Design Improvements in Liquid Argon Purification Techniques in DUNE Cold Electronics Test Cryostat (Iceberg)

F. Schwartz, FNAL; N. Vollmer, FNAL; D. Clark, FNAL

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Introduction

The testing of liquid argon detector electronics in a cold environment is an important component in the development of large-scale experiments such as DUNE. A 3000-liter cryostat (Iceberg) at Fermilab's Noble Liquid Test Facility (NLTF) was commissioned exclusively for such studies. The state-of-the-art filtration system for the liquid argon consists of a submerged, internal filter housing containing regenerable media, molecular sieve and activated copper, to capture the water and oxygen impurities, respectively. This filter, shown in Figure 2, allows the liquid argon to enter the filter volume until it is expelled by an electric heater cartridge, providing a throughput of <0.5 L/min. The highest measured electron lifetime achieved using this design was 1ms in the Iceberg cryostat, though typical runs experience lifetimes in the range of 300-700μs only.

Proposed Design Improvement

In order to more quickly improve the liquid argon purity within the cryostat, a commercially-available liquid pump will be utilized. A Barber-Nichols BNHeP-36-000 model pump was selected for this process, as it has proven success in other liquid argon applications. A filter media vessel will be installed downstream of this pump, containing both the molecular sieve and activated copper media. Flow rate will be controlled using a cryogenic control valve with feedback from a mass flowmeter. Aside from the pump, the remaining system components will be housed within a separate vacuum vessel acting as a valve box, as shown in Figure 3. The process diagram is shown in Figure 1 below.

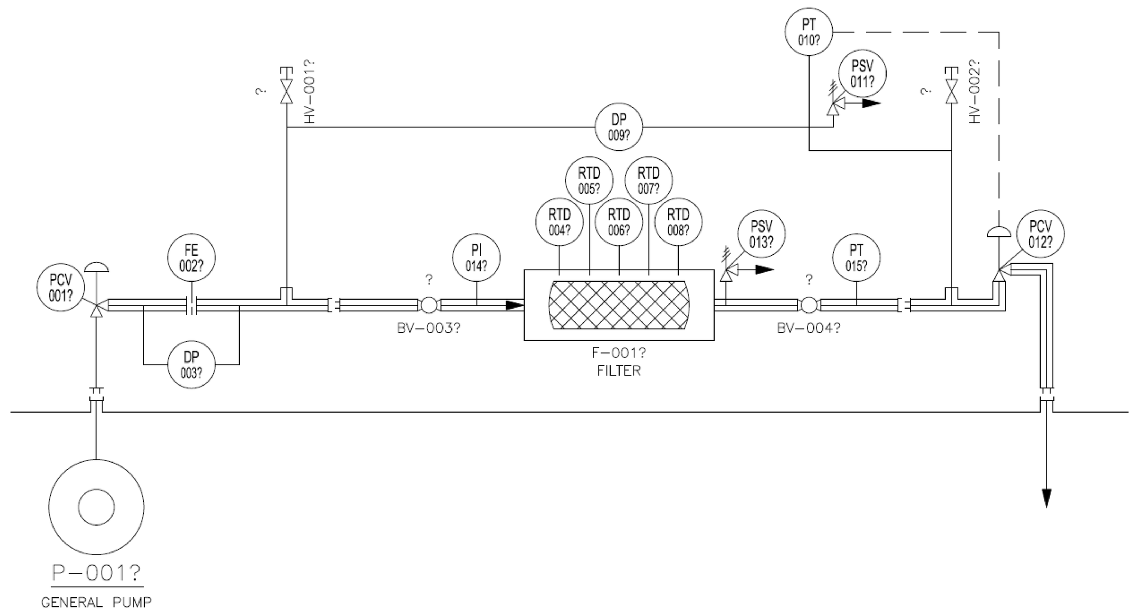

Figure 1 - Proposed process and instrumentation diagram for new filtration system

Current Filter Design & Operation

- Mounts to 14-inch conflat flange on cryostat top plate
- Vacuum isolation for regeneration of filter media, performed at temperatures >160°C
- Custom fabricated bottom isolation valve, operated manually using compressed helium
- Sintered metal disc at bottom to contain media within filter volume during operation and regeneration
- Fluid enters through bottom isolation valve by opening a valve between the top vent port and the cryostat ullage
- When liquid level inside the filter has reached the cryostat liquid level (maximum), the filter heater cartridge is activated with the vent closed to force the liquid out

