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Transport of hydrogen by maritime and inland vessels

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BRANCHENTAG WASSERSTOFF

11. Branchentag Wasserstoff

Wien, 8. April 2025

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Agenda

- H_2 physical and chemical properties
- Storage of hydrogen
- Marine containment systems and cryogenic equipment
- Marine transport of hydrogen
- Port infrastructure
- Marine transport of hydrogen carriers
- Conclusions

H2 - physical and chemical properties

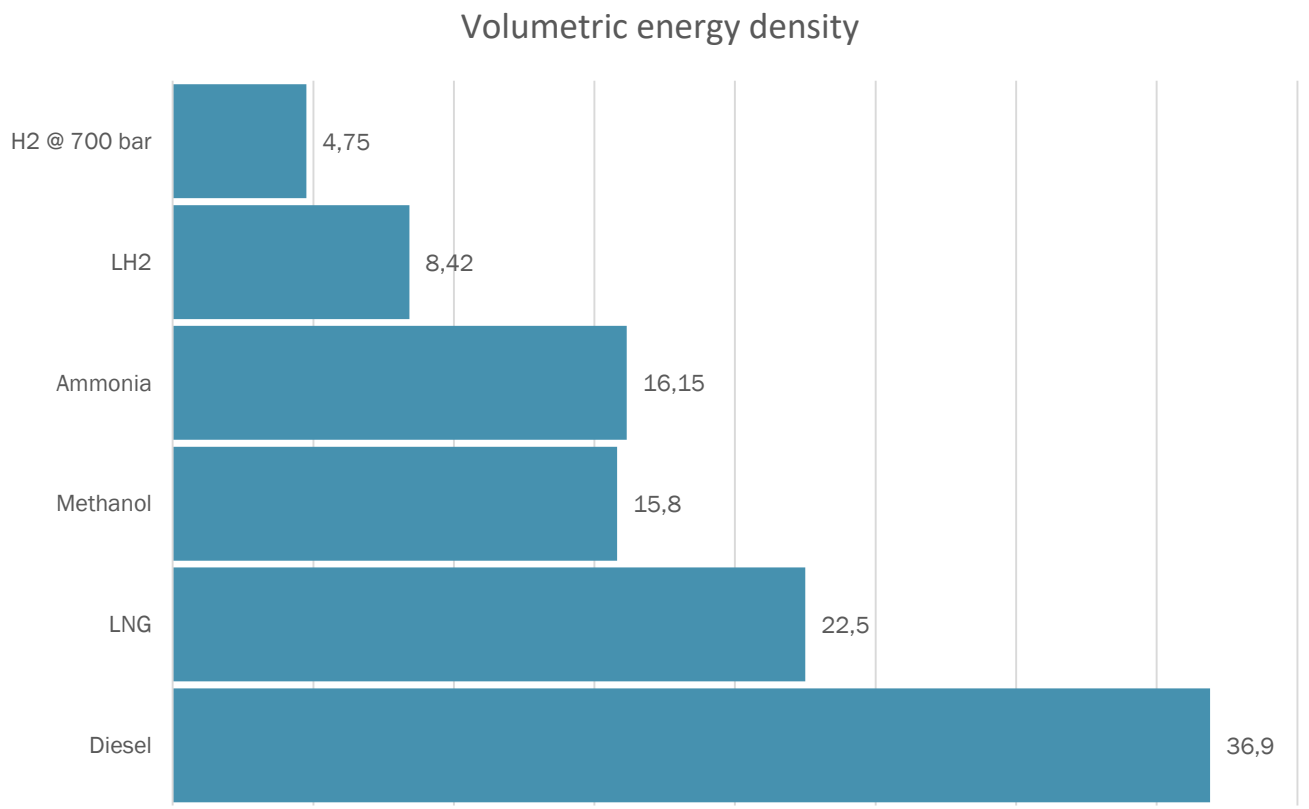
Non-toxic, colorless, odorless

Melting point: – 259.33 °C
Boiling point: – 252.88 °C

Critical temperature: – 240.15 °C
Critical pressure: 13.16 bars

Density: 0.08375 kg/m^3
Specific energy: 142 MJ/kg

Flammable, easy ignitable
Flame not visible



Storage of hydrogen

Liquefaction:

