Experiences and Lessons Learned with Liquid Hydrogen

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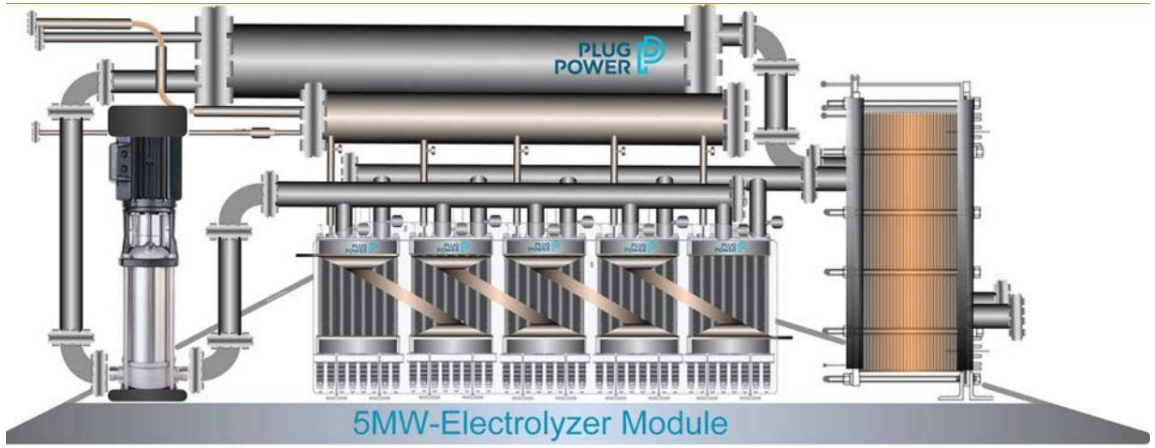
Liquid Hydrogen Workshop

Liquid Hydrogen Handling

- Production
- Storage
- Pumping
- Distribution



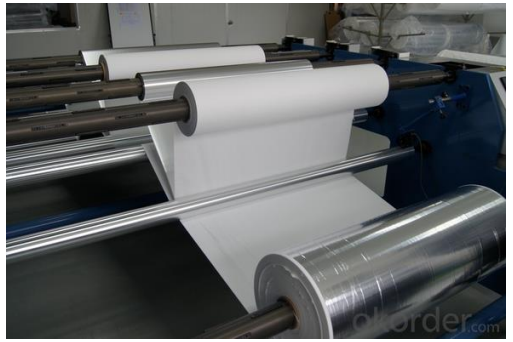
Liquid Hydrogen Production

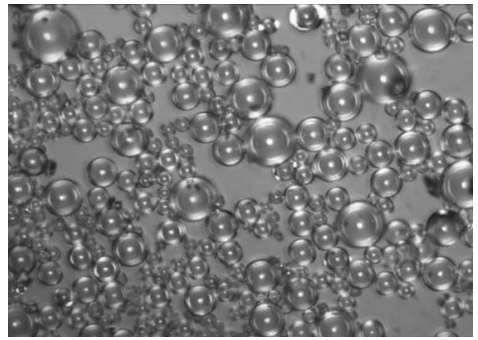
- **Selection of Precooling and Refrigeration Cycles**
  - **Reducing SEC and TCO are the ultimate objectives**
- **Hydrogen contains impurities when produced**
  - **Remove Moisture and CO_2 - winter can be a problem**
  - **Remove O_2, N_2, and Ar - N_2 Purging in the Production System can be a problem, air gases can come from blowdown**
- **o-p Catalyst loading in the heat exchanger**
  - **Better than doing it in beds outside the heat exchanger, but arrangements can be very challenging.**
- **Vendor Selection is Critical**

Liquid Hydrogen Storage

- **Tanks**
  - **Cylinder**
    - **Horizontal**
    - **Vertical**
  - **Spheres**
- **Insulation**
  - **Multi-layer VJ**
  - **Glass beads**
- **Material of Construction (316L vs 304L**
- **System Losses**
  - **Normal Evaporation Rate (NER)**
  - **Losses during various pumping operations**
  - **Transfer line heat loss**
  - **Blowdown losses**

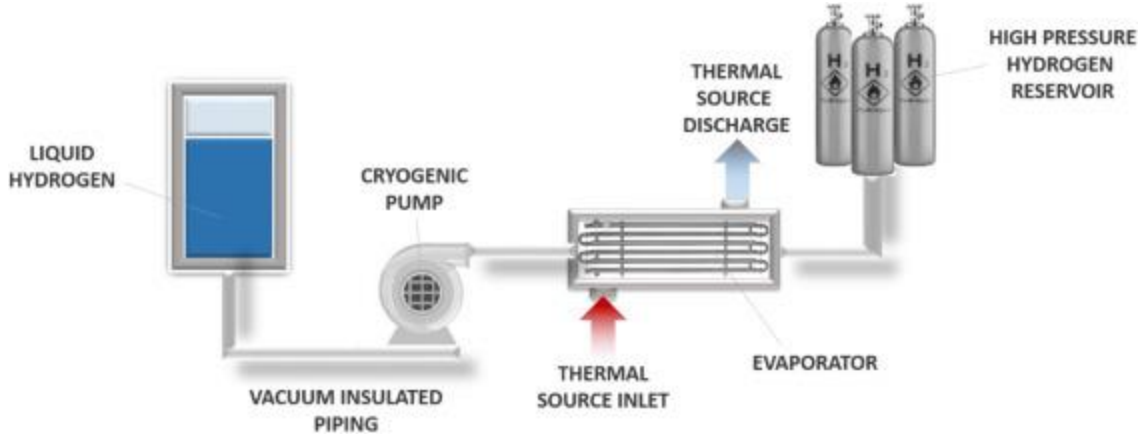
  Pump cooling losses
    - **When and Why?**
  - **Valve losses**
    - **Cooling**
      - **When and Why?**
    - **Leaking**
      - **When and Why?**





Liquid Hydrogen Pumping

- **Pump to vaporize**
  - **Vendors**
  - **Challenges**
  - **State-of-the Art**
  - **Vaporizers**
    - **Challenges**
  - **Thermal losses**
  - **Subcooling**
    - **Only way to avoid hydrogen venting**
  - **J-T Effect**
    - **Critical temperature**
    - **O-P equilibrium and conversation rate**
- **Liquid pumping**
  - **Vendors**
  - **Challenges**
  - **State-of-the Art**
  - **Thermal losses**
  - **Flashing**



Liquid Hydrogen Distribution

- **Liquid Tank Trailers**
  - **Vendors**
  - **Challenges**
  - **State-of-the Art**
  - **Road Safety**
  - **DOT**
  - **ASME**
  - **Normal Evaporation Rate(NER)**
  - **Maximum Rated Holding Time (MRHT)**
  - **One way travel time (OWTT)**

Thank You!
Let us discus!

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