LANL Liquid Argon System for CAPTAIN

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(for Walt Sondheim who is our expert)

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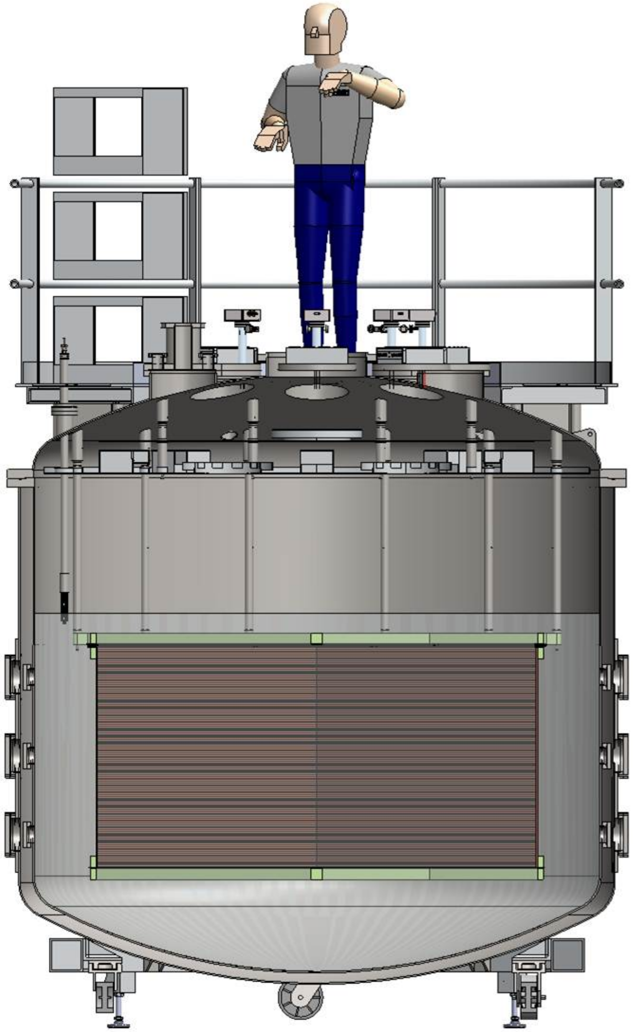
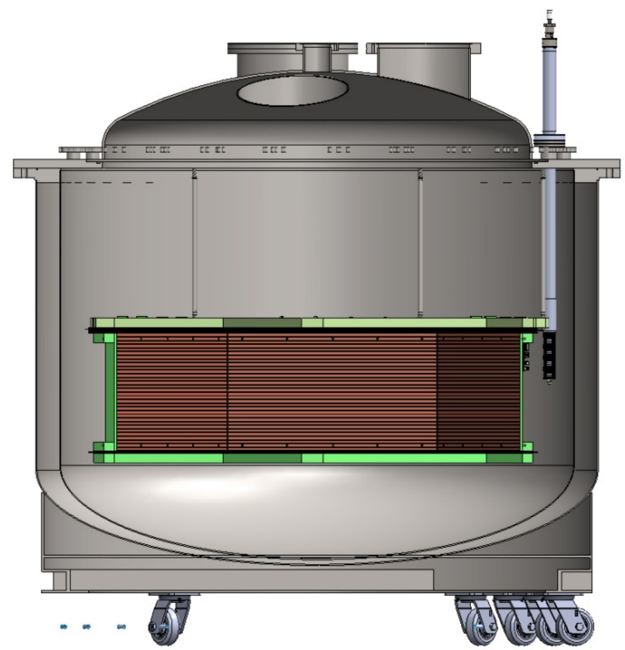
Conceptual Layout of Major elements:

- Large LANL cryostat (cut view)
  - Liquid Argon mass 10.5 tons
  - Volume 7,700 liters
- Small UCLA cryostat
  - Liquid Argon mass 2.08 tons
  - Volume 1,486 liters
- Liquid Argon:
  - Boiling point -186 C, 87.15 K
  - Liquid density 1402 g/L
  - Liquid-gas expansion ratio 860
- Liquid Nitrogen:
  - Boiling point -196 C, 77.15 K