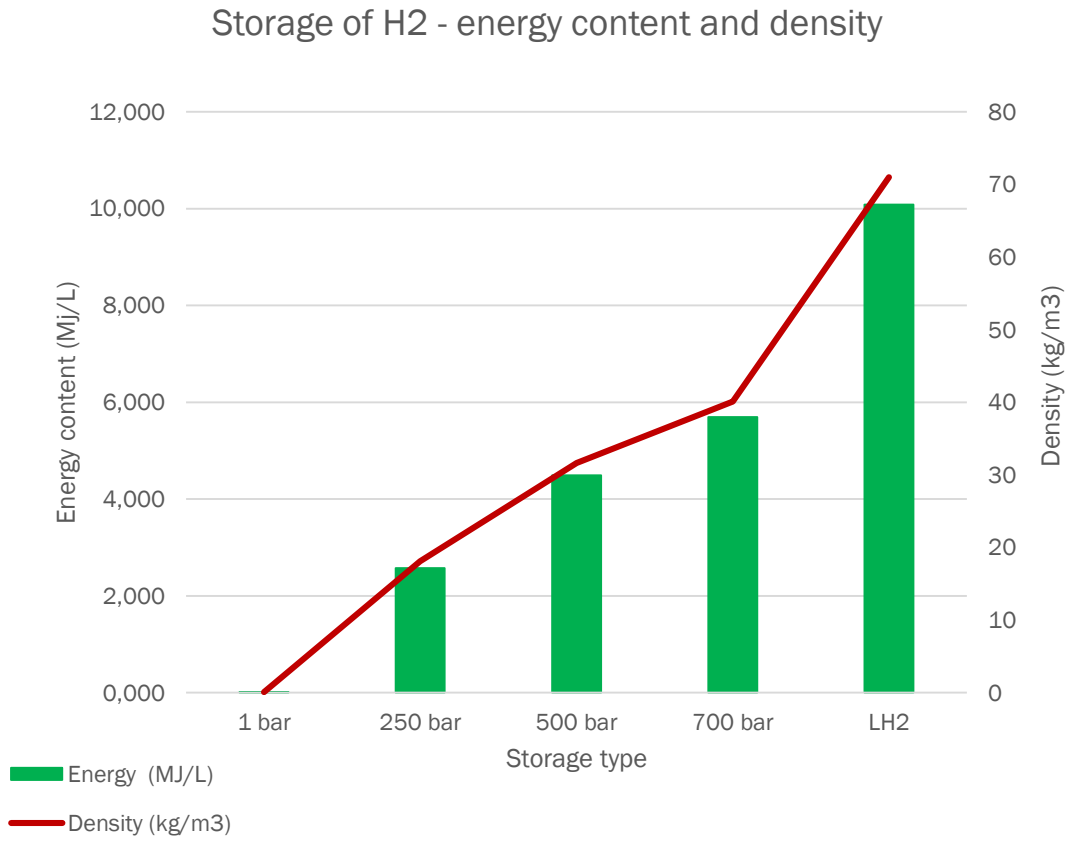
- Energy-intensive (30 – 40 % of the energy content)
- Complex process
- Volume reduction – 1/800 of its gaseous volume

Compression:

- Volume reduction
  - 1/225 @ 250 bars
  - 1/500 @ 700 bars

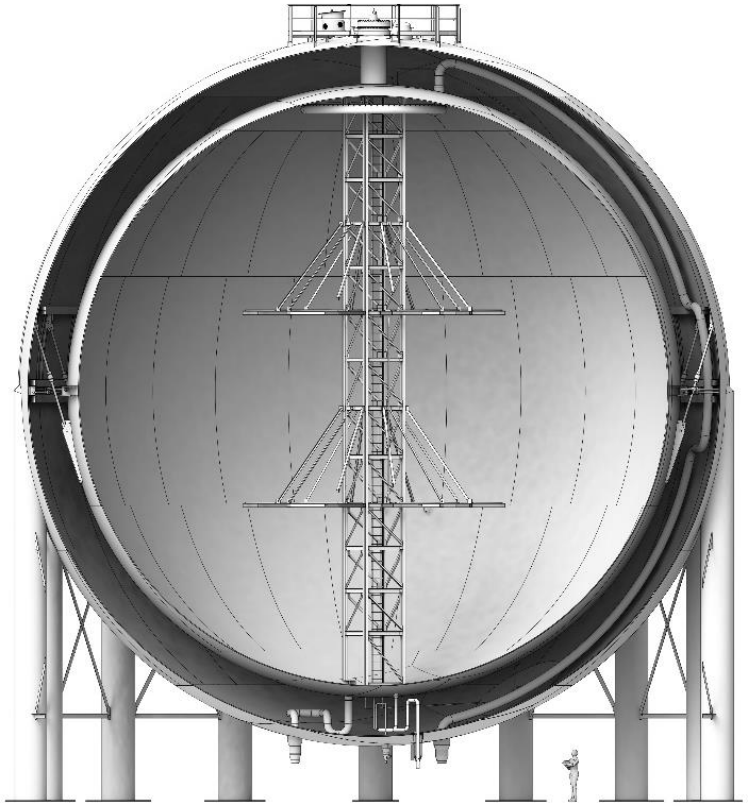
Hydrogen carriers

- Ammonia – synthesis / cracking
  - highly corrosive and toxic
  - cracking is not energy efficient
- LOHC – hydrogenation /dehydrogenation
  - Dehydrogenation is energy intensive
  - Production causes extra CO_2



LH2 landside storage tanks

- Cylindrical or spherical
- Stainless steel
- Insulation:
  - Vacuum perlite/panels
  - Liquid Nitrogen cooling
  - Reflective powder
  - Multi layer insulation (MLI)
  - MLI with vapor-cooled shield
- Subject to boil-off losses
  - 0.025 % to 5 %
  - Dependent of size and construction



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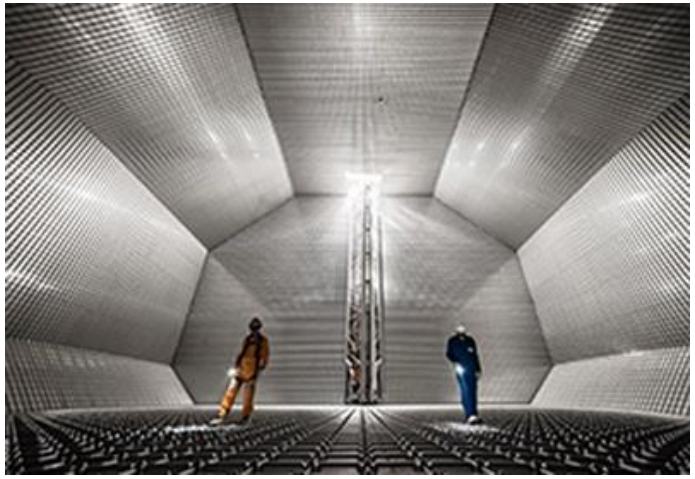
Marine cryogenic containment systems

LNG containment systems (– 160 °C)

- Independent tanks – IMO type B
  - MOSS spherical
  - IHHI-self-supporting prismatic
- Integral tanks – Membrane (GTT)



