ELVHYS project

Procedures for LH_2 transfer from trailer to a stationary storage tank

Air Liquide

ELVHYS Workshop #3 - 2024.06.07

Athens - NCSRD

Co-funded by the European Union

Clean Hydrogen Partnership

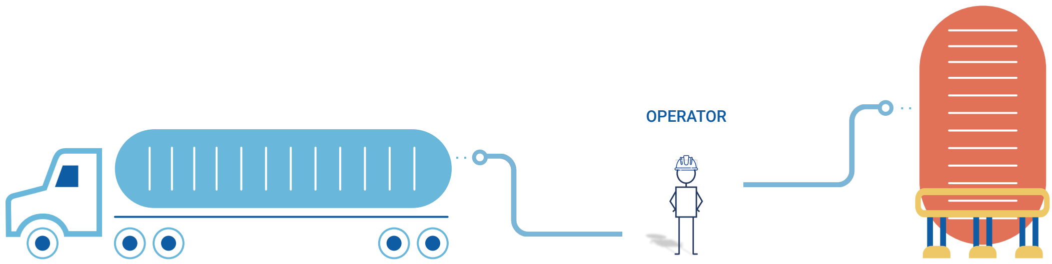
UK Research and Innovation

Introduction

Introduction

- **Topic**
  - Procedures for LH_2 transfer from trailer to a stationary tank
- **Described procedures**
  - Based on Air Liquide information
  - Potentially some deviations regarding to the company

CONVENTIONAL LH_2 delivery for STATIONARY tank



LIQUID TRAILER | HOSES | LIQUID STORAGE

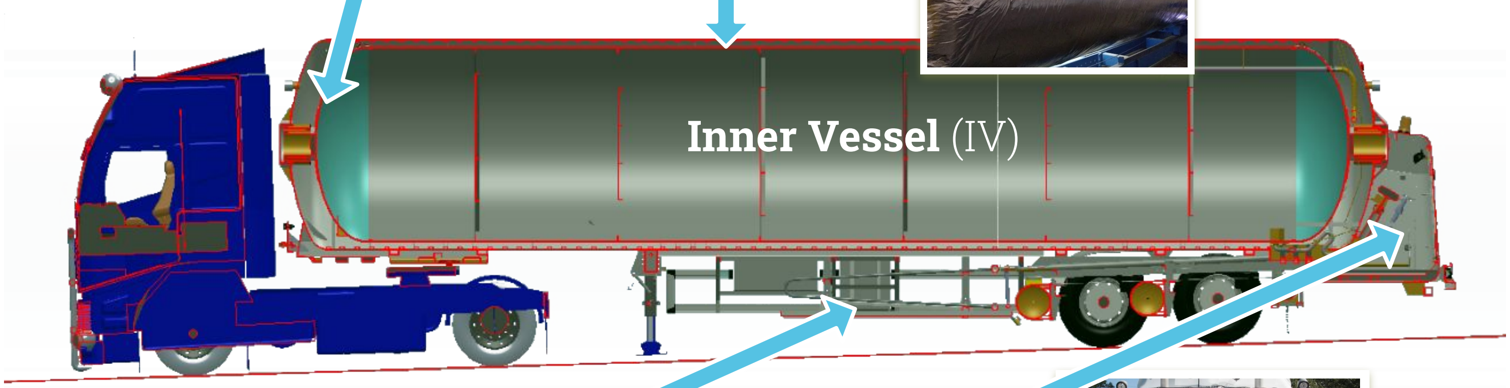
About LH_2 trailer and stationary tank

The LH_2 trailer - the “mother storage”

Main parts and functions

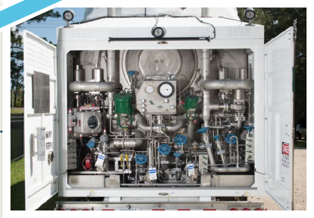
Outer Jacket (OJ)

Super Insulation (MLI) on **IV & Vacuum** between **IV and OJ**



Pressure Build-Up (PBU)

Control Cabinet



LH_2 stationary tank - the "daughter storage"

