



**GARDNER
CRYOGENICS**

Current Practices to Transfer and Deliver Liquid Hydrogen

**Day 2: Liquid Hydrogen Storage
and Handling Infrastructure:
Current Status and RD&D Needs**



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Workshop Agenda

- Introduction / Gardner History
- Current technology and practice to Storage and Deliver Hydrogen
 - Static and Transportable storage
- Distribution options and methods

History

1960

Gardner Cryogenics
Founded



1973

First 41,640 L (11,000 gal)
ISO Container

1972

First Portable
Customer Station

1982

First Liquid
Helium/Hydrogen
UN Portable Tanks

1981

Gardner purchased
by Air Products



1995

First 64,352 L (17,000 gal)
Hydrogen Semitrailers
for the U.S.



1992

ISO 9001 Certification
Accreditation

1996

OSHA Voluntary Protection
Program "Star Site"



2019

Introduction of Smartfuel®
Product for Liquid Hydrogen
Storage and Transportation



Liquid Hydrogen History and Gardner LHY Product

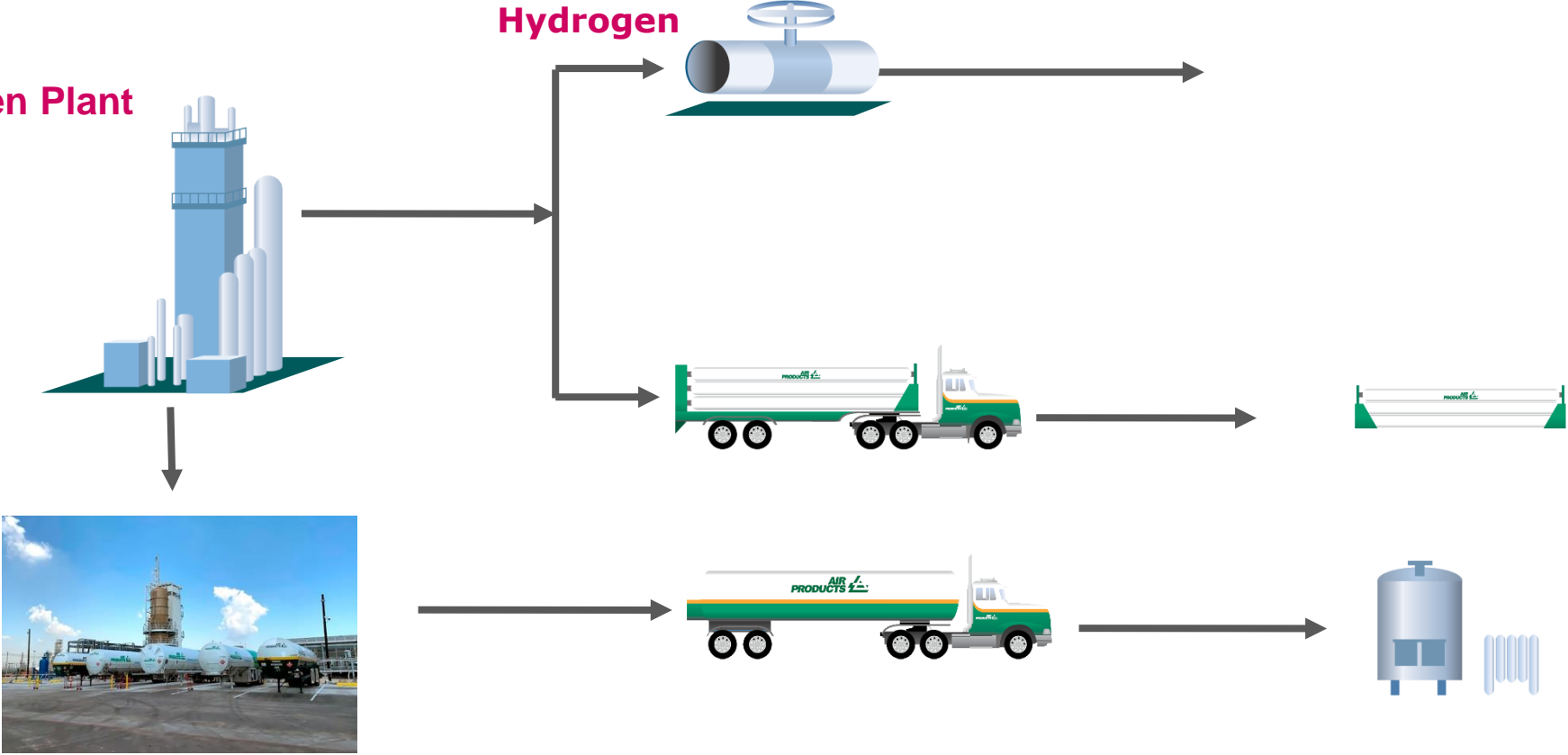
- Hydrogen Production started in 1950's to address hydrogen for Space Program
- Commercial use started in 1960's
 - Delivery mode
 - ◆ Liquid trailers up to 4400 kg
 - ◆ Gas trailer about 1000-1200 kg
 - Significant experience in North America and Europe delivering hydrogen
- Systems were sited and built per NFPA 55 (and NFPA 2)
- Transportation equipment meets county specific regulation, for US DOT requirements
- **Gardner Liquid Product.**
 - ISO Containers LIN shielded: 11,000 161 psi/ 30 days
 - Static tank up to 33,000 gal
 - Semitrailer up to 18,100 gallon
 - Dual Phase up to 14,000 gallon
 - Portable Road transportation : Up to 15,000 Gallon.

