Development of cryogenic tanks using the Scaled Half-Tank Test

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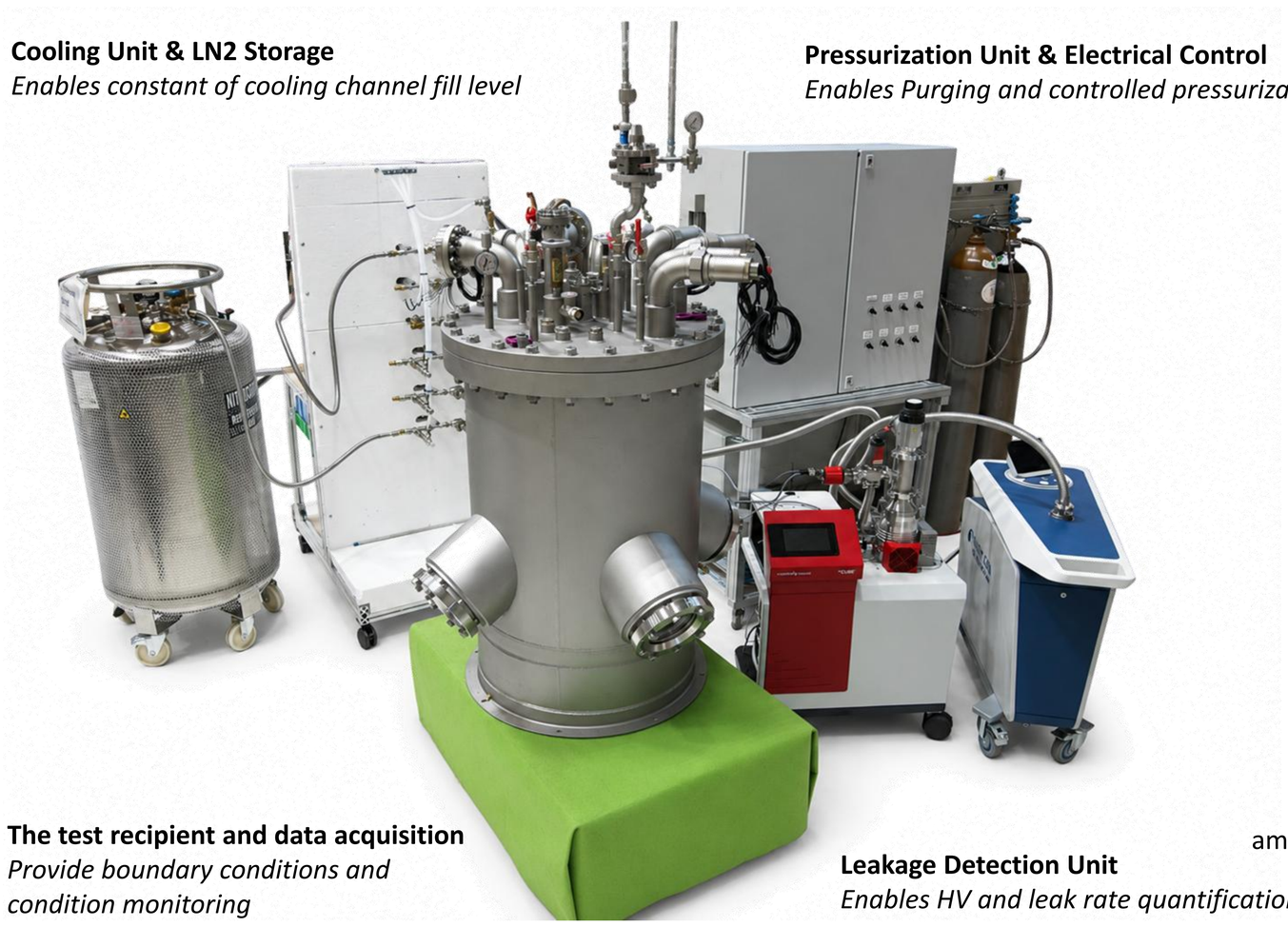