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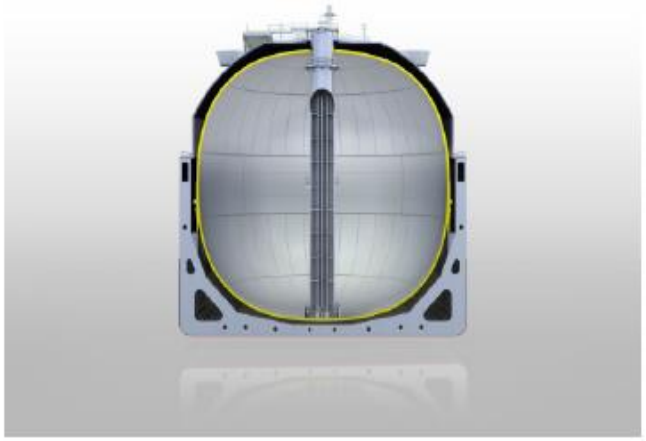

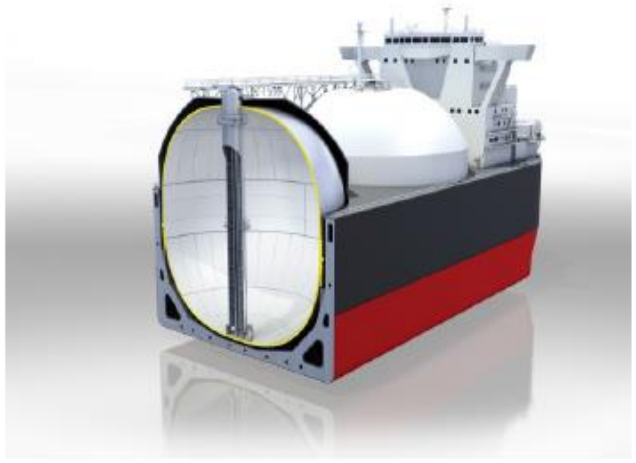

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Marine containment systems for LH2

© MOSS Maritime AS

© Kawasaki Heavy Industries

© CryoVac

Cryogenic gases handling equipment

Boil-Off Management

- Cryogenerator
- Compressor

Cargo transfer

- Submerged pumps
- Double-walled pipelines
- Cryogenic Breakaway Couplings

© Stirling Cryogenics

© Cryostar

© Chart Industries

Safety equipment

- Spill protection
- Flame detectors
- Gas detectors

© Autronica

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Vessels for transport of hydrogen

Suiso Frontier	
Length overall	116.0 m
Breadth	19.0 m
Draft	4.5 m
Gross tonnage	Approx. 8 000 t
Propulsion system	Diesel electric propulsion
Sea speed	Approx. 13.0 kn
Cargo tank capacity	Approx. 1 250 m^3 → Approx. 75 tonnes H_2
Storage temperature	- 253 °C
Containment system	Double-shell structure supported by high strength glass-fibre-reinforced plastic
Thermal Insulation	Vacuum ultra-high thermal insulation
Ship owner	CO_2-free Hydrogen Energy Supply-chain Technology Research Association (HySTRA)

© HESC - https://www.hydrogenenergysupplychain.com/

Vessels for transport of hydrogen

Kawasaki Heavy Industries Project	
Length overall	Approx 346.0 m
Breadth	Approx. 57.0 m
Draft	Approx. 9.5 m
Propulsion system	Dual-fuel propulsion able to use the Boil-off Gas Boiler and steam turbine plant capable of operating using H_2 as fuel
Cargo tank capacity	Approx. 160 000 m^3 / 10 000 tonnes H_2
Containment system	4 x 40 000 m^3 independent double-shell tanks, diameter approx. 43 m
Storage temperature	- 253 °C
Transfer system	Insulated double-wall pipes
Thermal Insulation	Vacuum ultra-high thermal insulation
AiP issuer	ClassNK

Vessels for transport of hydrogen

Provaris Projects	
Containment system	multi-layered carbon steel cylindrical tanks with internal liner, compressed H @ 250 bar
H2Leo – floating storage	
Cargo tank capacity	450 tonnes, scalable up to 2 000 tonnes
Development	AiP received 2021, final class approval expected 2025
H2Neo – Compressed hydrogen carrier	
Cargo tank capacity	Approx. 26 000 m^3
Development	AiP received 2021, final class approval expected 2025
H2Max – Compressed hydrogen carrier	
Cargo tank capacity	Approx. 120 000 m^3
Development	AiP received 2021, target