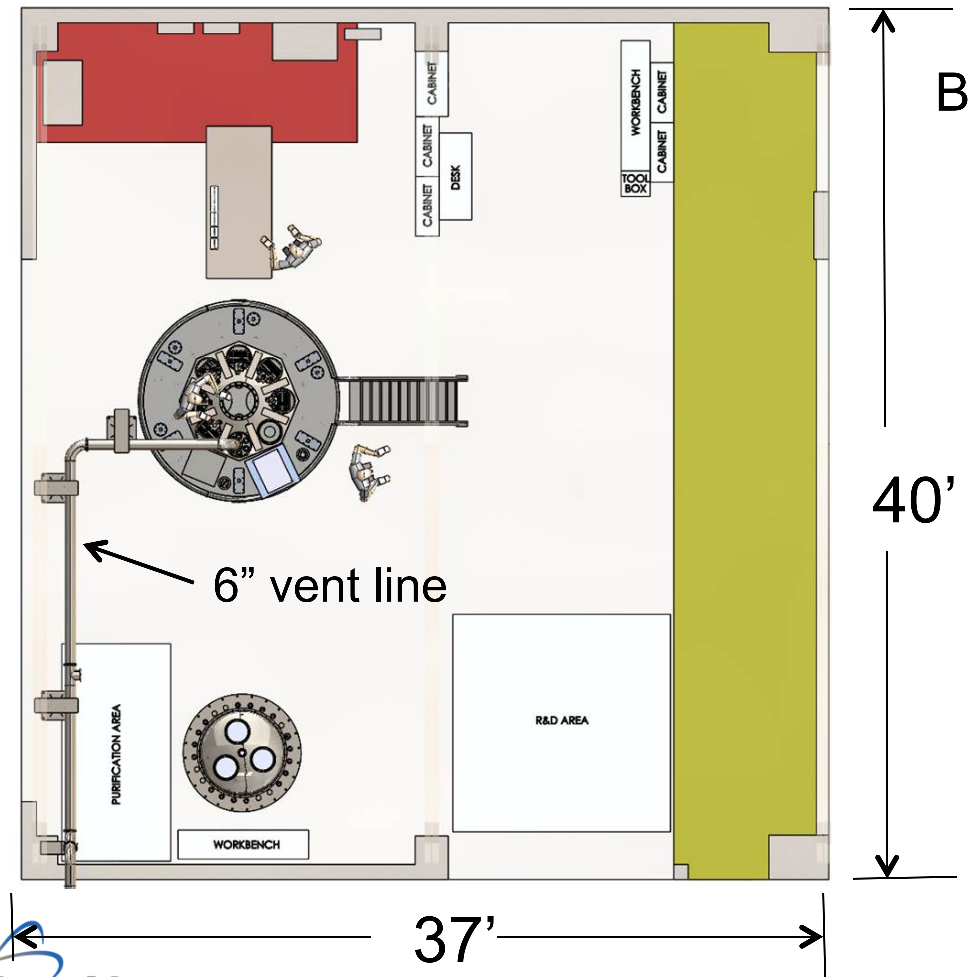


Conceptual Layout of Major elements - Processing:

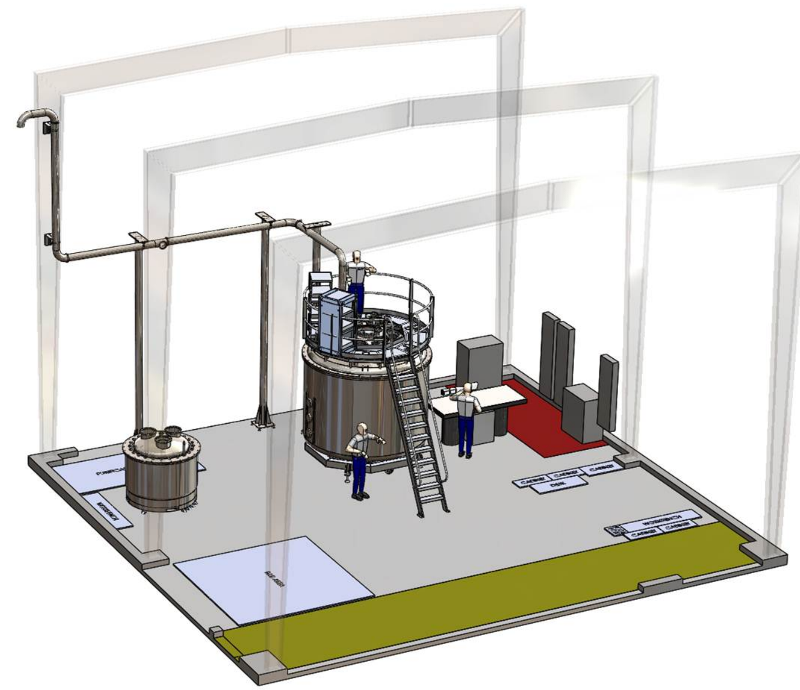
- Piggy-back on the development work at FNAL on the MTS, LADP, 35 ton Membrane Cryostat, MicroBoone and LArIAT, all of these systems include an Argon purification system with recirculation and a Argon vapor condenser
- Our smaller 1500 liter UCLA cryostat is a vacuum jacketed vessel with an inner wall thickness of 1/16”, outer wall 3/16” stainless steel, with layers of superinsulation in the vacuum region, 10^{-4} mbar. -- similar construction for the large cryostat



