Key features of fuel connectors and fuelling protocols for cryo-compressed and liquid hydrogen

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natürlich wasserstoff.

CEP platform

Source: https://cleanenergypartnership.de/en/about-us

Agenda

1. **Motivation for the use of cryogenic H_2 for Heavy Duty Vehicles (HDV)**
2. Deep dive: Background on cryogenic H_2 fuelling processes
   a. subcooled liquid H_2 (sLH_2)
   b. cryo-compressed H_2 (CcH_2)
3. Approach for standardization
   a. subcooled liquid H_2 (sLH_2)
   b. cryo-compressed H_2 (CcH_2)
4. Time schedule

Motivation for the use of cryogenic H_2 for HDV

The use of H_2 to power Heavy Duty Vehicles (HDV) requires

- increased storage densities to achieve comparable driving ranges to state-of-the-art technology
- a decreased target fuelling pressure for higher fuelling flow rates and lower fuelling station operation cost (electricity, maintenance)

Internal & external studies reveal a high potential for cost reductions by distributing LH_2

→ Two main paths exist for dispensing cryogenic H_2 into a vehicle

Cryogenic H_2 process paths

- **sLH_2**
  subcooled cryogenic (liquid) low pressure process
- **CcH_2**
  cryo-compressed hydrogen

☑ Increased storage densities
☑ Decreased energy demand (lower OPEX)
☑ Single hose filling
☑ no data communication in refuelling process
☑ High H_2 flow rate
☑ lower specific CAPEX (USD/kg) and smaller footprint

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sLH2 Fuelling for heavy duty land vehicles

Main characteristics of sLH_2 fuelling Stations:

- Filling of subcooled LH_2 at approx. 26 K into a vehicle tank to pressures up to 1.6 MPa
- Advancement of known technology LH_2 filling (at pressures up to 0.6 MPa)
- sLH2 Filling offers many advantages over LH_2 filling
- Allows high flow fuelling (> 400 kg H_2/h) with very low TCO
- Linde and Daimler collaborate on making sLH_2 the leading heavy duty H_2 technology
- sLH_2 Fuelling Process and Interface are written in open CEP working groups


Home · News & Media · Press Releases · Linde and Daimler Truck to Collaborate on Hydrogen Refueling Technology