© Provaris

LH2 Port Terminals

Hy touch LH2 Terminal Kobe

- CO_2-free **Hy**drogen Energy **S**upply-chain **T**echnology **R**esearch **A**ssociation
- 2 500 m^3 19 m diameter spherical storage tank
- Double-shell vacuum-insulation
- Boil-off Gas holder
- 6” cargo arm, double-walled vacuum insulation

Port of Hastings

- Liquefication on site
- 0.25 t per day liquefication capacity
- 41 m^3 LH_2 storage container
- 1st shipment 2022 – Hydrogen Energy Supply Chain Project

Demonstration Project for Establishment of Mass Hydrogen Marine Transportation Supply Chain Derived from Unused Brown Coal subsidized by NEDO

© Kawasaki Heavy Industries / HySTRA

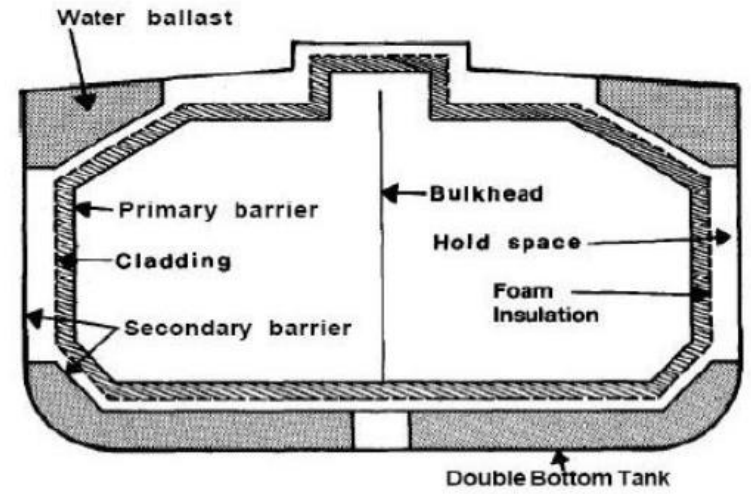
Marine containment systems for ammonia

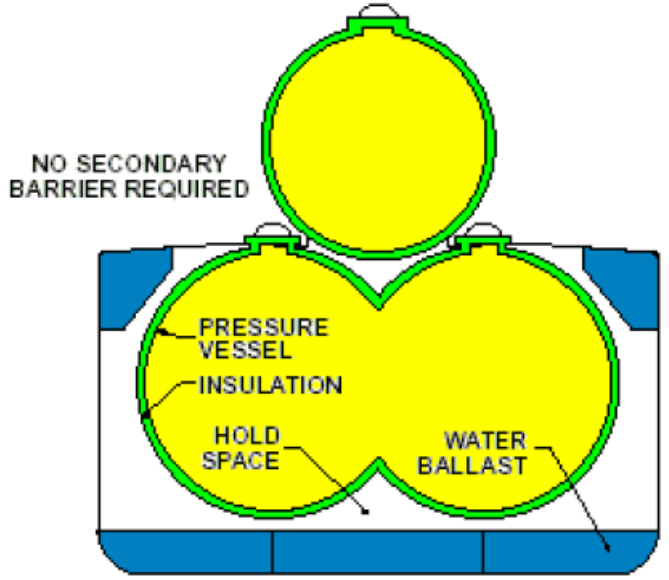
Transport and storage modes:

- Fully refrigerated (near atmospheric pressure @ –33°C)
- Semi-pressurised (5 to 7 barg @ –0°C)
- Pressurised (18 barg @ ambient temperature)

Vessels

- Fully refrigerated LPG ships (most common)
  - Capacities 15 000 m^3 to 100 000 m^3
  - Type A prismatic tanks - internal centreline bulkhead to improve stability and reduce sloshing.
  - Secondary barrier provided by the use of special steels for all hull structure
- Semi-pressurised ships
  - Capacities 2 500 m^3 to 15 000 m^3
  - Independent type C tanks
  - Carbon manganese steel