Conceptual layout for major cryogenic components in existing LSND support building:



Building has 5 ton bridge-crane



X location for Argon buggy-dewar external to building

5,700 liter Argon buggy-dewar:

- 5,678 liter, 1,500 gallon capacity @ 50 psi max Argon supply dewar

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Argon cryogenic processing small cryostat;

- Small test cryostat;
  - Plan to fill test cryostat to 75% with liquid allowing 25% head for boil-off. By controlling pressure, collect and re-condense cold vapor, circulate through filter system, return to cryostat.
  - Initial goal of 1 msec per meter electron drift, corresponds to an Oxygen equivalent concentration by volume of 300.0 ppt, 30.0 cm of electron drift corresponds to .3 msec lifetime and a O2 equivalent of 1.0 ppb

Process Monitoring:

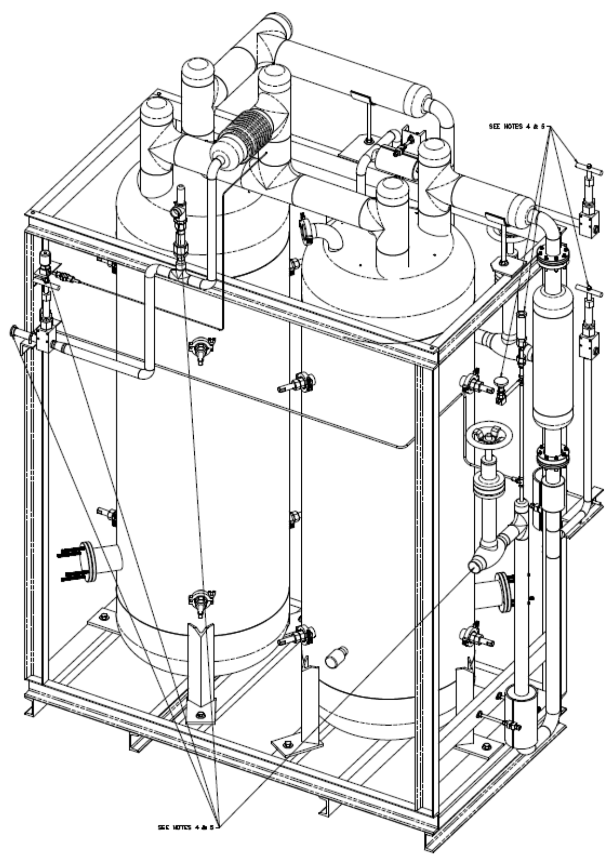
- Minimum equipment needed to monitor contaminates;
  - H_2O: Tiger Optics Halo Trace, works well down to the 10 ppb level
  - O_2: Delta F DF-310E, contamination levels 0–50 ppm
  - O_2: Delta F DF-560E*, ppb O_2 contamination, works well at the < 100 ppb level
    - *Needed for the large cryostat

Argon recirculation system & filtering:

- Based on filter sizing formulas in document 488 v-1, on DOCUB, the filter material requirement for the larger LANL cryovessel to obtain the necessary Oxygen purity;
  - LANL cryovessel has a volume of 7.5 m^3 this is equivalent to 6.3027 m^3 @ stp Argon gas.
  - At 1.0 ppm of O2, this will be a contaminate level of .0063 m^3 at STP O2 gas.
  - This is equivalent to 8.253 gram of Oxygen
  - Requiring 16.5 kgms of filter material
  - Packing density .81 kgms/liter giving a volume of filter material needed to remove 1 ppm of Oxygen from the supply Argon is 20.3 liters
  - There are 2 types of filter material needed;
    - Sigma 4A molecular sieve to remove water
    - Copper-0226 S14x28, (Copper coated Alumina beads) for Oxygen removal

