

Integrated Refrigeration and Storage of LNG for Compositional Stability



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Introduction

- Many future launch vehicles are planning to use liquefied natural gas (LNG) in combination with liquid oxygen (LOX)
- LNG as a rocket fuel
 - Highly efficient, widely available, and low cost
 - Clean combustion characteristics, improving refurbishment and reusability
 - Can self-pressurize ullage of tanks (reduces helium usage)
- Compositional changes due to preferential boiloff (or weathering) occur
- Integrated refrigeration and storage (IRaS) can provide active heat extraction (i.e. refrigeration) to eliminate weathering)

Experimental Cryostat Apparatus

- 400-liter vertical vacuum-jacketed cylindrical vessel (cryostat) with an integrated pulse tube cryocooler (approximately 50 W at 100 K)
- RTDs and 1.6-mm diameter liquid sample tubes on vertical rake for 5 liquid levels



(Image: NASA)

Objectives

1. Compare composition changes of LNG using traditional boiloff/venting to using IRaS
2. Study feasibility and cost-effectiveness of long-term storage using active refrigeration
3. Investigate feasibility and benefit of densified LNG

Experimental Approach

Test steps

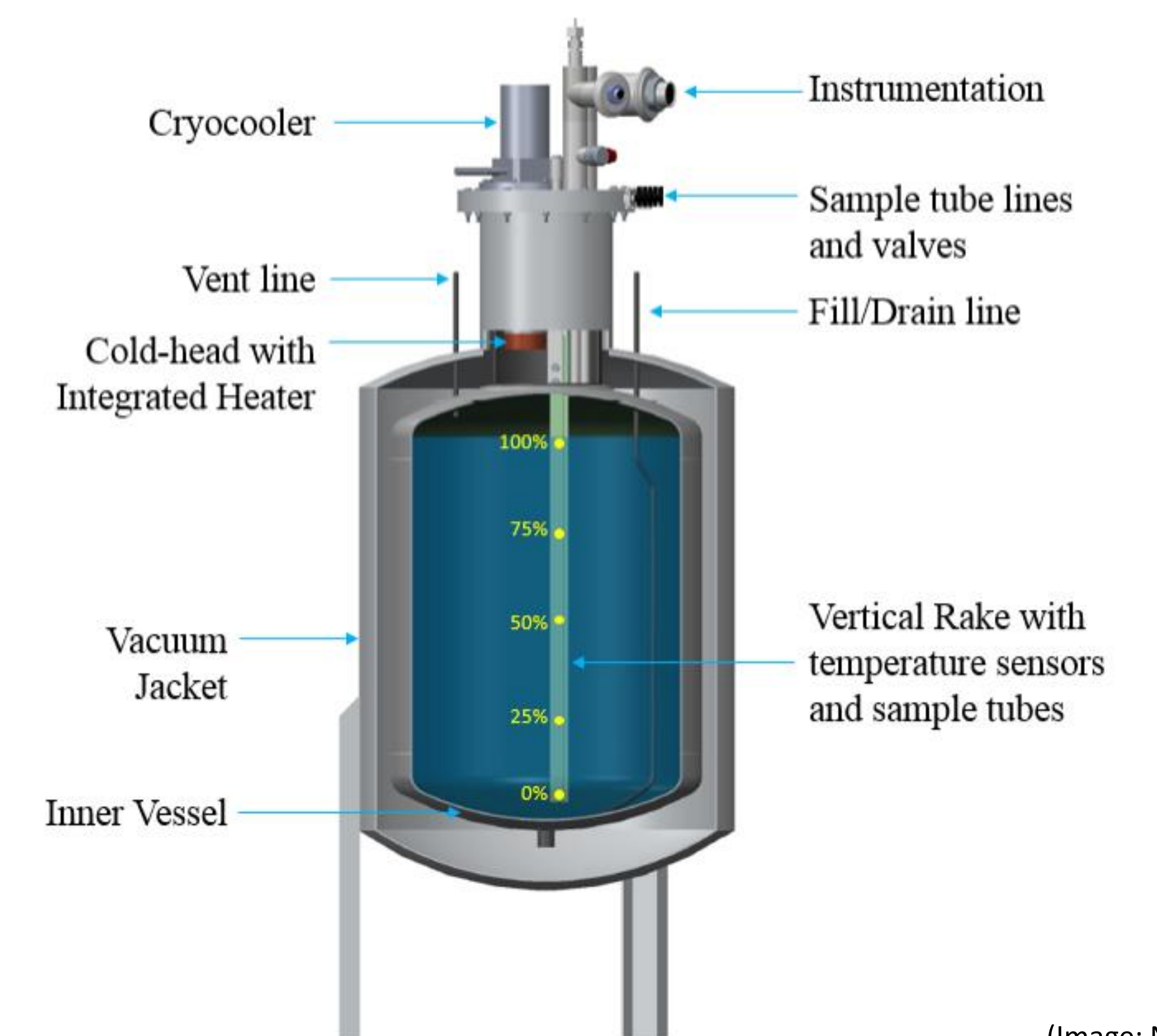
1. Fill with LNG and leave vent open
2. Sample LNG while LNG evaporates, until tank is empty
3. Fill cryostat with LNG again
4. Close vent and turn on cryocooler
5. Adjust heater controls for zero boiloff (ZBO)
6. Allow zero boil-off for 2 weeks

Sampling procedure

1. Continuously analyze vent output with mass spectrometer (only during boiloff test)
2. Three times a week, sample each of the five liquid levels
3. Once a week, sample each of the five liquid levels using a gas analyzer

Modes of Operation

- Boiloff: Without refrigeration, in order to determine a baseline in the change in composition, and to study stratification of the LNG (boiloff test)
- Zero boiloff: Cryocooler active to determine the operational parameters of the IRaS system for eliminating the weathering as well as stratification effects in the bulk liquid



(Image: NASA)

Sampling Methods

- Sampling two different ways
- Precise 5-283 Gas Analyzer from MKS (Infrared /optical analyzer)
- Mass spectrometer

Gases measured

Methane
Ethane
Propane
Iso-Butane
n-Butane
Pentanes
CO₂

Status

- LN₂ boiloff test performed for heat leak approximation. The heat leak during this test was < 22 W.
- Cryostat with integrated cryocooler and heat exchanger built and in place
- Connecting hardware, instrumentation, and data-recording setup in-work
- Sourcing LNG