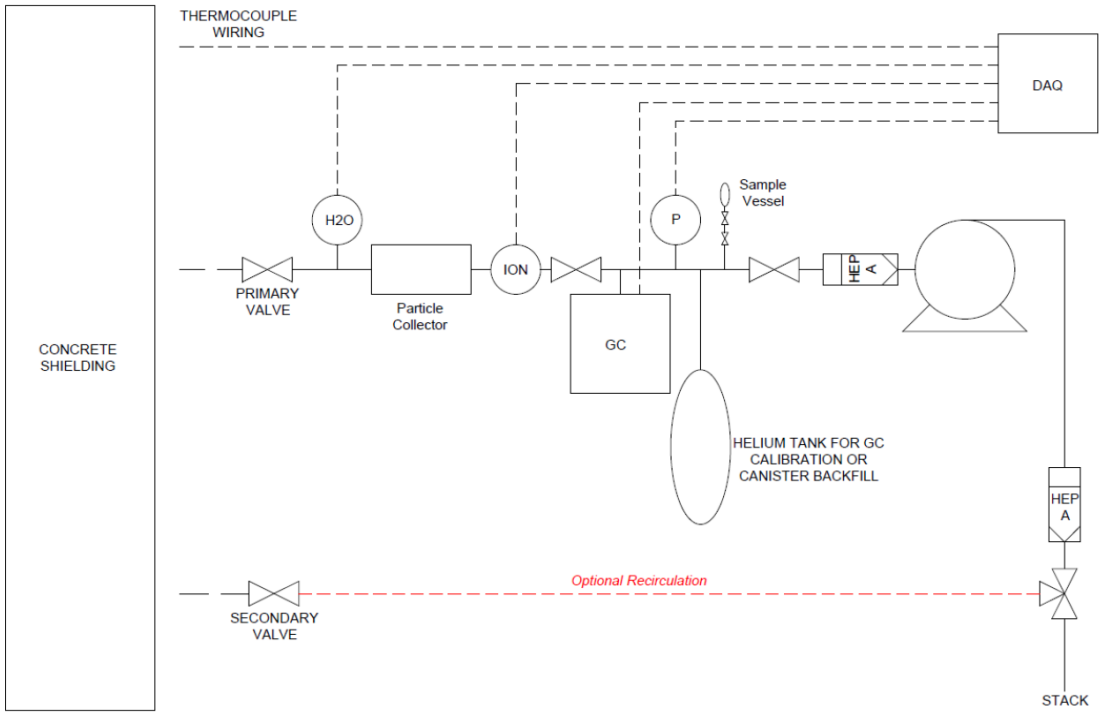

Figure A-1: Piping and Instrumentation Diagram of anticipated gas manifold for lid instrumentation.