Cryo Ops Workshop – Summary of Day 2

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MicroBooNE – Mike Zuckerbrot

- Target: 100 ppt O2 equivalent purity. Achieved 14 ms lifetime.
- How to get from air to sub-ppm without evacuation.
  - Piston purge + GAr recirculation + Venting from chimneys.
- Gradual cooldown (< 20 K delta T) with a three-pass heat exchanger.
- Issue: contractual issues with LAr procurement (spec on N2 contamination and aggressive schedule).
- Fill LAr w/o passing through the filters.
- Two LAr pumps (one in service, one backup).
- Two Condensers (one in service, one backup).
- Not purging the chimneys continuously during normal operations.
- Own purification system: copper + mol sieve.
- O2, N2, H2O samples.
- Issue: bearing failure (~ 6,000 hr). Maintenance was supposed to be at 5,000 hr, but experience suggests a longer lifetime. So they left it running.
- Post-mortem showed that the night before a damaged PT causes the pump to change speed frequently, which may have caused an excessive wear and tear of the bearings.

35 ton Phase 2 – Fritz Schwartz

- Prototype using the membrane cryostat technology.
- Recondensed LAr goes to the pumps inlet to be purified before returning to the cryostat.
- Commercial laboratory gas analyzers (down to 1 ppb) and Purity Monitors below that.
- Same piston purge and GAr recirculation (1.2 m/hr to avoid mixing and push the impurities out).
- Cool down sprayers (to meet 10 K/hr from membrane manufacturer). Mist of LAr/GAr circulated inside the cryostat.
- 3 ms electron lifetime.
- Issues:
  - LAr pumps seizure (Could not start them.
  - Power outage (showed purity stratification. Believe that only the bottom portion of the liquid was being purified. Location of LAr return and LAr pumps suction.
  - Vapor pump failure (vibrations caused the pipe to sheer off. It was a temporary installation that was not checked for longer usage). Filters saturated in 20 minutes. Complete loss of purity in 30 m. Too contaminated to recuperate.
  - Locate analyzers in a location where they could detect early the contamination and prevent a total loss of purity.
- Future work:
  - High voltage test.
  - Beam plug test.
  - Raise the LAr return to the top of the LAr level.
  - Add heaters to the bottom of the cryostat to boil it off to remove LAr/GAr from the cryostat faster.

ICARUS – Claudio Montanari

- First multiton LAr TPC.
- Very stable T distribution inside the cryostat.
- 15+ ms lifetime (~20 ppt O2 equivalent contamination).
- Non-regenerable commercial LAr filters.
- Cool-down rate: 2 K/hr. Cool-down from outside, via thermal shields wrapped around the vessels (Two-phase saturated N2).
- Thermal shields around purification vessels and LAr lines.
- Cool-down only during the day, to maintain the max temperature differential across the detector.
- Ar purification strategy:
  - Selection of materials (LAr T, outgassing).
  - Surface treatment and material cleaning (pickling, passivation, ultrasound washing).
  - Assembly in clean room.
  - Vacuum purge (differently from previous experiences).
  - Initial Ar purification with dedicated pre-filters (Two in series) during the filling.
  - Continuous LAr and GAr filtration (with Oxysorb 75% and Hydrosorb 25%) with different filters than for filling. Purification always in liquid phase (GAr boil-off is recondensed before purification).
- LAr pumps:
  - Used ACDs most of the time (< 3,000 hr maintenance cycle).
  - Replace one with Barber-Nichols to increase the lifetime (> 3 years without maintenance).
- Issues:
  - Heat load x3 design value. Custom made vacuum panels that did not hold the vacuum properly.
- Successfully completed first run (already at the 700 ton LAr scale). A refurbished version is now coming to Fermilab.

Asphyxiation – Robert Done

- Safety Audit.
- Asphyxiation.
- Causes of Oxygen Deficiency Atmosphere.
- Importance of Ventilation and location of the oxygen sensors.
- Risk assessment: how to calculate the O2 concentration in the environment and what the effect is on the human body.
- Case study: calculation of O2 % during normal and accidental release. Recommendation for accidental release (oxygen sensors and forced ventilation).
- Remember more than 1% of this talk!

Comparison of ODH techniques – Brian Degraff

- ODH review.
- Comparison between risk based (SNS) and probability based (Fermilab). Different from the one of the previous contribution.
- Other lab experiences.
- This should serve as a starting point to develop an improved ODH analysis based on the existing practices.
- Table of ODH exposure from CERN with time of useful consciousness.
- SNS method:
  - Works care released method.
  - Decision tree analysis to identify the worst case scenario.
  - Determine consequences of unmitigated risk.
  - Selection of appropriate mitigation strategies.
  - Re-assessment of mitigated risk.
  - Selection of mitigation hardware (including SIL level).
  - Identification of the risk category.
  - Modeling of the release, but no spill test to validate the model.
- Fermilab method:
  - Requires quantitative assessment of increased risk fatality from exposure to reduced O_2.
  - Follows ALARA.
  - Calculate all possible contributions to ODH and overall ODH risk.
  - ODH classification.
  - Mitigation to give an equivalent level of safety of a Class 0.
- Advantages & Disadvantages of both analysis.
- LBNF following Fermilab.
- CERN same as SNS.
- ESS applies probability + worst case.
- LCLS-II applies probability + CFD modeling.
- Future development needs: opportunity to develop a unified methods that could combine both risk and probability approaches.

Oxygen Deficiency Sensors – Sung Kwon

- System response to potential spill of cryogen.
- Type of sensors, how they respond to oxygen deficiency, response time and recovery time with various O2 level.
- N2-O2 all as expected, but the presence of Helium may affect the performance of the sensor.
- Long term stability.
- Temperature, Vibration effects.
- Radio interference.
- Chose the two sensors solution for redundancy.

Membrane cryostats – Jerome Pelle

- Membrane cryostat technology (from 17 to 200,000 m^3).
- Passive insulation.
- Modular design: insulation and membrane panels of fixed shape and size to fit customers needs.
- Long successful history with 390 LNG carriers and 33 onshore tanks (since 1972).
- Now LAr tanks for scientific applications.

Turbo-Brayton – Jean-Marc Bernhardt

- Turbo-Brayton highlights:
  - 30-150 K range.
  - Skid mounted, compact design.
  - High efficiency.
  - High reliability.
  - Long intervals between maintenance.
  - No oil, no leak, no seal.
  - Motor connecting directly the compressor and the expander.
- Available power: 7.6-150 kW (at 77K). Wide range of operations.
- One unit in service on the International Space Station (100 W at -80C) and one in China (15 kW at 150K).
- Other units of increasing size being installed and tested (up to 48 kW at 110K).

Questions

- Is there an interest in developing a unique method to address O2 deficiency atmosphere?
- How to proceed, which steps can be taken to achieve that?
- Any comment on membrane cryostat technology for LAr applications?
- Does the Turbo—Brayton solution represent a good solution for future projects?