AL technical specifications

Horizontal liquid hydrogen tanks

- 20 to 75 m³
- 9.9 to 12 barg
- LH_2 capacity up to 4 tons

Vertical liquid hydrogen tanks

- 44 to 75 m³
- 9.9 to 12 barg
- LH_2 capacity up to 4 tons

Technical specifications

Technical specifications	**Horizontal storage*** *RH20 - 143 PSIG / 9.9 BARG (up to 12 barg with PED)*	**Vertical storage*** *C56 - 143 PSIG / 9.9 BARG (up to 12 barg with PED)*
Range of products	From 20 up to 75 KL (gross tank capacity) for vertical storage and equivalent for horizontal storage	
Total gross tank capacity @ ambient temperature (US Gal / liters)	5,051 / 19,121	14,754 / 55,850
Total net tank capacity @ cold temperature (US Gal / liters)	5,005 / 18,948	13,160 / 49,816
Ullage volume (%)	10	10
LH_2 payload (lbs/ kg) (LH_2 density @ 101 325 Pa)	2,734 / 1,240	7,776 / 3,527
Maximum Allowable Working Pressure (MAWP) (psig / barg)	143 / 9.9 (up to 12 barg with PED)	143 / 9.9 (up to 12 barg with PED)
Normal Evaporation Rate (NER)	< 1% per day	< 0.9% per day
Length (inches / m)	220 / 5.59	147 / 3.73
Width (inches / m)	132 / 3.35	154 / 3.91
Height (inches / m)	119 / 3.02	579 / 14.70
Estimated tare weight (lbs / kg)	22,267 / 10,100	47,180 / 21,400
Design temperature (°F / °C)	-423 °F to +212 °F / -253 °C to +100 °C	
Design code	ASME Section VIII Division 1 / PED Europe Pressure Equipment Directive / Korea Gas Safety certification	

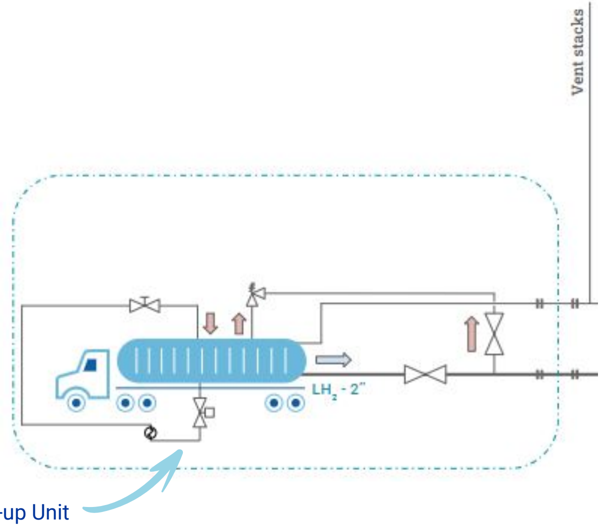
** Datas given for indicative purpose only.*

Perlite

Principle of LH_2 transfer

LH_2 stationary storage tank filling
Principle

- **For transferring LH_2 from the LH_2 trailer to a LH_2 stationary storage tank the main method is the pressure build-up**
  - This method is widely used in the industrial gas industry
- **Pressure build-up is "natural" or a voluntary vaporization of LH_2 via a small external heat exchanger (PBU)**
- **Hence, for LH_2 transferring from the LH_2 trailer**
  - the pressure in the "mother storage" - i.e. the LH_2 trailer - is higher than the pressure in the "daughter storage" - i.e. the LH_2 stationary storage tank
  - LH_2 transfer - driven by the pressure difference - is easy
- **The main drawbacks of this method are**
  - a long operating time
  - and an increase of the pressure in the LH_2 trailer leading sometime to the need of a voluntary and controlled pressure venting
- *Pumping in the "mother storage" using an appropriate transfer centrifugal cryogenic pump is possible, but not yet used for LH_2*



Pressure Build-up Unit (PBU) to pressurize LH_2 in the trailer

LH_2 transfer procedures

In detail, Step-by-Step

Conventional LH_2 unloading/transfer

Main steps

Trailer arrival

Trailer departure

Trailer connections → Hose Prefill → Delivery Pressure Management → Transfilling → Pressure Management → Post Fill before disconnection → Trailer venting

SET
- 1 - Grounding
- 2 - Connect Lines
- 3 - Inert Lines
- 4 - Condition Lines

FUEL
- 5 - Pressurize Source
- 6 - Transfer LH_2
- 7 - Receiver EOF* Detect

CLOSE
- 8 - Depressurize Source
- 9 - Warm-up Lines
- 10 - Inert Lines
- 11 - Disconnect

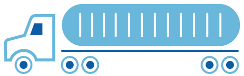
LH_2 transfer

A few additional data

LH_2 transfer

Generic characteristics

Trailer filling



- **Loading of a trailer**
  - Filling center: 8 000 to 10 000 $L.h^{-1}$
    depends on the initial conditions:
    - trailer temperature, level of residual H_2
  - Gravity-based filling
    e.g. 37 m^3 filling in 2h (1 $t.h^{-1}$)
- **Unloading at the customer**
  - 50 $kg.min^{-1}$
    ΔP-based filling

Stationary tank

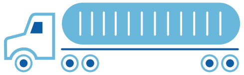
- **Process**
  - Temperature = 20 to 24 K
  - Pressure = 1 to 10 bara
- **Characteristics**
  - Time: ~ 2 ½ hrs (½ + 1 + ¾)
  - Mass flow: Up to 2 $t.h^{-1}$
  - Losses: could be 5%