Vessels for transport ammonia

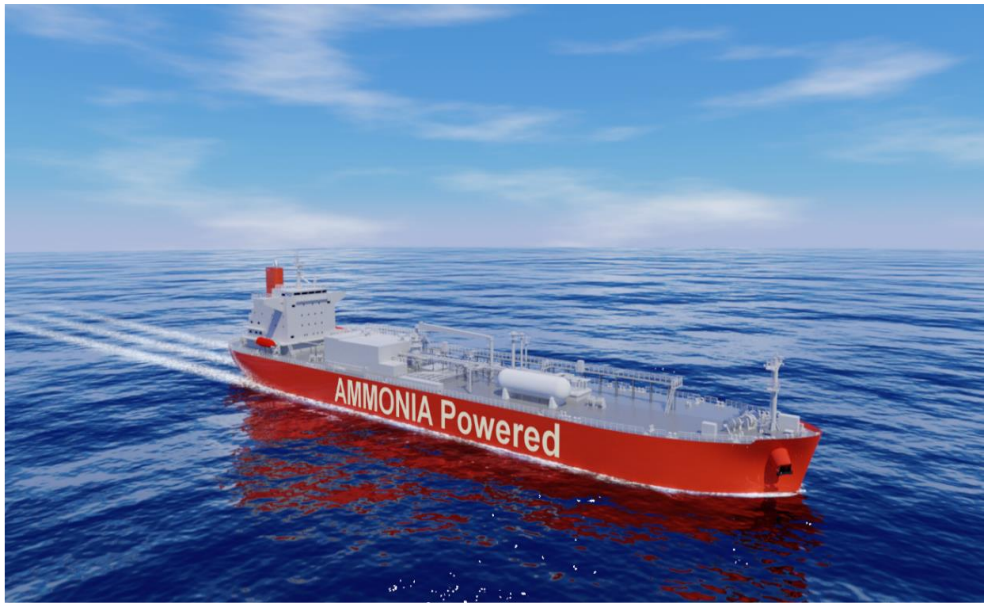
Gas Amethyst

Length overall: 229.90 m
Breadth: 37.20 m
Draft: 11.65 m
Tank capacity: 86 953 m^3
Dual-fuel diesel/LPG engine

©Kawasaki Heavy Industries

MOL,Tsuneishi & Mitsui Project

Length overall: Approx. 180.00 m
Breadth: Approx. 30.00 m
Depth: Approx. 19.00 m
Tank capacity: Approx. 40 000 m^3
Dual-fuel ammonia engine (MITSUI-MAN B&W)



© Mitsui O.S.K. Lines

Ammonia inland vessels

HGK Pioneer

Length overall: 135.0 m
Breadth: 17.5 m
Low-water optimized design
Diesel-electric propulsion
Cargoes:

- cold liquefied (–33 °C)
- pressure liquefied (18 barg)

© HGK Shipping GmbH

DAMEN Liquid Cargo Barge

Length overall: 30 – 140 m
Breadth: 9 – 45 m
Draft: 1.5 – 12 m
Tank capacity: 1 000 – 25 000 m^3
Cargoes: LPG, LNG, Ammonia, LCO_2

© DAMEN

Transport of LOHC

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- Physical and chemical properties similar to diesel
- Transported at normal temperature/pressure
- Same infrastructure and vessels

−

- Dehydrogenation is energy intensive
- Production causes extra CO_2

Transport capacity

- 1 m^3 of LOHC can store 57 kg H_2
- 18 0000 m^3 tanker → Approx. 1 000 t H_2

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Conclusions

- The physical and chemical properties of hydrogen raise significant challenges to its shipment by vessels.
- The experience gained in the transport of cryogenic and pressurised gases can be used to meet these challenges.
- The shipping industry has technical solutions that can be implemented once the transport of hydrogen by ship becomes economically viable.
- For the transition phase to a large LH_2 fleet hydrogen can be transported using hydrogen carriers such as ammonia and LOHC.

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Thank you for your attention!

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