Hydrogen Sourcing

Distribution

Delivery Station

- Hydrogen Plant



Hydrogen Liquefaction

Liquid Hydrogen Delivery Options



**Semi
Trailer**



**Portable
Tank**



SWAP/ISO

Liquid Hydrogen Storage Option



Horizontal – LIN Shield

- ✓ Up to 33,000-gallon, Thermal Shielded
- ✓ Support storage of LHY for long duration
- ✓ 30+ year of experience, non permit load
- ✓ Low heat concept and high performance



Static Tank

- ✓ Up to 25,000 Gallon and up to 175 psi
- ✓ Horizontal and *Vertical tank**
- ✓ Used for mobility market and industrial application
- ✓ 25+ year of experience

* Photo represent horizontal tank

LIN Shielded ISO



- ✓ 11,000-gallon, 40 ft, stable containerized Dewar
- ✓ Approx. 2.6 ton pay load
- ✓ UN Portable Tank, for shipment via land and ocean.
- ✓ 25+ year of experience
- ✓ LIN tank to carrying refrigerant for 30 days

Portable Tank: latest Innovation



- ✓ This size was specially built for US market
- ✓ 10,000-gallon, 30 ft ISO frame for road transportation
- ✓ Approx. 2.4 ton pay load and shorter length for HRS locations
- ✓ UN Portable code basis, plus DOT-Special Permit
- ✓ low venting concept .

Dual Phase



- ✓ Up to 15,000 Gallon, 45 ft, trailer
- ✓ Approx. 3.4 ton pay load
- ✓ TPED /DOT for gas (3000 and 8000 psi) & liquid delivery.
- ✓ High flow vaporizer, 10K pump with electric or hydraulic drive
- ✓ 15+ year experience

Semi Trailer



- ✓ Up to 18,100-gallon.
- ✓ Approx. 4.4 ton pay load
- ✓ Semi Trailer design
- ✓ 30+ year experience
- ✓ For shipment of molecule from LHY plant to customer site

Delivery Safeguards

- Standard Industrial Safeguards
 - Anti-pullaway, chocks, etc
 - Industrial Emergency Shutdown
 - ◆ Automatic Valve on Trailer, Check Valve on Tank
 - ◆ Manually operated trailer pneumatic shutdown
- Retail Stations
 - Automatic Valve on Trailer, Automatic Valve on Tank
 - Interlocked with stationary fuel station pneumatic shutdown
 - ◆ Station alarms also stop fill
 - ◆ Additional emergency stops, both auto/manual
 - ◆ Flame detection
 - ◆ Gas detection tethered to back of trailer
 - ◆ Pneumatic line provides additional fire/pullaway protection
- Automated fill control from station and process shutdown

Wrap up: LH2 distribution

- More than 5 decades of LH2 transportation experience
- Vacuum technology, MLI and thermal shielding allows for minimizing boil off
- Thermal Shielding Technology provides longer hold time enabling LH2 to be transported internationally
- Codes and Standard for industrial application well established in NA, Europe and Japan, Need enhancement for regulation and siting requirement for mobility market, (HRS)
- Lower pressure storage and large pay load provides better distribution economics
- Excellent safety record
- Some Concern
 - Separation Distances
 - LH2 not as well known or understood globally
 - Delivery concerns such as potential leaks/spills



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THANK YOU

