



# Liquid Hydrogen Technologies Workshop

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# Space Shuttle External Tank

Approximately 385,000 gallons  
of liquid hydrogen



# LIQUID HYDROGEN STORAGE SPHERE







# STANDARD PRACTICES

## OSHA 1910.119

Process safety management of highly hazardous chemicals

- Maintain helium blanket purges in stand-by configuration
- Extensive training and certifications for operators
- Limit personnel during haz ops
- Wear PPE during haz ops (flame retardant coveralls, cryo gloves, face shields, non-porous footwear, etc.)
- Pre-planned procedures documented for off-nominal scenarios (isolate, vent, purge)

## NFPA 497

Recommended practice for the classification of flammable liquids, gases, or vapors and of hazardous (classified) locations for electrical installations in chemical process areas



## AIAA/ANSI G-095A-2017

Guide to safety of hydrogen and hydrogen systems

- Verify <1% oxygen in lines prior to flow
- Ground all hardware
- For flow operations, flare vent gas
- Flow-through and pulse purge with helium post flow
- Verify <1% hydrogen in lines post flow





# LH2 TANKER OFFLOAD

- Verify certification of purity
- Offload a maximum of 5 tankers at a time
- Install VJ flexhoses for transfer between tanker and pad system
- Monitor mechanical connections for icing – leakage
- Maintain cognizance of liquid air forming on and dripping from uninsulated surfaces







# LH2 SYSTEM LEAK CHECK & SAMPLING

- Part of the annual system maintenance plan
- Utilize the main vaporizer to pressurize the storage tank
- Leak check the system for hydrogen leakage
- Obtain a sample of liquid hydrogen from the bottom of the storage tank and send for purity analysis in the lab
- Utilize the auxiliary vaporizer to pressurize the storage tank
- Leak check the auxiliary lines for hydrogen leakage





# ET LH2 LOADING

- Open manual block valves, evacuate the pad
- Initiate unpressurized **CHILLDOWN** by venting system and opening fill valves
- **SLOWFILL** to 5% using chilldown valve
- **FASTFILL** to 85% by opening main transfer line valve
- Lower flowrate for **REDUCED FASTFILL** to 98% by reducing storage tank pressure and partially restricting flow path
- **TOPPING** to 100% through chilldown valve
- Maintain 100% fill level using a modulating valve during **REPLENISH**

~2.5 - 3 hours



Automated operations  
Monitor for anomalies  
Execute pre-planned procedures





# LH2 TANKER FILL



[U.S. Congressional Record, Dec. 5, 2006](#)  
*"NASA's generous actions allowed for the continued, albeit reduced, supply of liquid hydrogen to most commercial customers across the United States and prevented the shutdown of numerous manufacturing facilities and commensurate job losses throughout the nation."*

- August 2005, Hurricane Katrina caused significant damage to KSC's LH2 supplier, Air Products
- Plant damage resulted in a critical national shortage of LH2
- NASA transferred ~660,000 gallons back to Air Products to support national needs
- Limited to fill of a single tanker at a time due to local venting
- Remotely pressurized the storage tank
- Reversed flow from the fill line in order to drain the storage tank to fill each tanker



## LH2 TANK DRAIN

- January 2010 – dozens of tanker loads of hydrogen drained from Pad B tank and transferred to Pad A LH2 tank prior to STS-130 loading
- August/September 2011 – dozens of tanker loads of hydrogen drained from Pad A tank and transferred to other government users
- Residual hydrogen was burned through the flare system in both cases



An aerial photograph of a space shuttle on the launch pad at a spaceport. The shuttle is white with orange external tank and boosters. It is surrounded by complex metal scaffolding and support structures. In the background, another shuttle is visible on a different launch pad. The landscape is green with some water bodies. The word "QUESTIONS?" is written in large white letters across the center of the image.

QUESTIONS?