A Boiloff Calorimetry Test Configuration for the Characterization of Thermal Insulation Systems in Flammable Background Gasses

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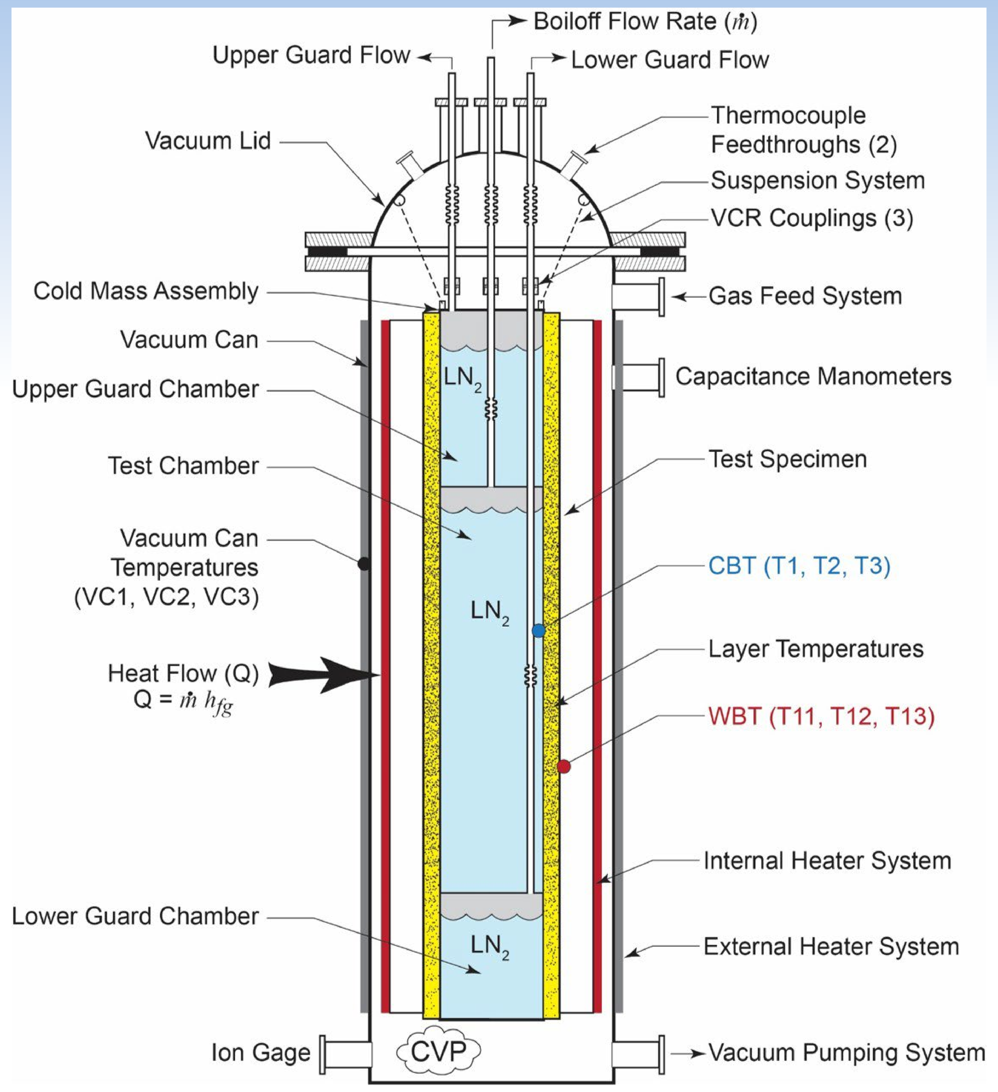
Background

- **Liquid hydrogen** (**LH_2**) for shipping terminals requires a massive scale-up in tank volume
  - Largest LH_2 tanks in the world exist at NASA-KSC: 3,200 m^3 and 4,700 m^3
  - Shipping terminals will require 50,000+ m^3, and perhaps greater than 100,000 m^3
- Vacuum-insulated LH_2 tanks will be **difficult or impossible** at very large scales
  - Non-vacuum tanks may require non-condensable background gas in the insulation space: **Helium** or **Hydrogen**
  - Need to understand the impact to insulation performance using hydrogen background gas
- Cryogenics Test Laboratory Cryostat-100 LN_2 boiloff calorimeter required modifications to test in **flammable background gasses**
  - ASTM C1774, Annex A.1 standardized test equipment/method
  - Most equipment could not conform to NFPA code

