

AIR
PRODUCTS



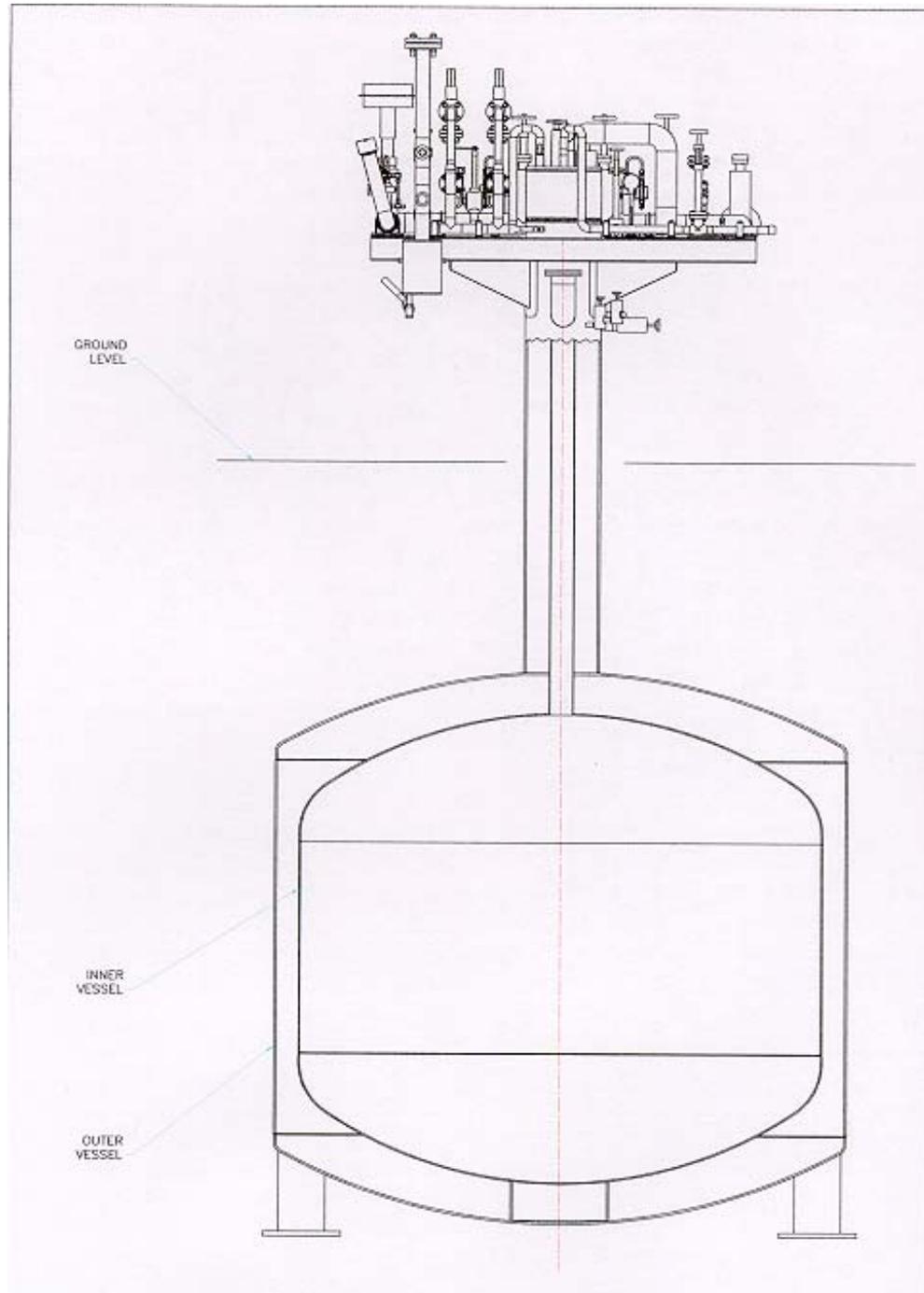
LIQUID HYDROGEN

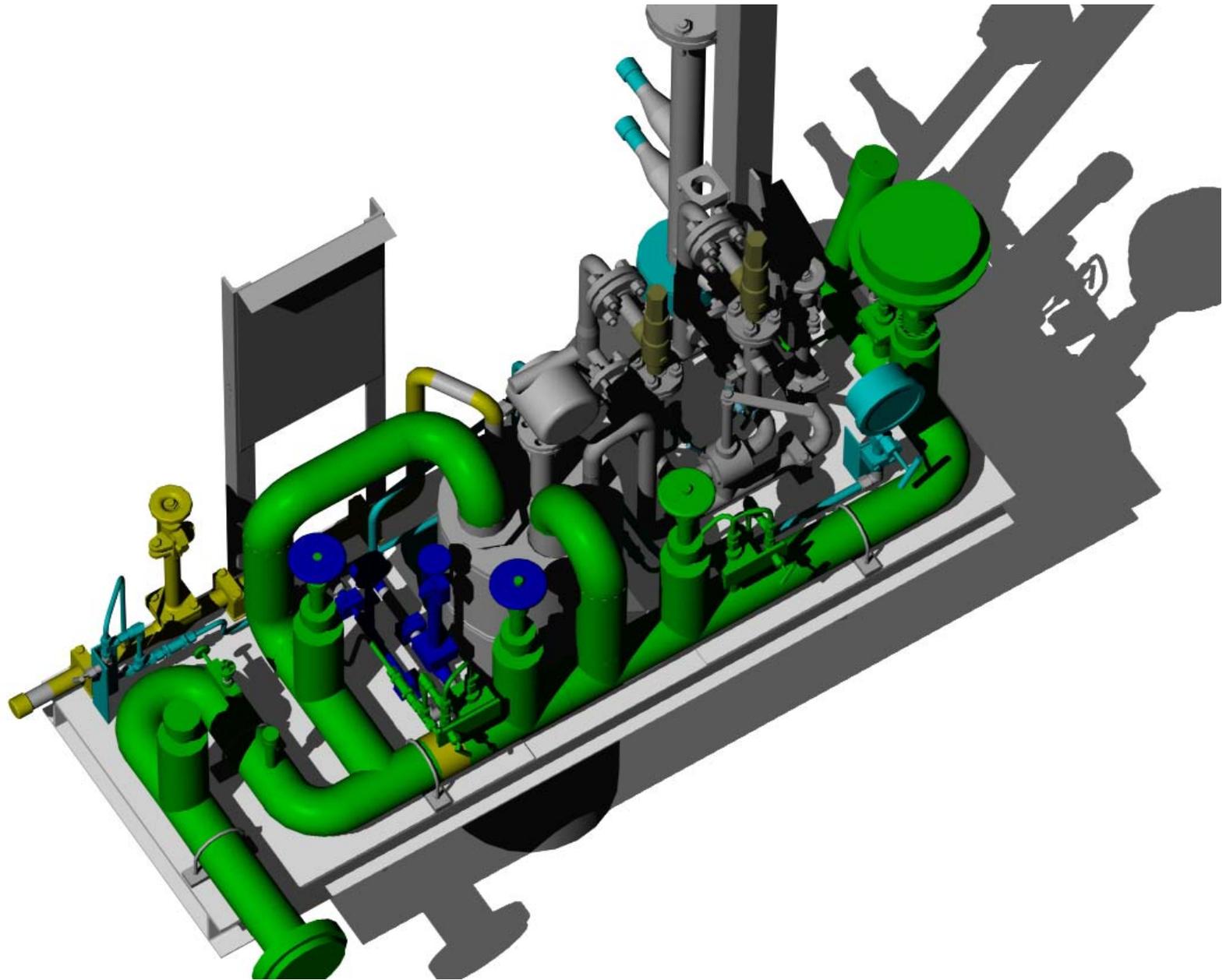
UNDERGROUND STORAGE

Fuel Cells Summit VII

May 28, 2003

Tom Joseph





LH2 UNDERGROUND STORAGE

● STORAGE CONDITIONS

- State: Cryogenic liquid
- Capacity: 1500 - 9000 gallons
- Temperature: -425 F
- Pressure: 80 – 170 psig

● TANK DESIGN

- Pressure and Vacuum
- Code: ASME Section VIII Div 1, CGA 341
- Material: Stainless Steel
- Safety: ASME devices
- Criteria: CGA S-1.3

● CONSTRUCTION

- ASME Inspections
- Cold shocking
- Helium leak detection
- Radiography

LH2 UNDERGROUND STORAGE

● INSULATION SYSTEM

- Boil off: 0.5%/day
- Super or Multi layer insulation
- Minimum heat leak
- All 3 modes are minimized
 - Conduction – support system
 - Convection – vacuum can
 - Radiation – multiple layers
- Piping as part of the system

● VACUUM JACKET

- Designed for pressure and vacuum: CGA 341
- Over pressure protection system
- Overall protection for the storage system
- Material: Stainless steel

LH2 UNDERGROUND STORAGE

- RELIEF SIZING CASES – eg. 1500 gallon tank
 - CGA S-1.3
 - External Fire (30% engulfed)
 - Loss of vacuum without fire
 - H₂ in annular space
 - Condensing air
 - Vapor generation during fill
 - Pumping systems
 - Pressure transfer systems
 - Liquid overfill case
 - Normal heat leak
 - 0.86 lbs/sec dropping to 0.1 lbs/sec in 200 secs
 - PRV & RD (all cases)