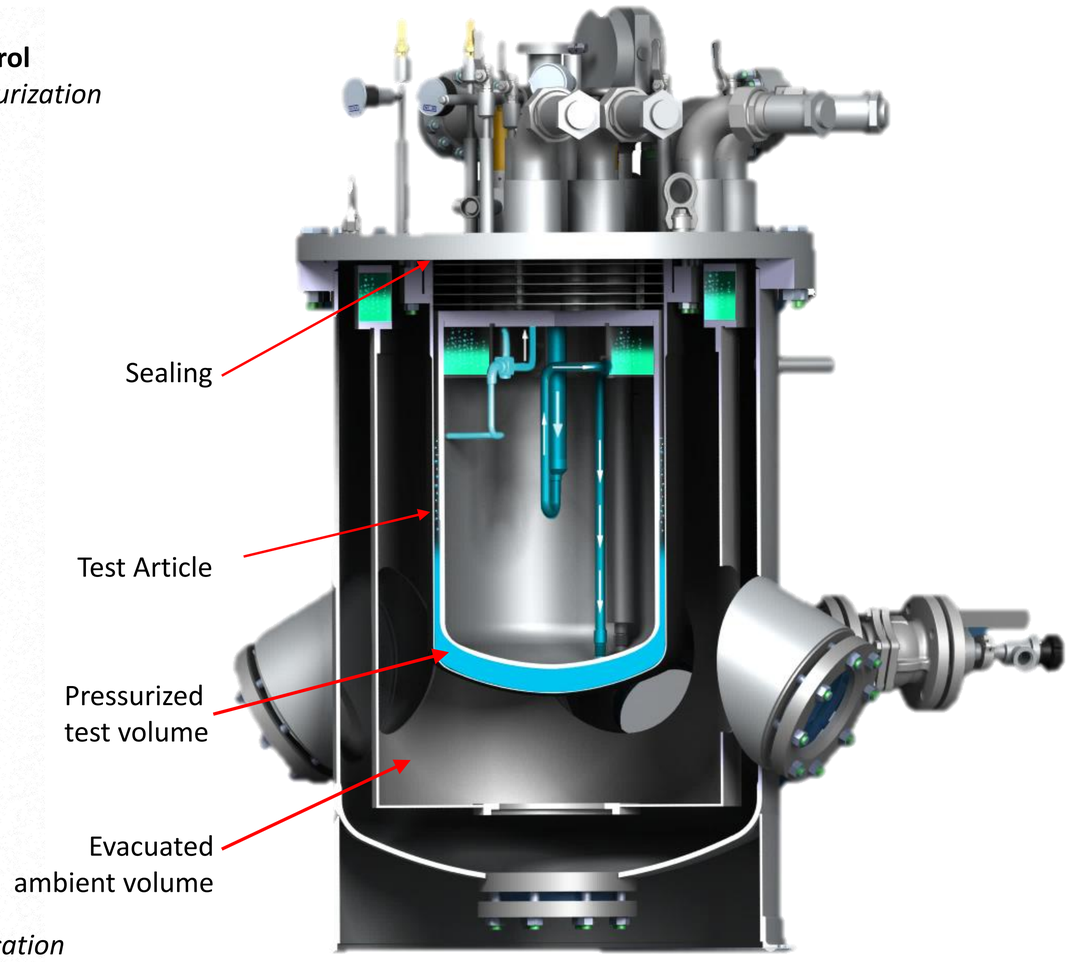

Figure 1: The Scaled Half-Tank Test is a mobile test setup designed to investigate cryogenic tank structures under various conditions. It consists of a central recipient that maintains the test environment, supported by multiple subsystems and interfaces for fluid supply and instrumentation. (Left) Overview of the complete system; (Right) Cross-section of the central recipient.

Scaled size for effective testing

Developing cryogenic tank systems made of carbon fiber composites is challenging due to the strict requirement for leak-tightness. The 400 mm Half-Tank Test addresses the lack of intermediate validation between material testing and final component certification providing cost-effective development. The modular test setup allows for the integration of realistic system features, including structural connections and feedthroughs. It enables comprehensive characterization of permeability under realistic pressure, temperature, and fluid environments, providing data essential for validation of structural design under consideration of as-built manufacturing. Key Focus is on:

- Material development
- Manufacturing technologies
- Tank system integration & verification
- Validation of simulation capabilities

Test Methodology & System Assessment

The experimental protocol utilizes a representative specimen, either a full tank segment or a critical component, selected for its research relevance.