Linde and Daimler Truck to Collaborate on Hydrogen Refueling Technology

Print

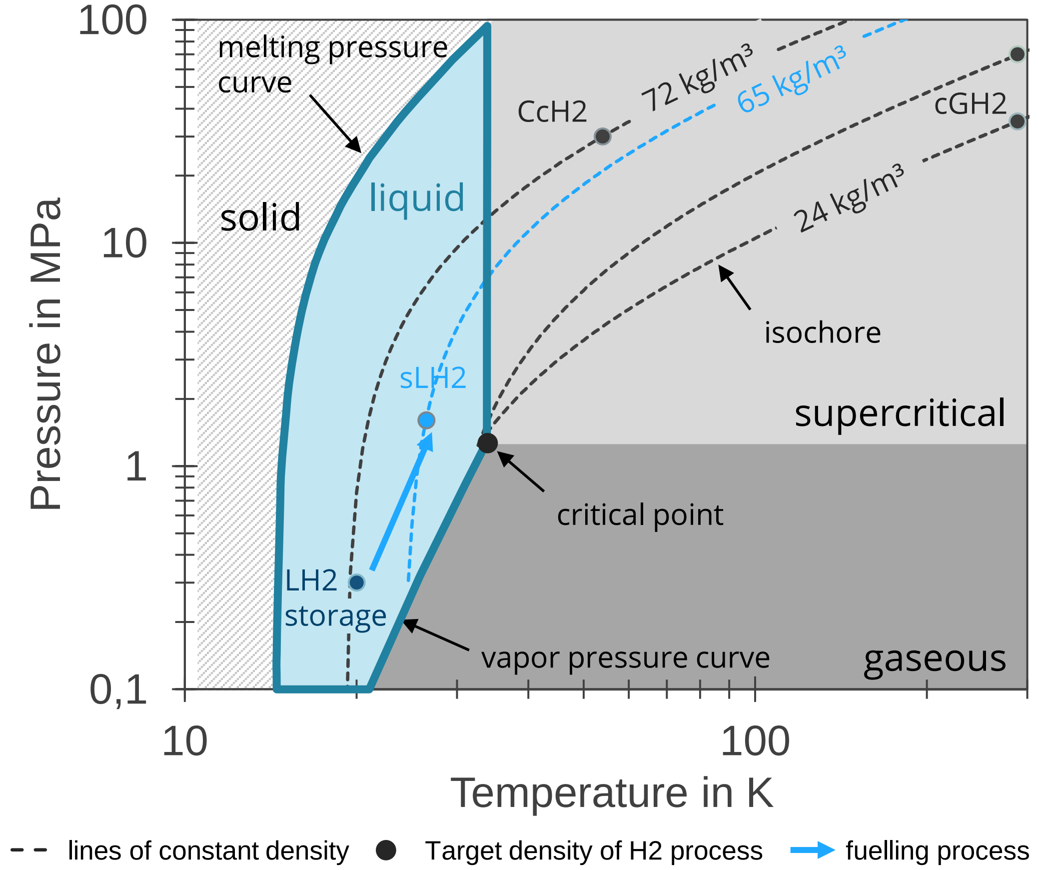
December 10, 2020

Guildford, UK, December 10, 2020 - Linde (NYSE: LIN; FWB: LIN) has signed an

Press Releases in December 2020

Process Parameters of the sLH_2 process

Process overview in a *T*-*p*-plot



Main process specification

- Start at ~ 0.3 MPa with LH2 from the storage
- sLH2 pumps LH2 at a variable flow rate (~400kg/h) into the vehicle tank
- H2 in the tank is cooled down, condensed, and the tank is filled to a pressure of 1.6 MPa
- Normal tank operation during driving is in the liquid phase below the critical temperature

Main technological challenges

- Most parts are available based on experience with LH2 filling
- Adaption to sLH_2 requirements for pump, dispenser components, flow meter, fuelling interface, and vehicle tank

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CcH_2 - Fuelling for heavy duty land vehicles

Main characteristics of CcH_2 Storage and Fuelling Technology:

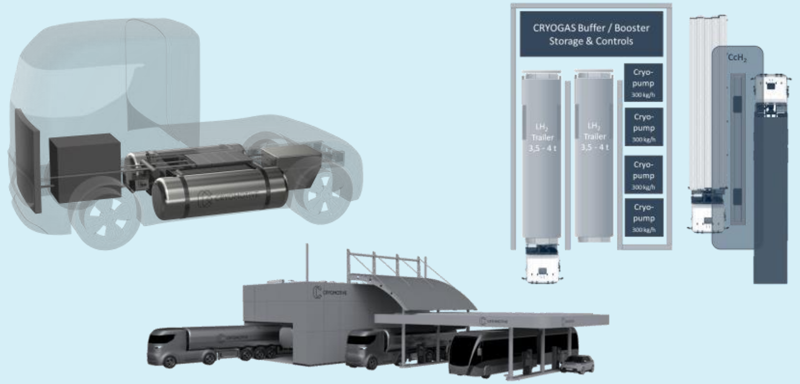
- Storage operation in (cryo-compressed) gaseous state, pressure supply for fuel cell and HICE (1 – 3 MPa)
- Storage densities up to 75 kg/m^3 when using an LH_2 cryo-pump, up to 65 kg/m^3 with a cryo-cooler
- Thermally robust, less stringent insulation requirements than LH_2, no boil-off onboard, no back-gas to station
- Synergies to CGH_2, use of liquid hydrogen and gaseous hydrogen distribution; option for CcH_2 distribution

Passenger car, low-flow refuelling (TRL7)

2015 TRANSFER TO HDV 2024

CcH_2 storage system, refuelling station

Heavy-duty truck, high-flow refuelling (TRL7)