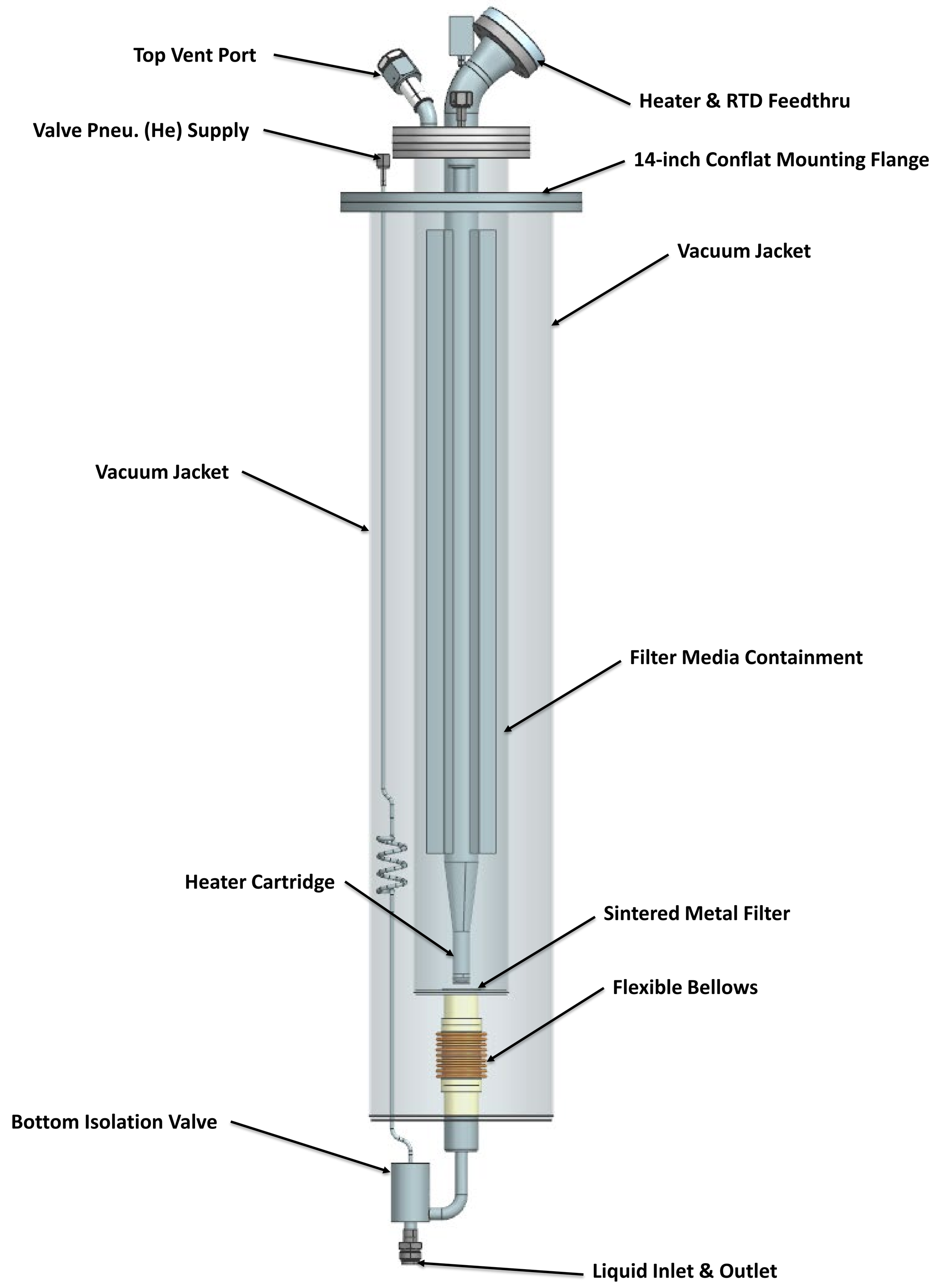

Figure 2 – Model of current internal filter used in Iceberg cryostat

Proposed Filtration System Design

- Filtration components external to cryostat
- Cryogenic pump capable of circulation rates <13 US GPM (50 LPM) per manufacturer – Figure 4
- Mobile vacuum vessel setup for ease in connecting to regeneration infrastructure
- Vacuum jacketed, flexible hose connection to cryostat
- Phase separation on return piping prevents gaseous argon issues with electronics
- Adaptable for use with other, similar cryostats at FNAL