Cryostat-100 (CS-100)



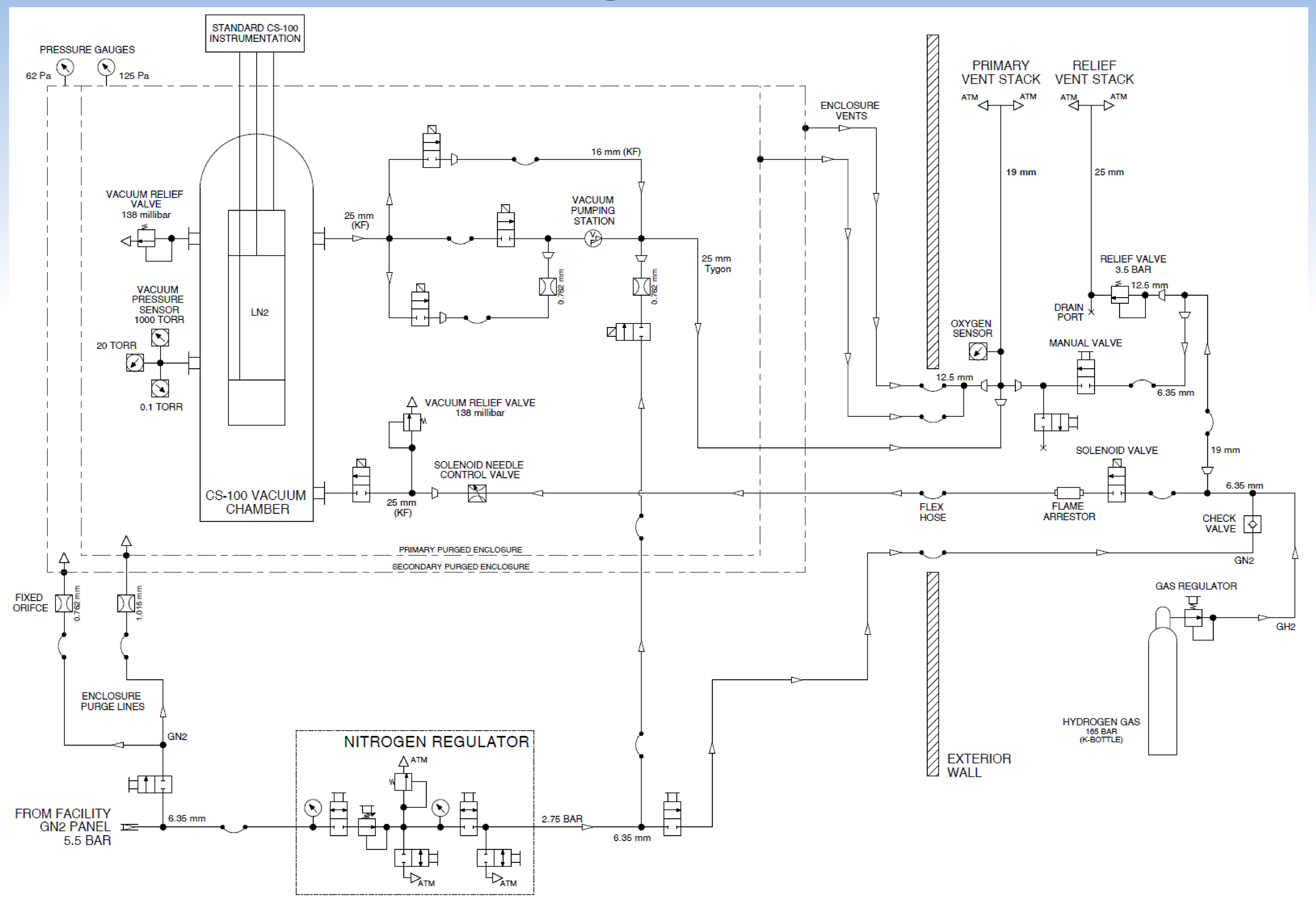
Design Considerations

- What modifications will minimize risk and comply with the codes and NASA standards to the greatest extent practical, yet still allow for semi-normal CS-100 operations?
  - Continuous nitrogen (GN_2) supply available, and penetration through the outer lab wall near CS-100 previously installed

