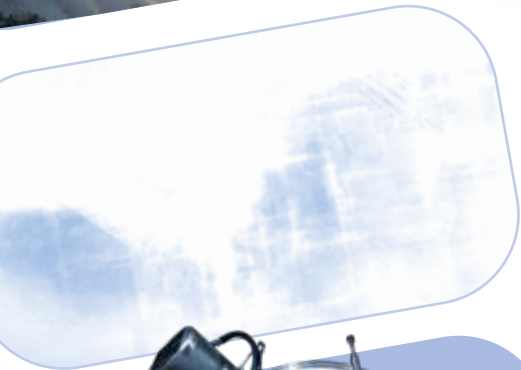


HYLIAL

Range of automatic hydrogen liquefiers



HYLIAL liquefiers is a comprehensive range of hydrogen liquefiers, based on Air Liquide experience on small scale (HELIAL) and large scale helium refrigerator/liquefier (CERN, QATAR, KSTAR, JT-60SA, ITER...).

To simplify matters, all your operations are controlled automatically: compressor management, system cooling, nominal operating conditions and liquefier shutdown.

Our experts can tailor-made the system to meet your specific needs, through a wide range of solutions to fit diverse applications: industry, space, hydrogen energy.



Guarantee from a world leader in cryogenics

Air Liquide is the world leader in gases, technologies and services for Industry and Health with more than fifty years of technical, industrial and commercial experience in mechanical cold production, liquefaction, storage and distribution of cryogenic fluids at very low temperatures: a benchmark in expertise.

An expertise in hydrogen

Air Liquide has built up a unique expertise in managing the entire hydrogen chain, covering not only production, distribution, and storage but also its applications right down to fuel cell level.

- **Production:** more than 200 hydrogen units worldwide
- **Distribution:** operation of the largest hydrogen network in the world with more than 1,800 km of pipelines in total
- **Storage:** liquid and gaseous form (more than 1,000 trucks)

All hydrogen equipment are tested in a dedicated hydrogen area on our test center.



The turnkey liquefaction system

Air Liquide offers a comprehensive refrigeration system: compression, refrigeration and distribution.

Legend: Basic offer — Hydrogen
 Optional offer — Helium

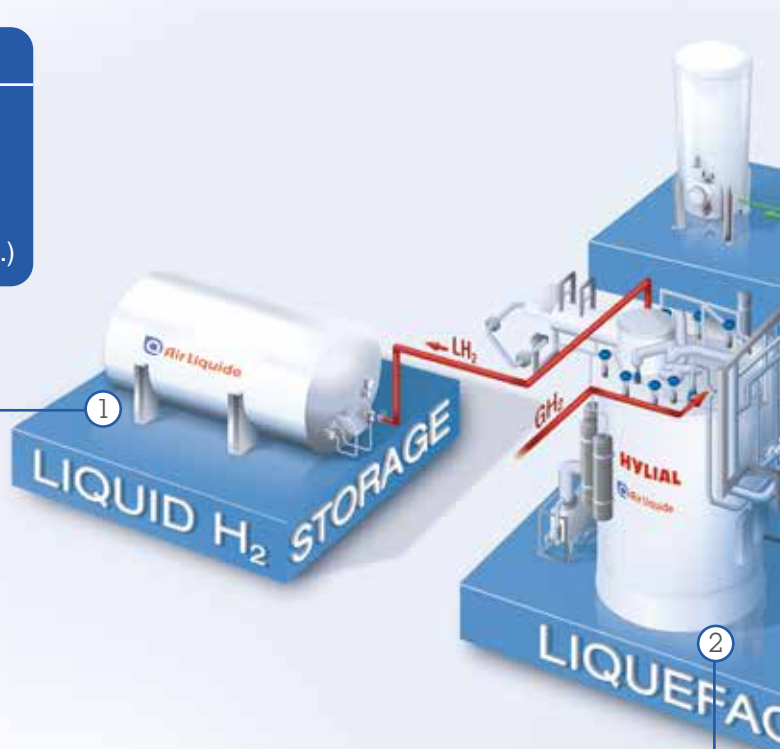
APPLICATIONS

- Industry: liquid hydrogen for industrial processes
- Space: liquid hydrogen for propulsion (test facilities and space launch pads)
- Sustainable energies: hydrogen supply chain and charging stations for Fuel Cell Electric Vehicles (cars, buses, forklifts...)