Testing employs a standardized procedure to establish controlled, stationary thermomechanical states across varying pressure and temperature ranges. At each state, the system-level leak rate is precisely quantified, providing an integral assessment of the entire tank assembly. Mapping these results across multiple conditions reveals the system's dependency on pressure and temperature, while abrupt increases in leakage serve as clear indicators of structural damage or progressive degradation. Additionally, integrated strain and temperature measurements enable a comprehensive correlation of thermomechanical performance under cryogenic operating conditions.

Bridging the Validation Gap

- **Intermediate Testing Scale**
  Systematic evaluation between material coupons and full-scale tank prototypes
- **Representative Geometry**
  400 mm half-tank specimen capturing critical load paths (dome, shoulder, cylinder)
- **Decoupled Load Control**
  Independent regulation of differential pressure up to 20 bar and thermal state down to 20 K
- **Multi-Modal Sensing**
  Integrated strain, temperature, pressure & leak rate monitoring to correlate thermomechanical state with permeation behavior
- **Component Integration Testing**
  Capable of testing tank systems including feed-throughs, fittings, structural connections, and insulation concepts

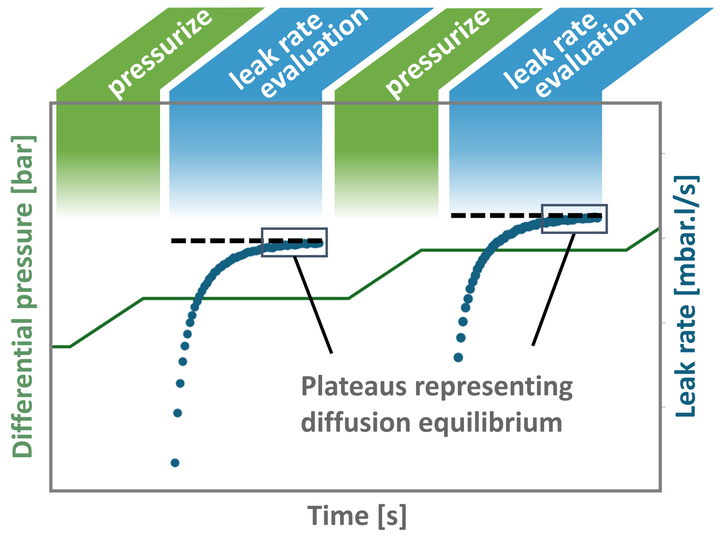

Figure 2: Schematic diagram of the leak rate evaluation for a half-tank system subjected to two sequential pressurization steps under constant temperature and fluid conditions.

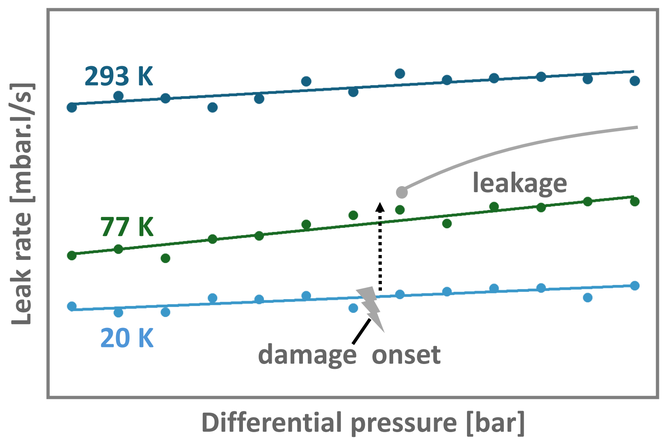

Figure 3: Schematic diagram of the expected leak rate evolution with respect to pressure and temperature, comparing leak-tight behavior (blue, green, light blue) with a scenario exhibiting leak formation (gray).

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