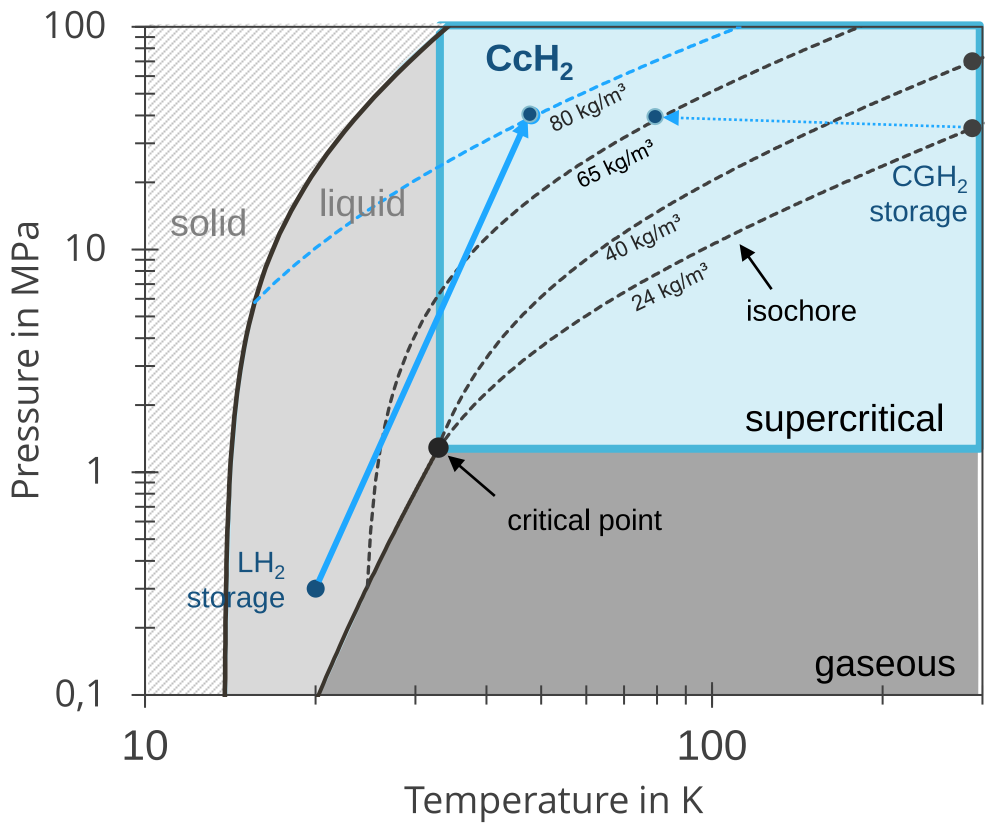


Picture Sources: BMW

Picture Sources: Cryomotive, 2021

Thermodynamic background on CcH_2 process

CcH_2 Process overview in a *T-p*-plot



- - - lines of constant density ● Target density of H2 process ➜ fuelling process

Main process specification HRS

- Cryogenic gas refuelling
- Two different CcH_2 refuelling routes:
  1. LH_2 cryopump to 35-50 K, up to 40 MPa
  2. GH_2 cryo-cooling to about 70 - 80 K, up to 40 MPa

Motivation for CcH_2 HRS

- Refuelling densities up to 80 kg/m³
- Boil-off-free gaseous fill with no need for back-gas / vent
- Synergies with H35/H70 CGH_2 HRS
- Compatible with LH_2 and GH_2 delivery

Main technical challenges of CcH_2 HRS

- Material durability (e.g. hose)
- Metering
- High-flow cryo-pump and cryo-cooler

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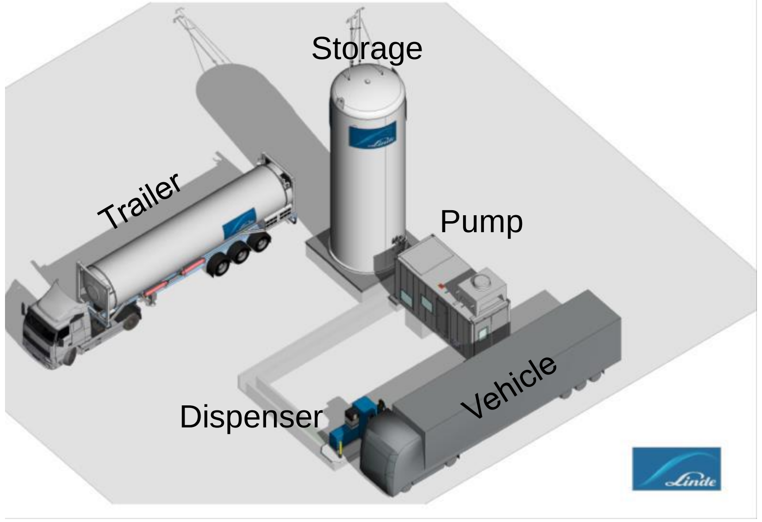
Approach for standardization of the sLH_2 process

Discussion on possible approach:

- Use white papers for sLH_2 interface and process of CEP as basis
- For sLH_2 fuelling interface: Update of ISO 13984:1999 – Liquid hydrogen – land vehicle fuelling system interface
- For sLH_2 fuelling process: New WIP
- For sLH_2 fuelling station: tbd



New WIP for sLH_2 process

Update ISO 13984:1999 for sLH_2 interface

LH_2 delivery by truck → LH_2 storage ISO 21009-1 (above or below ground) → Low pressure cryogenics pump ISO 24490 → Dispenser (including metering) → Vehicles

