



# Liquid Hydrogen Storage Technologies

23 February 2022



# Current State of the Art



- Vessel designed, fabricated, and constructed by CB&I at LC39B at Kennedy Space Center
- Net Capacity of 1.25 million gallons (4,732 m<sup>3</sup>)
- Max. Boiloff rate < 0.05% per day
- Employs two new storage technologies developed by NASA that provide large-scale liquid hydrogen storage and control capability





# New Technologies



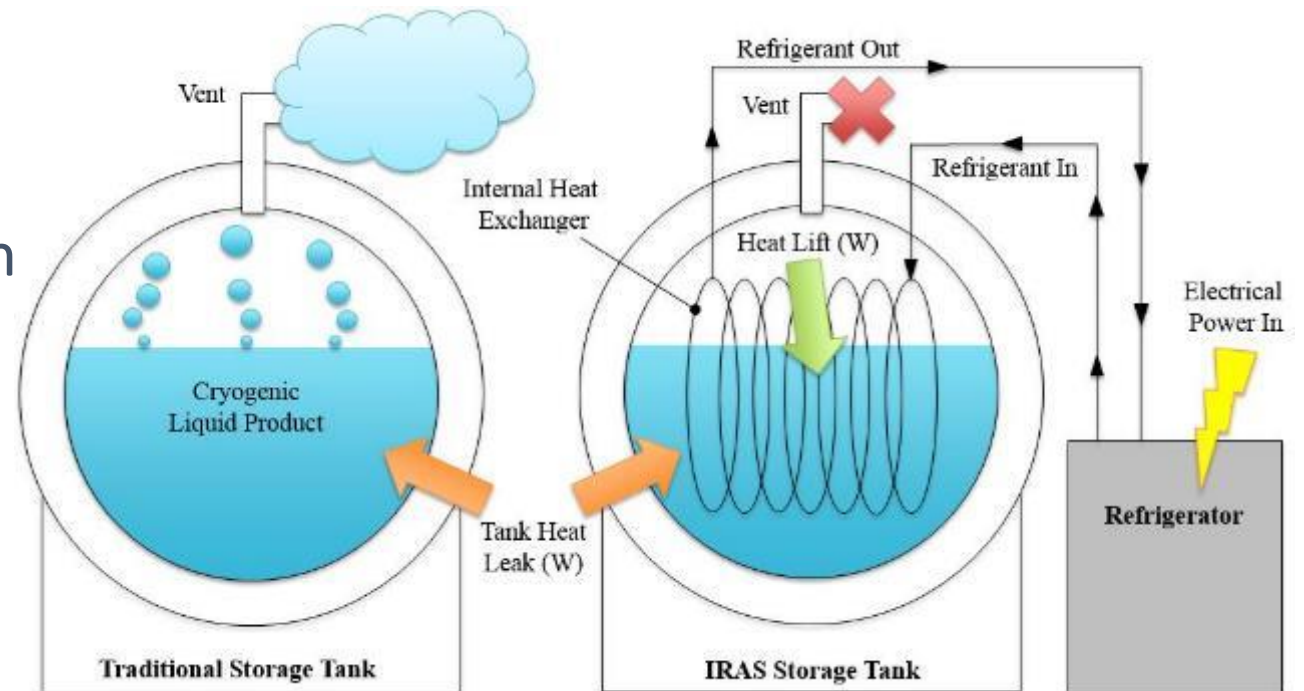
- Glass Bubble Thermal Insulation System (Evacuated)
- Integrated Refrigeration and Storage (IRAS)



