Preliminary Design of a New Helium Liquefaction System at LBL

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Abstract

A new high efficient helium liquefaction system with high capacity is under design and will be built at Lawrence Berkeley National Laboratory in the next couple of years to replace an existing 43-years-old liquefier. The new liquefaction system will provide at least a mixed 80 liter per hour liquefaction rate and 35 W refrigeration capacity at 4.5 K without liquid nitrogen pre-cooling, or a mixed 140 ltr/hr liquefaction rate and 35 W refrigeration capacity at 4.5 K with LN_2 pre-cooling. It can be operated mainly at two modes, liquefaction mode and liquefaction/refrigeration mixing mode. As a core element, the new liquefaction system will significantly improve the capability and efficiency of the magnet testing facility at LBL in developing and testing novel magnet configurations. The system shall be designed and built with the capability to be further expanded to 1.8 K to 2 K by adopting a warm pumping system, as well as to furthermore enable future integration of helium recovery and purification capability. It will be critical to deliver on LBL's commitments to the US Magnet Development Program (MDP) and to support the High Energy Physics (HEP) Program at LBL. This paper describes the preliminary design of the new liquefaction system including its performance, operation modes, main components, layout plan and so on.

Background

- The Berkeley Center of Magnet Technology (BCMT) at LBL has been very active both on low-temperature and high-temperature superconducting magnet technology development, leads the community in developing and testing novel magnet configurations, and developing high-field magnet technologies for future colliders supported by the HEP-funded US Magnet Development Program (MDP).
- In support of that development, the LBL-BCMT has not only a strong magnet development and testing team, where novel concepts are explored through an iterative design-fabricate-test process, but also a variety of testing infrastructure, which includes the state-of-art power supplies and power extraction, fast diagnostics of various flavors, and a helium liquefier system which is critical to enable cost-effective testing of high-current, large-stored-energy superconducting magnet systems.
- The performance degradation and costly operation, maintenance & repair of the existing 43-years-old CCI liquefier became a bottleneck to support the LBL's R&D program in magnet technology in the last 15 years or so.
- Funded by DOE-HEP office, a new, automated and advanced He liquefier system will replace the old CCI liquefier, enable faster and more efficient magnet testing, result in significantly lower operating and maintenance costs, address the major current uncertainties associated with reliability of the liquefier, as well as support other users in LBL and UCB and serve the community.

Performance Requirements of New Liquefier

Two primary operation modes based on application requirements: liquefaction mode and liquefaction/refrigeration mixing mode.

- **Liquefaction mode**: ≥ 4.5 K 140 ltr/hr liquefaction rate with LN2 precooling, and ≥ 4.5 K 80 ltr/hr liquefaction rate without LN2 precooling

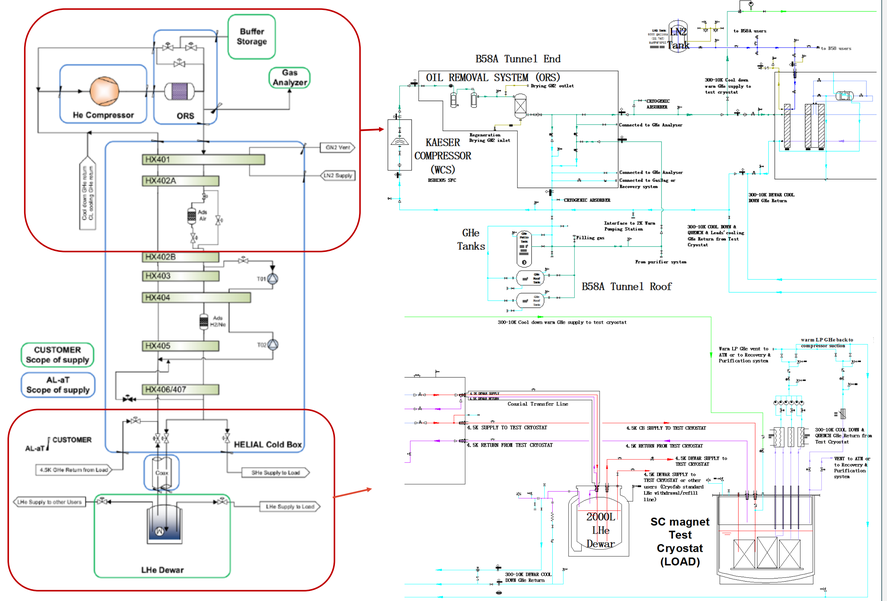
  The liquefier system supplies LHe to users at LBL and UCB such as MDP, ALS-U, Molecular Foundry, Cyclotron, etc.
- **Liquefaction/refrigeration mixing mode**: mixed 80 ltr/hr liquefaction rate and 35 W/4.5 K refrigeration capacity without LN2 precooling, or mixed 140 ltr/hr liquefaction rate and 35 W/4.5 K refrigeration capacity with LN2 precooling.

  The liquefier system will be used for testing of novel magnet configurations and advanced equipment such as CCT magnets, LTS/HTS hybrid high-field magnets, HTS Gantry prototype, ECRIS MARS-D magnet, etc.
- **Future integration of a portfolio of helium recovery and purification capabilities** to be extended to serve a broader spectrum of DOE users.
- **Capability to be further expanded to 1.8 K to 2 K** by adopting a warm pumping system.

