Cold Facts Spotlight—NASA Kennedy Cryogenics Test Laboratory

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Adam Swanger
Principal Investigator
Cryogenics Test Laboratory
NASA Kennedy Space Center, Florida USA

For over 20 years, the Cryogenics Test Laboratory at NASA Kennedy Space Center (KSC) (CSA CSM) has stood as a one-of-a kind capability for research, development, and application of cross-cutting technologies to meet both government and industry needs. With four overarching technology focus areas—Thermal insulation systems, Integrated refrigeration systems, Advanced propellant transfer systems, and Low-temperature materials and applications—and a theme of *Energy Efficient Cryogenics*, the Cryo Test Lab has pioneered technologies such as Integrated Refrigeration and Storage (IRAS)[1] for advanced liquid hydrogen (LH_2) operations; aerogel blanket insulation[2], the world's best insulation material in ambient pressure and soft-vacuum; and the patented-pending Cryogenic Flux Capacitor[3] for high-density storage, and on-demand supply of cryogenic fluids.

Practical cryogenic thermal insulation system testing is a cornerstone of the Cryo Test Lab identity. Through a suite of custom-built liquid nitrogen (LN_2) cryostats, the Lab has produced high-quality thermal performance data for a huge variety of insulation materials and systems, from common to exotic, and formalized the process of LN_2 boiloff calorimetry by spear-heading the writing, and eventual adoption of ASTM standard C1774. The Cryostat-100 (C-100)[4], a vertical-cylindrical cryostat, is the flagship calorimeter of the Lab, and been successfully used to test insulation systems with R-values as high as 9000 Btu·in/hr·ft^2·°F and heat loads ranging from 100 mW to 130 W. Testing can be conducted over the full vacuum pressure range, from 10^{-8} torr up to ambient pressure, and has historically been limited to inert background gases such as nitrogen or helium. However, recently C-100 has been modified to test with hydrogen as a background gas, and is currently characterizing the performance of bulk-fill insulation materials such as perlite and Glass Bubbles purged with hydrogen for potential use in future mega-scale (100,000+ m^3) LH_2 storage tanks. Core features of the C-100 design, along with the invaluable practical experience gained from operating the instrument for many years, is now being applied to the design and construction of an LH_2-based boiloff calorimeter deemed Cryostat-900. This new capability is planned to be operational in 2023, and will fill a crucial gap in the cryogenic insulation system data archive by providing absolute performance measurements at operational conditions for actual LH_2 storage tanks and equipment.

As is most likely apparent from the recent cryostat work, much of the current Lab portfolio focuses on liquid hydrogen-related topics. Although this is in-part a response to the rapidly growing hydrogen economy, being located at the Kennedy Space Center—site of the largest LH_2 storage and transfer systems in the world, built to support the Apollo, Space Shuttle, and now Artemis manned spaceflight programs—the Cryo Test Lab has always been well-positioned to tackle various LH_2 challenges. Through projects such as the Cost-Efficient Storage and Transfer (CESAT) of Cryogens[5] that constructed and tested a pair of 1000 liter spherical cryostats using LH_2, and laid the groundwork for the adoption of Glass Bubble insulation in the new 4,700 m^3 storage tank at KSC[6]; and the Ground Operations Demonstration Unit for Liquid Hydrogen (GODU-LH2) that pioneered large scale IRAS, the Cryo Test Lab has safely and successfully conducted complex testing programs using LH_2 on numerous occasions. However, in many cases using LH_2 is not practical, especially for small, lab scale type testing. In these instances the Lab has numerous cryocoolers and associated vacuum chambers capable to test at temperatures as low as 14 K.

Consistent utilization of cryocoolers began at the Cryo Test Lab in the 2011 timeframe with the purchase of an AL230 Gifford-McMahon unit from Cryomech (CSA CSM). This machine has been a workhorse for the Lab, supporting a host of unique test setups for everything from training of low-temperature shape memory alloys[7], to performance characterization of deep space cryogenic thermal coatings[8]. In the years since purchasing the initial AL230, the Lab has added five additional units: two AL325's and a PT30 pulse-tube from Cryomech, a sterling cycle Cryotel GT unit from Sunpower (CSA CSM), and a STC90 machine from AFCryo (now Fabrum) (CSA CSM). These cryocoolers have played a critical role in many of the Cryo Test Lab's research projects over the last decade, including CO_2 capture for Mars In-Situ Resource Utilization (ISRU), sub-20 K and extreme thermal cycling (e.g. 20 K to 373 K) component testing, and dry-charging of Cryogenic Flux Capacitor's. Beginning in 2018, the Cryo Test Lab has also been involved in the development of novel hydrogen-based cryocoolers that may aid in long duration cryogenic propellent management to support future deep space missions.

<u>References</u>

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Figures

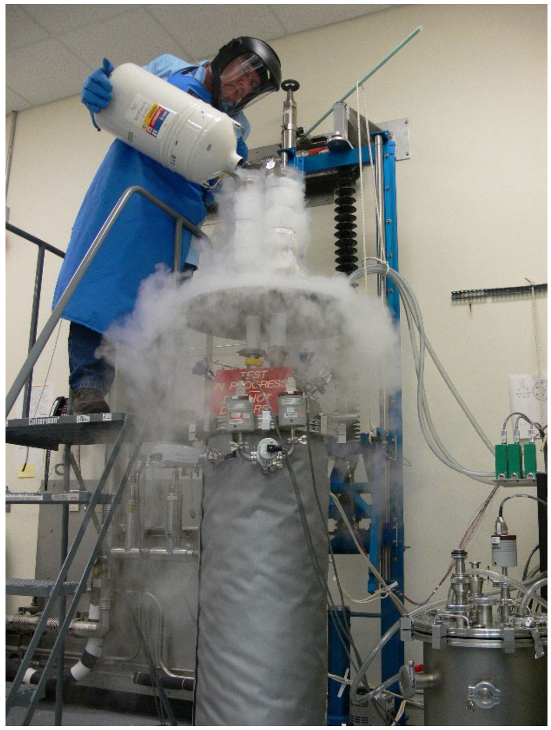

Figure 1. Filling Cryostat-100 with LN_2 in Preparation for Insulation Testing
Image Credit: NASA

Figure 2. Space Irradiance Simulator[8] Test Setup Powered by a Cryomech AL230 G-M Cryocooler
Image Credit: NASA