1. LIQUID HYDROGEN STORAGE

Liquid hydrogen storage tank

It ensures that the liquid hydrogen produced can be stored, with a static evaporation rate of less than 0.5% per day.



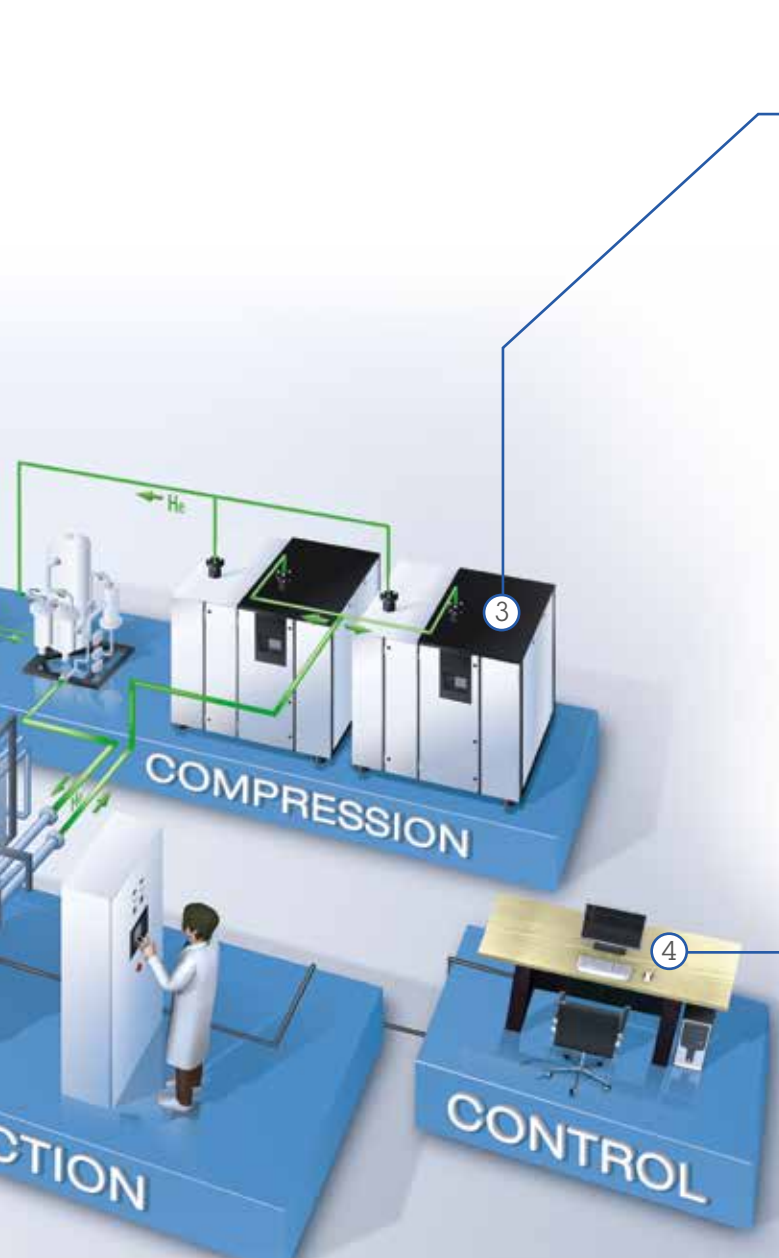
2. LIQUEFACTION

Cold box

The heart of the liquefaction system, it includes heat exchangers, ortho-para converter, cold adsorbers for helium and hydrogen, turbines and cryogenic valves.

Cryogenic transfer line

It ensures the transfer of the fluid between the cold box and the storage unit. The length can be adapted upon request.



3. HELIUM COMPRESSION

Medium pressure pure helium buffer

It maintains a constant cycle pressure in the liquefaction-compression loop.

Compression station with oil lubricated screws

Air- or water-cooled, it compresses helium gas at the start of the cycle and includes a primary de-oiling.

Oil removal system

Once compressed, the gas must then be purified. The oil is removed using coalescent cartridges and then by adsorbing the oil vapors on activated charcoal. It is connected with the buffer and also includes the cycle pressure management system (*high pressure and low pressure regulation*). At output, the helium has no trace of oil and can be used in the cold box.