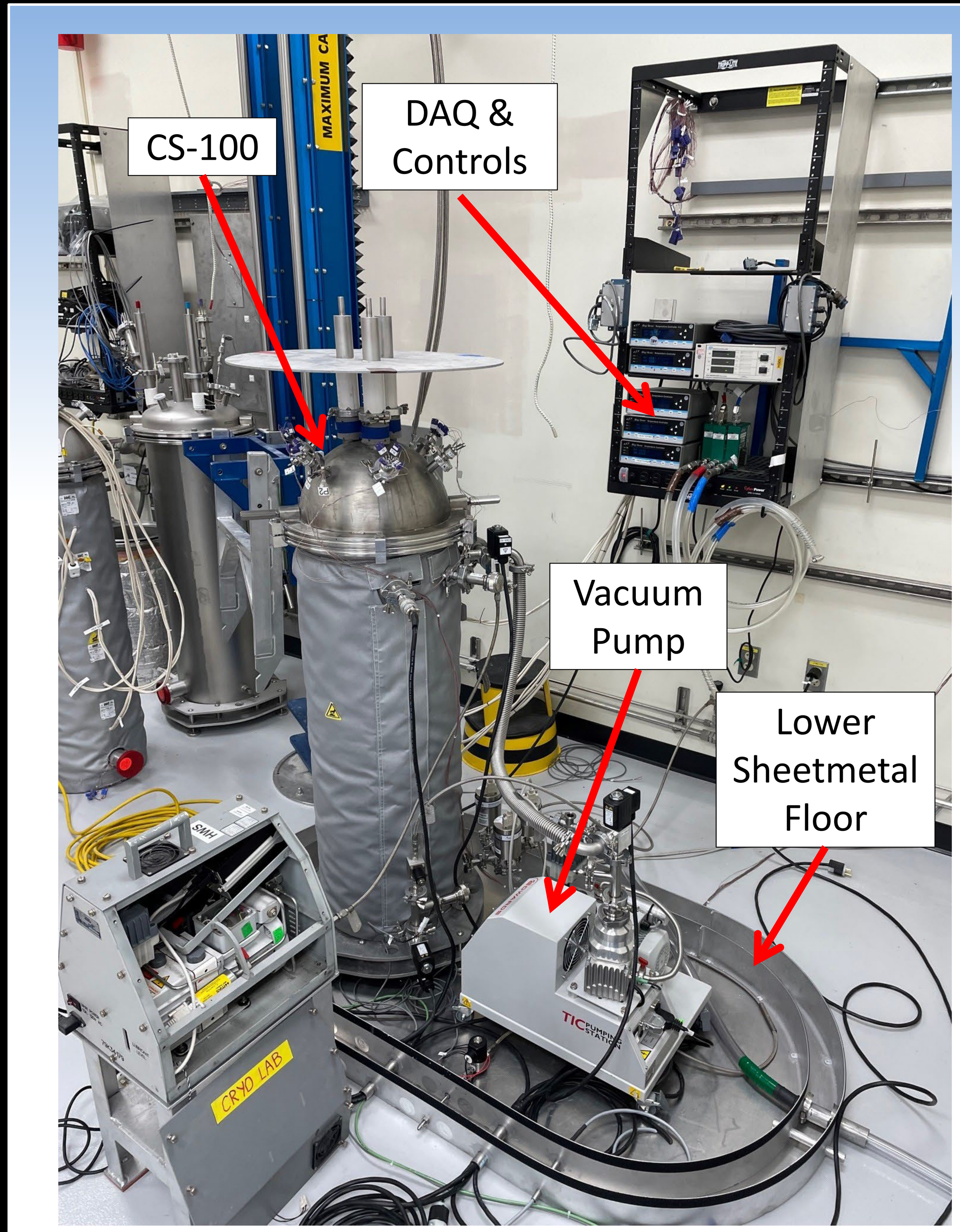
  ✓ Contain the CS-100 and most electrical hardware inside a nitrogen-purged enclosure with a captured vent