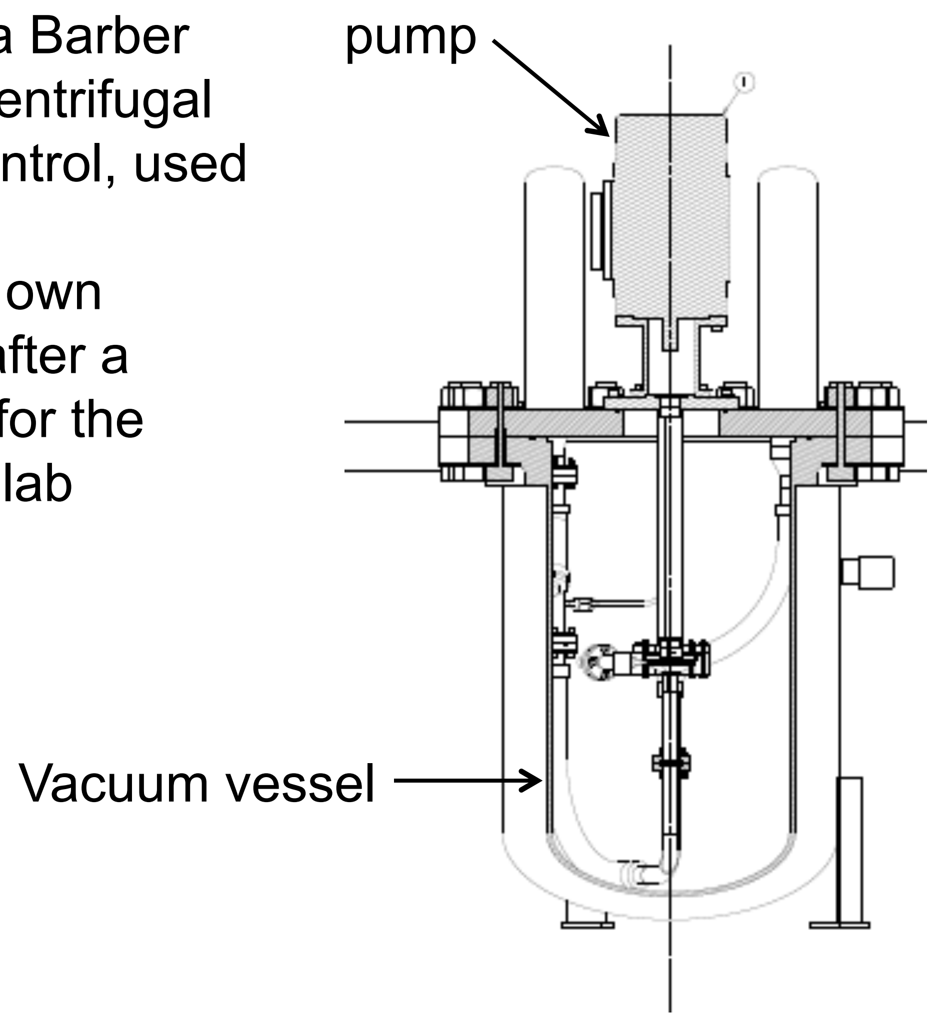
Argon recirculation system & filtering continued:

- Both filter materials would have a shared volume of 40.6 liters, this could occupy a 12 inch diameter, schedule 10 stainless steel pipe with a length of 24 inch. This would be an inner vessel requiring an ASME code stamp. This will be located in an outer vacuum vessel.
- The filter material will need to be regenerated by heating to 250^{o} C, after which the Argon gas is replaced by a 2.5% Hydrogen/97.5 % Argon mixture to absorb the Oxygen to form water.
- The filter vessel is similar in design to one being fabricated for Micrboone – with only one vessel



Argon recirculation system & filtering continued:

- The recirculation pump will be a Barber Nichols magnetically coupled centrifugal pump, with a variable speed control, used to maintain Argon purity.
- This pump will be housed in its own vacuum vessel, also modeled after a similar vessel being fabricated for the Micrboone experiment at Fermilab