About safety

Examples of safety features for LH_2 trailers & stationary storage tanks

LH_2 trailers

What	Where	For what
Two safety valves with at least one pneumatics	Tank	According to ADR, during transportation all storage are isolated by a valve
Road safety valve	Tank	Evacuate overpressure
Rupture disc	Tank	Avoid burst of the storage in case of pressure increase
PRD	Tank	Limit the risk of boil-off



LH_2 stationary tanks

What	Where	For what
Pressure and temperature monitoring	Tank	Detect insulation default
Level monitoring	Tank	Avoid overfilling
Rupture disc	Tank	Avoid burst of the storage in case of pressure increase
PRD	Tank	Limit the risk of boil-off

LH_2 transfer

Additional safety considerations & Potential improvements

Conventional LH_2 unloading/transfer

Remarks

- **Slight changes can appear depending on the type of the liquid hydrogen trailer and on the local liquid hydrogen stationary storage**

- **Nevertheless, as shown through the main steps of the unloading of liquid hydrogen from the liquid trailer to a local liquid hydrogen storage, the transfilling requires lots of manual actions and checking operated by the driver alone**

Main safety risks during delivery

Root causes
Focus on 2 areas:

INTERFACES
Site configuration, safety rules

PROCEDURE
Human factor

Trailer arrival

Trailer connections

↓

Hose Prefill

↓

Delivery Pressure Management

↓

Transfilling

↓

Pressure Management

↓

Post Fill before disconnection

↓

Trailer venting

Trailer departure

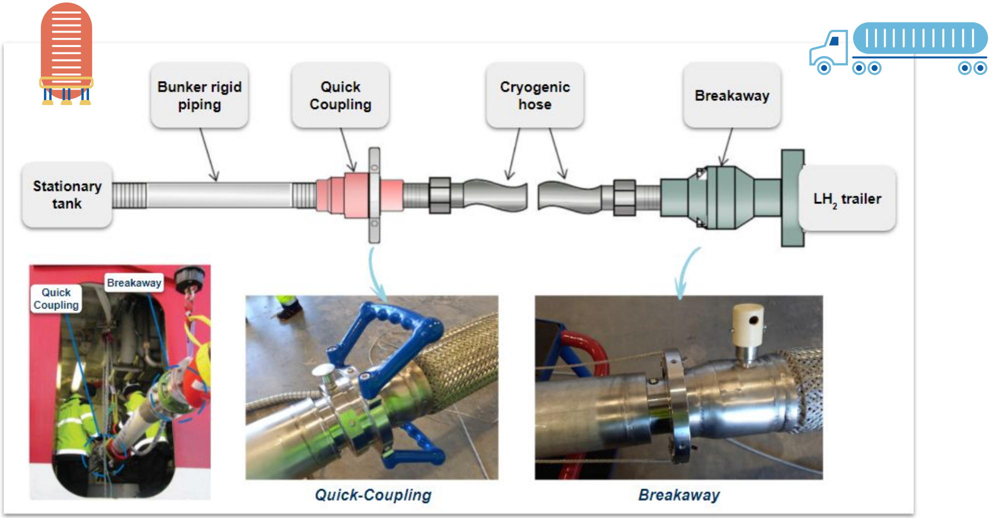
POTENTIAL RISK	EXAMPLE SCENARIO
External fire	Trailer Emergency Shut Off (ESO) not connected to site, fire & detection system
Loss of utility	Instrument air supplied from brake circuit instead of point of delivery
Ignition source	Grounding failure
Small Leakage	Hose coupling failure
H_2/O_2 mixture	Wrong purge of the hose
Large Release	Automatic valve opening when hose disconnected
High pressure	Trailer delivery pressure above receiver tank pressure
High level receiver tank	Overfilling
Large release	Hose rupture
High pressure trailer	Forget closing Pressure Builder Unit before departure
Large release	Residual LH_2 in hose when disconnecting
Unsafe venting	Trailer vent stack used instead of customer vent stack

Ref: AL - 2023 CHS Conference, Rotterdam

Conventional LH_2 unloading/transfer

Next steps

- **Some improvements are under development in order to deploy safer filling aiming - for instance - to decrease the likelihood of non respect of the procedure**
  - **Advanced monitoring** and more **automated procedures** when possible
  - **Equipment** is a part of the solution as well



  - In fine, **modelling** could bring additional information for **procedures improvement/optimization** for **safety**, **efficiency** and **limit losses**

Conclusions

Air Liquide is developing semi-automatic delivery in public area with LH_2 trailers

Loading/unloading guidelines and advanced procedures

Define safety rules minimum requirements and guideline for interface panels (e.g. interoperability of delivery)

Standardization workgroups are in progress

Thank you for your attention

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