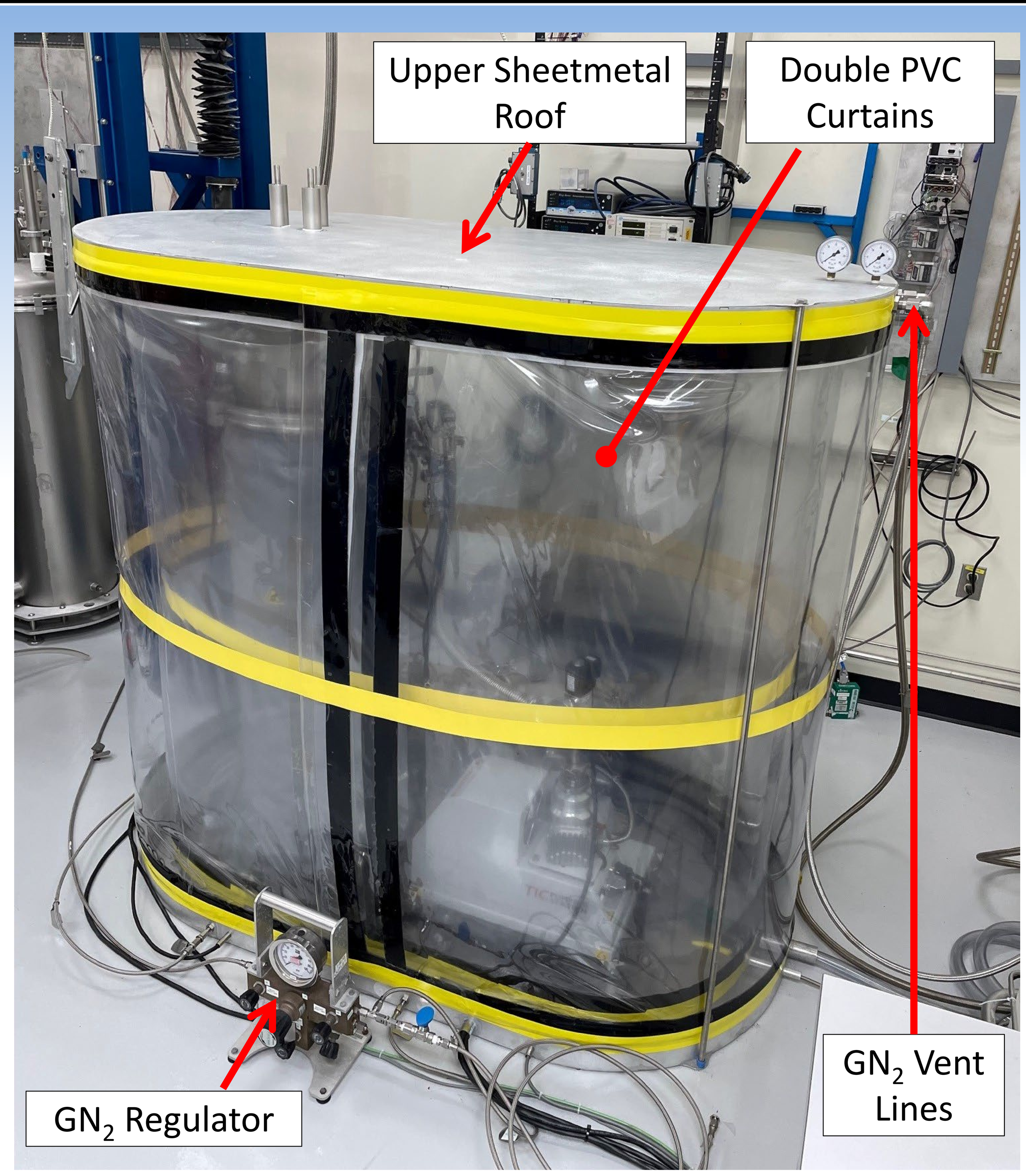
  ✓ Place GH_2 bottle and all other potential leak points outside the building
- Enclosure would comply with NFPA 496 Standard for Purged and Pressurized Enclosures for Electrical Equipment
  1. Enclosure shall be constantly maintained at a positive pressure of at least 25 Pa above the surrounding atmosphere during operation
  2. Failure to maintain positive pressure within a protected enclosure shall be communicated by an alarm or an indicator (gauge)
  3. Diluting an inert gas to reduce oxygen content in the enclosure to a level of not more than 5% by volume, or 50% of the minimum concentration of oxygen required to form a flammable mixture

Test Configuration P&ID



Final Test Configuration





- Sheetmetal floor and roof assemblies define enclosure boundary around CS-100 and equipment
- Inner and outer PVC curtains form walls of enclosure, secured to sheetmetal via hook-and-loop, and sealed with vinyl tape along edges
  - Redundant, independent purged enclosures in case of GH_2 leak
- Most valves were solenoid type, remotely operated using on/off switches; vacuum pump controlled through DAQ system
- GN_2 flow rates of 116 L/min and 65 L/min for inner and outer enclosures respectively
  - 10:1 ratio of nitrogen-to-hydrogen flow into the inner purged volume in the case of a leak.