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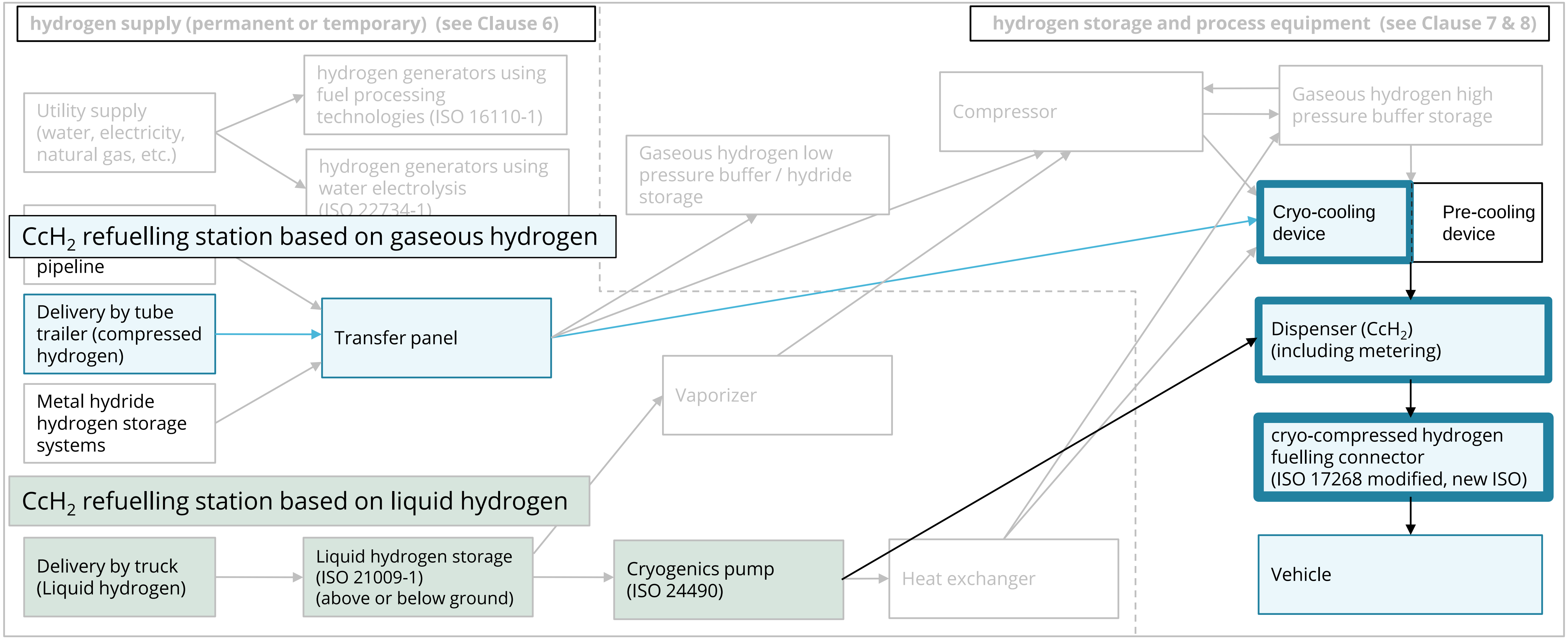
Approach for standardization of the CcH_2 process

ISO 19880 – DEVIATION OF STANDARD

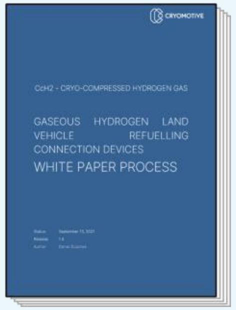


Source: figure based on ISO 19880-1:2020(en), Gaseous hydrogen — Fuelling stations — Part 1: General requirements

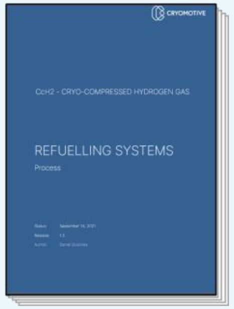
Approach for standardization of the CcH_2 process

CEP - WORKING GROUPS

<u>White Paper Process</u>



Interface
(based on ISO 17268)



Refuelling process

(~ 36 involved parties)

ISO - WORKING GROUPS

<u>Standardization process</u>

- ❑ Interface
  - → Amendment ISO 17268
- ❑ Refuelling process
  - → Amendment
  - → new WIP

TARGET

<u>CcH_2 Standard</u>

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4. **Time schedule**

Time schedule

2021

Completion of
- Interface and Process White Papers for sLH_2 and CcH_2 within CEP working group
- sLH_2 and CcH_2 process pre-design

NOW Heavy-Duty Workshop

2022

Interface & concept pre-testing

Start ISO norming process

ColdHyFuel (planned) funding project

Start of pilot tests

Thank you for your attention.

Clean Energy Partnership

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