# IRAS Heat Exchanger



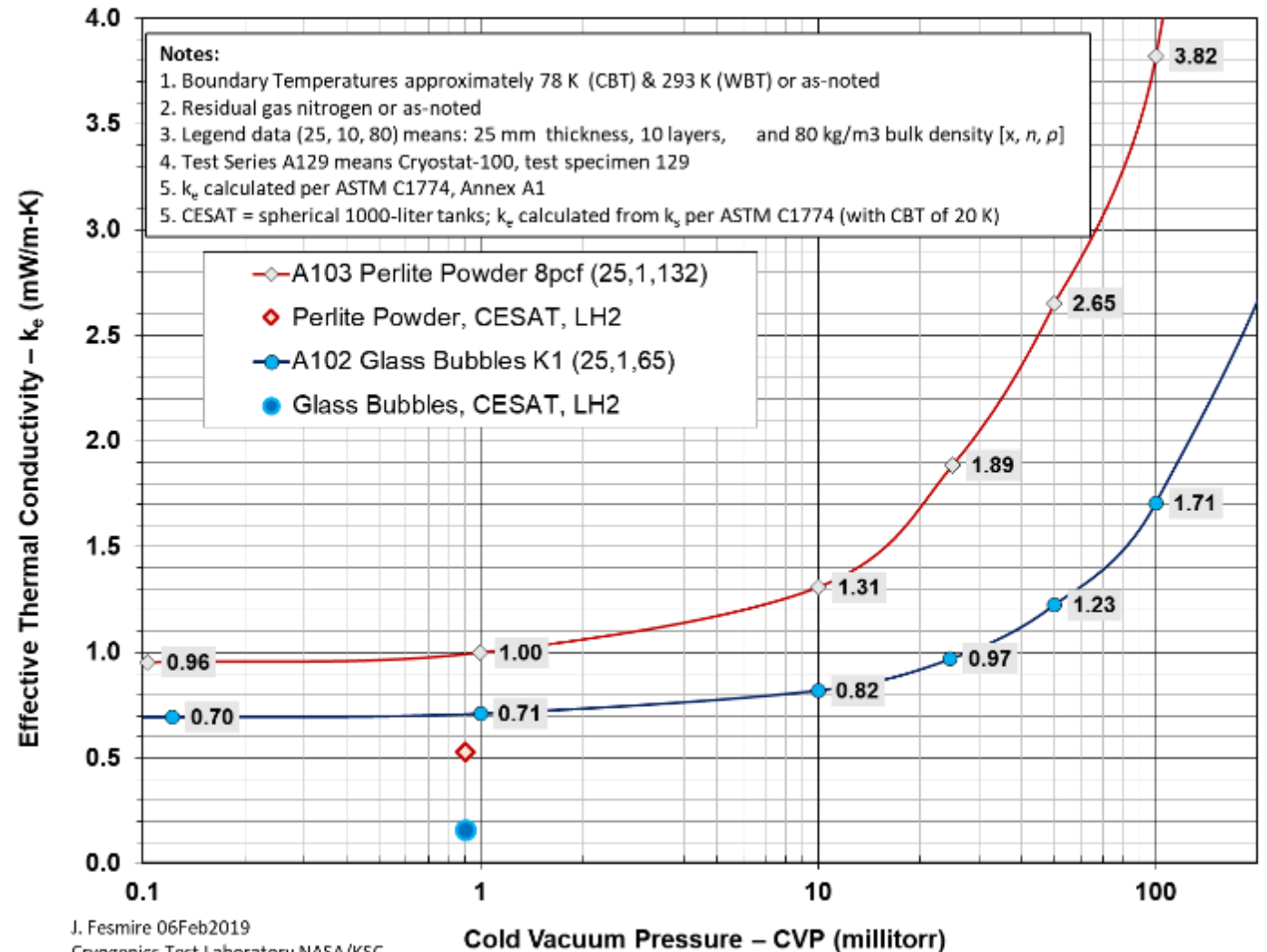
- Developed by NASA
- Provides active thermal control by taking up heat through an internal heat exchanger
- Helium refrigerant will be fed through 43m of stainless steel coils located at the 25% and 75% fill levels



# Glass Bubbles Insulation System



- The vessel annular space is filled with 3M's K1 glass bubbles
- Glass bubbles are predicted to show a 40-100% better performance compared to perlite
- Field testing with a 190-m<sup>3</sup> (50,000-gal) VJ LH<sub>2</sub> sphere at Stennis Space Center gave an average boiloff reduction of 46% over three thermal cycles in six years



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Cryogenics Test Laboratory NASA/KSC

\*Fesmire, J, Swanger, A, Jacobson A, Notardonato "Energy Efficient Large-Scale Storage of Liquid Hydrogen, 2021 Cryogenic Engineering Conference and International Cryogenic Materials Conference (CEC-ICMC)

# Advancing the State of the Art – 40,000 M<sup>3</sup> LH<sub>2</sub>



**Offering**

40,000 m<sup>3</sup> liquid hydrogen storage

**Storage System**

Double wall vacuum insulated storage sphere

**Ready for Market**

CB&I's basic design and constructability study is complete for our 40,000 m<sup>3</sup> storage sphere. CB&I also offers:

- Boil off gas handling solutions
- Send out systems such as truck loading
- Please discuss needs for larger capacity with CB&I for the best overall storage solution

## Storage Technology

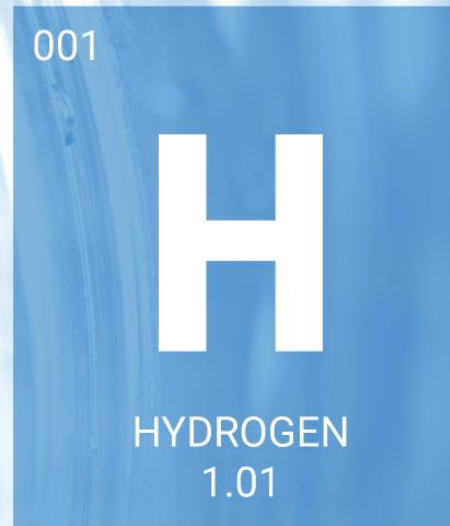
- Liquid hydrogen stored at -253°C (-423 °F)
- Vacuum insulated annular space made possible at large scale with proprietary design and construction innovations
- Optional glass bubble bulk fill insulation instead of perlite to reduce boil-off
- Optional integrated refrigeration and storage heat exchanger to keep hydrogen liquefied and minimize boil-off



# Scaling Beyond 40,000m<sup>3</sup>



**Shell-led Consortium Selected by  
Department of Energy to Demonstrate  
Feasibility of Large-Scale Liquid  
Hydrogen Storage**



**CB&I**  
STORAGE  
SOLUTIONS

**GENItz**  
DISCOVER HYDROGEN



# CB&I Snapshot 2022 – Liquid H2 Storage



- CB&I can now offer 40,000 m3 LH2
- Developing up to 100,000 m3 under a US DOE H2@Scale funded study
  - Shell, CB&I, NASA, GenH2, and University of Houston
  - 2021 - 2024

## DOE H2@Scale

100,000m3  
*future capacity*

Industry partners to develop feasible materials

Next generation insulation systems

Remove requirement for vacuum annular space

Build demonstration vessel to prove the technology

This is the target of our Shell/NASA/DOE project