4. CONTROL

Monitoring station

You can monitor your liquefaction system remotely and continuously through a network connection. Your system can also be placed under the control of Air Liquide technical team via a remote access, offering monitoring, alarm notification and diagnosis.

Gas analysis system

Hydrogen and helium can be analyzed continuously at different points in the facility so that any anomaly can be detected.

Air Liquide supports you throughout the different phases of design, commissioning and operation of your liquefaction system.

Design

- Support you with designing specifications
- Advice on the choice of components

Commissioning

- From monitoring on site equipment installation and connections to complete on site facility implementation
- Start-up supervision and support
- Acceptance tests on-site
- Provision of appropriate fluids for start-up

Operation

- Training of operation teams
- Maintenance contract
- Extension of warranty

After-sales service

- Technical support
- Spare parts
- Advice and optimization
- Customer network

Key benefits of **HYLIAL** liquefiers

✓ High reliability

- **Improved safety** thanks to a **helium loop separated** from hydrogen circuits
- **Manufacturing quality complies with prevailing international standards and codes**
- **Quality assurance system** of production processes

✓ Easy to use

- **Automatic and programmable operations, smart supervision system**
- **Communication interfaces are user-friendly**
- **Remote monitoring**

✓ High efficiency

- **Optimized pressure ratio on compressor** to achieve higher efficiency
- **Static gas bearing turbo-expanders** (up to 82%)
- **LN₂ pre-cooling of the cycle and continuous hydrogen ortho-para conversion**, enable you to increase your production of liquid hydrogen

✓ Low maintenance

- **No wearing parts** for the liquefier
- **Low maintenance** on the compressor
- **Reliability of turbines** based on static gas-bearing technology
- **Reliability and robustness** of integrated components
- **Continuous self-diagnosis** of system so that any breakdowns can be anticipated

✓ Controlled operating costs

- **Minimum consumption of utilities** (nitrogen, water, electricity and compressed air)
- The production of liquid hydrogen can be **adjusted to meet your needs**
- **Specific training of the team** for optimum use of the liquefier
- **Customized support and advice**
- Use of **standard equipment** on helium circuit (compressor, valve, instruments...)



Turbines with the highest MTBF* value on the market

HYLIAL liquefier is equipped with turbo expanders which constitute the core system of the liquefaction process.

Specifically developed by Air Liquide to operate in harsh industrial environments, our turbines are tested in real conditions on dedicated test benches.

Our turbines use extremely reliable static gas-bearing technology, reaching rotation speeds of up to 300,000 revs per minute with the highest measured on-site MTBF value on the market, namely 150,000 hours.

* *Mean Time Between Failures*

Main technical features

Liquefaction capacities, consumption and dimensions	HYLIAL 600	HYLIAL 800	HYLIAL 1500
LH ₂ production	600 L/h	800 L/h	1,500 L/h
Expected compressor power	550 kW	690 kW	1,260 kW
Cold Box size (L x W x H)	8.1 x 4.8 x 5.5 m (with gangway)	8.1 x 4.8 x 5.5 m (with gangway)	9 x 4.5 x 5.5 m

Air Liquide references

In 2008 HYLIAL met its first success. The first two HYLIAL 600 (600L/h H₂ liquefiers) started in China, for BLC & Xichang projects, over-performed the required liquefaction rate (+12% measured vs guarantee), resulting in a high customer satisfaction.

Along the years, HYLIAL have demonstrated an easy and safe operation with stable production, even during the H₂ adsorbers' regeneration phases.

HYLIAL

2012	BLC, China	600 L/h
2011	Xichang, China	600 L/h
2011	Hainan, China	1,500 L/h
2007	BLC, China	600 L/h

Previous H₂ liquefiers

1990	Ariane Space, Guyana	1,375 L/h
1988	Pacific H ₂ , Japan	850 L/h
1987	Hydrogenal, Canada	6,000 L/h
1987	Wazier, France	6,000 L/h
1977	Iwatani, Japan	760 L/h
1966	Frais Marais, France	600 L/h
1964	Predictown, USA	3,600 L/h

...and over 30 H₂ liquefiers in several labs (14-40 L/h)

Contacts

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A world leader in gases, technologies and services for Industry and Health, Air Liquide is present in 78 countries with approximately 64,500 employees and serves more than 3.8 million customers and patients.