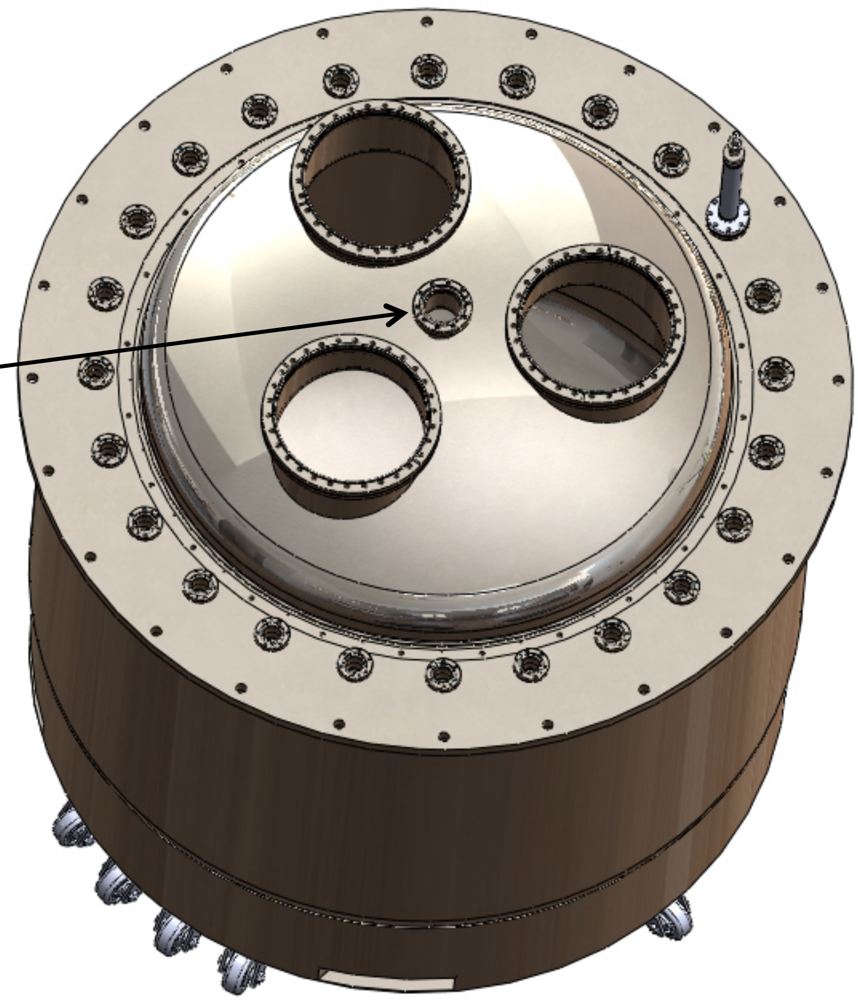


Safety, vent line calculation for UCLA cryovessel:

- Question: will one of the 1.5” diameter ports on the UCLA top flange be adequate to vent a 75% full UCLA cryovessel with liquid Argon?
  - Calculate the “wetted” internal surface with LAr, = 4.528 m^2
  - Assume a heating rate from LAr spoiling, with 10 layers od super-insulation, of 1800 watts/m^2 (Cryogenics, vol 52 (2012) pp 331-335)
  - This gives a heating rate of 8,150.4 watts = 8.15045 kjoules/sec
  - The latent heat of vaporization for Argon is 16,081 joules/kgram
  - The mass flow rate 8,150.4/16,081 = .5068 kgms/sec
  - The density of Argon gas at STP = 1.63 gms/liter
  - The volumetric flow rate 506.8/1.63 = 311 liters/sec = .311 m^3/sec
- For a 1.375” diameter orifice (1.5” SS pipe ID) = area of .000958 m^2 which gives a flow rate of 325 m/sec. Unfortunately the speed of sound in Argon is 323 m/sec! This flow rate is not acceptable. If you use the 3” diameter port in the center of the head – running similar calculation gives a velocity of 81.84 m/sec or 81.83/323 = .25 for a mach number
- More calculations needed, pressure drop in vent pipe, etc.

Safety, vent line calculation for UCLA cryovessel:

Location of 3" pipe for vent



Final Thoughts: how long to empty the LAr

- Question. how long would it take the liquid Argon to boil off in the UCLA cryostat, if the liquid level was 10.0 cm above the top of the TPC? The answer is 47.5 hours (for 1500 liters and 37.9 hours for 1200 liters). For quicker access the installation of a heater will be needed.
  - The mass flow rate was 12.3 gms/sec
  - Density of liquid Argon 1.4 gms/cm^3
  - Time = 1200/(.0123*360) = 37.9 hours