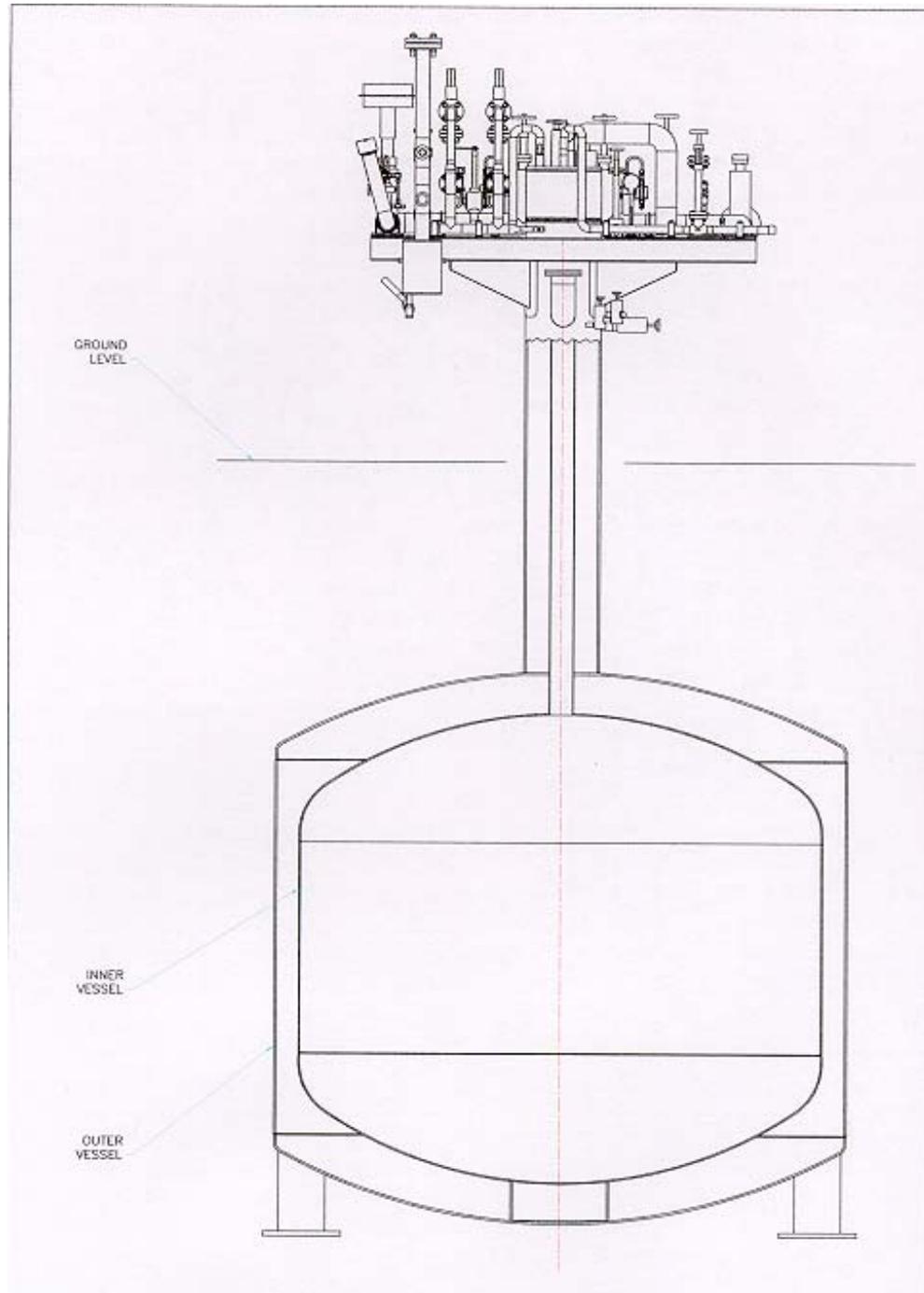
LH2 UNDERGROUND STORAGE

- **SAFETY FEATURES: eg. 1500 gallon tank**
 - Piping within the annular space
 - Over pressure protection CGA P-40 method
 - Low heat leak design
 - Vent system dispersion analysis
 - Stack design - heat flux at ground level
 - Protective coating for corrosion
 - Cathodic protection
 - Installation to prevent external freezing
 - In-ground anchoring
- **SAFETY RISK – VAULT DESIGN**
 - Water accumulation
 - Fuel accumulation
 - External fire risk
 - Confined space
 - Security risk

LH2 UNDERGROUND STORAGE

- **SITING DETAILS**
 - No direct standards
 - Similar to LNG
 - Both Cryogenic, Flammable
 - NFPA 57, 59A, 30 and 30A

- **CODE CHALLENGES**
 - **CGA for vacuum jacket and annular space design**
 - **CGA for underground cryogenic piping**
 - **CGA for relief sizing**
 - **NFPA/ICC for vacuum vessel protection**
 - **NFPA/ICC for underground installation**
 - **CGA/NFPA/ICC for vent piping**
 - **Main vent**
 - **Annular space vent**



Thank you

tell me more

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