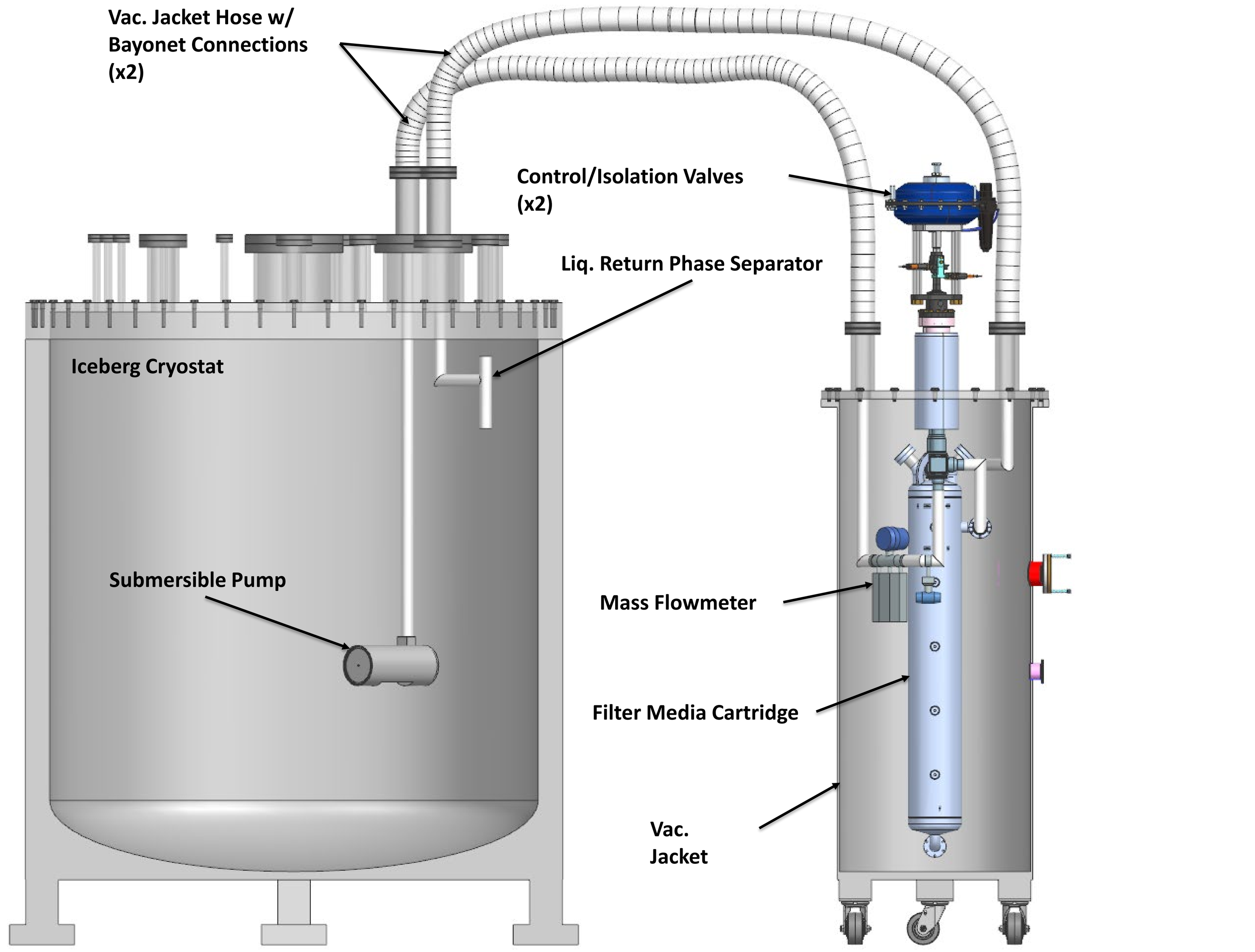

Figure 3 – Model of new filtration system design connected to the Iceberg cryostat

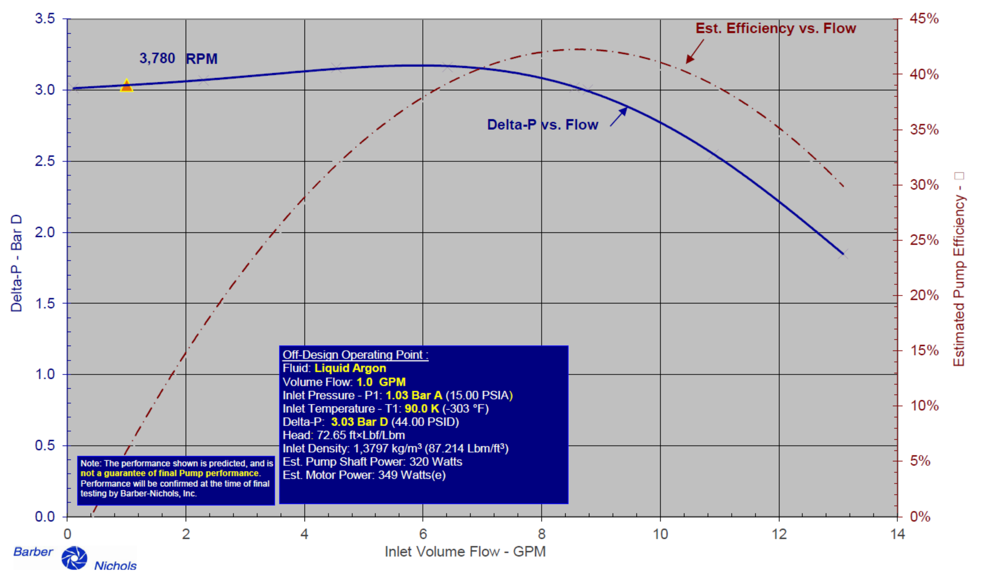

Figure 4 – Pump curve for the Barber-Nichols BNHeP-36-000 submersible pump