LBL New Liquefaction System: Process Flow Diagram & Main Components

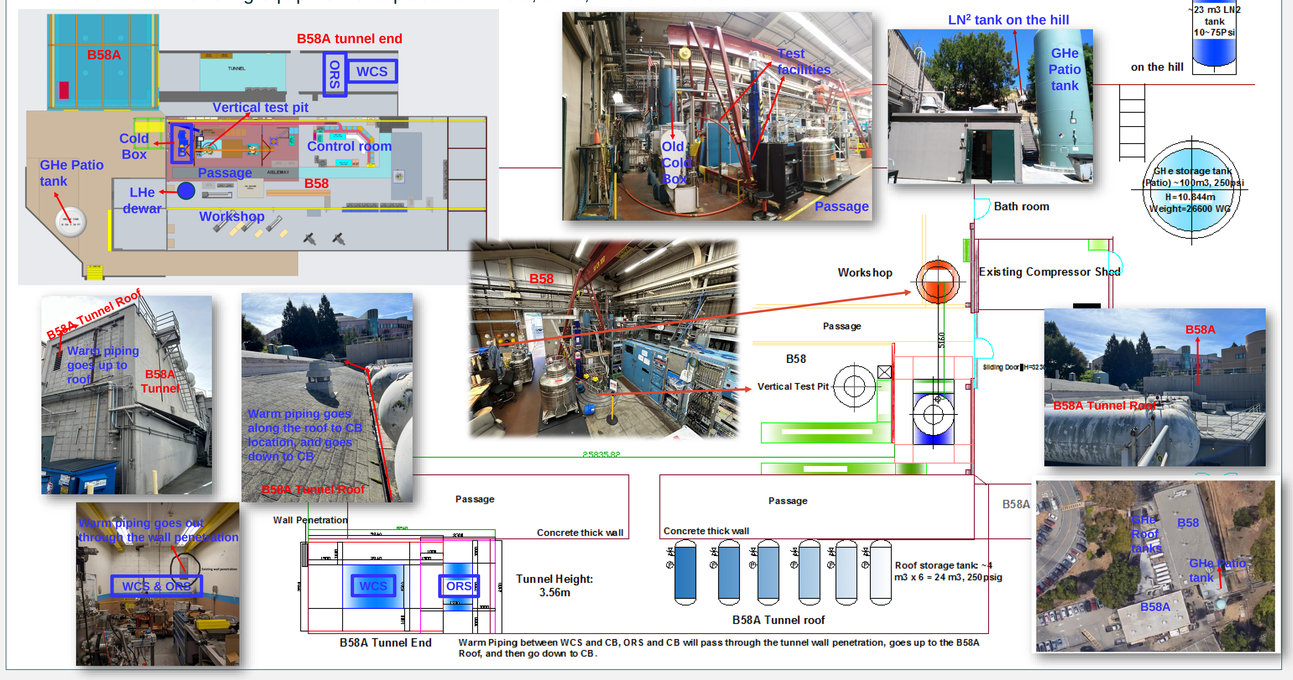
Main components:

- **Core elements of the liquefier** to be provided by ALaT includes warm He compressor (WCS), oil removal system (ORS), cold box (CB), coaxial transfer line and associated control cabinets.
- **Existing equipment at LBL**
  - GHe storage/buffer tanks: Patio 100 m^3+ Roof 40 m^3, MAWP 250 PSIG
  - LN2 tank & supply VJ transfer line from LN2 tank to B58: 23 m^3, MAWP 75 PSIG
  - 36" test cryostat in vertical pit: under upgrading, to be equipped with 2 pairs of 25 kA VCCLs
- **To procure by LBL**
  - Gas analyzer: to monitor online N2, H2O and CxHy
  - LN2-cooled Cryo adsorber: work as portable external purifier
  - Customized 2000L LHe stationary dewar



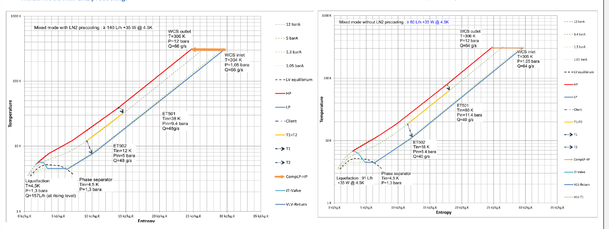
Layout Plan

- To remove the existing equipment and place new WCS, ORS, CB and LHe dewar



T-s Diagrams

- T-s diagrams provided by ALaT



Operation Scenarios and Processes

Operation scenarios

- CB shall supply 1.3bara/4.5K LHe or 3bara/5K SHe directly to LOAD (cryostats).
- CB shall supply 1.3bara/4.5K LHe to Dewar.
- CB shall supply 1.3bara/4.5K LHe directly to LOAD, in the meantime, supply LHe to Dewar.
- CB shall supply 1.3bara/4.5K LHe to Dewar, and Dewar shall supply LHe to LOAD.

Cool down processes

- CB shall cool down individually without LHe dewar and LOAD
- LHe dewar shall be cooled down together with the CB from room temperature to 4.5K.
- LOAD shall be cooled down together with the CB from room temperature to 4.5K.
- LOAD shall be cooled down after cool down of CB & LHe dewar and LHe has been accumulated in LHe dewar.

Training of SC magnets and Cool down over again

- During training of SC magnets resided in LBNL test cryostats, SC magnets will undergo repeated excitation and quench. Ghe buffer tanks and pressure relief valves at the suction side of the WCS shall be designed to stabilize the pressure surge.
- After quench of magnets, the liquefier shall cool down the test cryostats over again.

Warm up process

- All the helium in the liquefier, LHe dewar and LOAD will be automatically recovered to the GHe storage tanks.

Status & Schedule

- Final design of the Liquefier core elements (WBS, ORS and CB) was reviewed in the middle of May. ALaT will deliver them in April 2025.
- The LBL onsite acceptance test is expected around September 2025.
- LBL-BCMT is working on design of the whole liquefaction system.
- Old CCI liquefier will be removed by LBL facilities planned around early 2025 in order to install new He liquefier.