Hydrogen
Hydrogen

Technology Leader

As the global leader in engineering and contracting for synthesis gas technologies, Air Liquide Global E&C Solutions can build on vast experience in engineering, procurement and construction of hydrogen plants. Focusing on customized solutions that reflect individual client and project requirements, Air Liquide Global E&C Solutions provides the full range of services from technology packages to ownership of large scale industrial lump sum turn key projects.

In addition to our outstanding experience of designing over 110 steam methane reforming (SMR) units worldwide, the integration of S/U experience, the results of significant R&D efforts and the long term operational experience led from conventional SMR to the proprietary design of today’s Lurgi Reformer® technology.

Safety and Environment

Air Liquide Global E&C Solutions hydrogen plants are designed to meet the most stringent international safety and environmental standards throughout the design, construction and operation of the plant.

Customized Solutions

The majority of hydrogen produced worldwide is consumed in refineries and petrochemical industries. Hydrogen is also used as transportation fuel and for a large number of industrial processes such as the production of metals, electronics, edible fats and oils, or production of float glass.

This variety of established and future oriented hydrogen offtakers leads to solid growth rates in global hydrogen demand, of which today more than 95% is covered by units applying SMR of hydrocarbon feedstocks.

Refinery and chemical companies have various options to cover hydrogen demands including:

- Recovering hydrogen from refinery fuel gas or chemical unit off-gases
- Revamping existing steam reforming units
- Building and operating a new steam reforming units
- Opting for an alternative hydrogen production method such as gasification technology
- Importing hydrogen over the fence from an industrial gas supplier

“With cutting-edge technologies and services to define your solution.”
For all options, Air Liquide Global E&C Solutions commands the full range of engineering services to develop the optimum technology solution for the individual client concept.

The project specific customization process for Lurgi Reformer® typically includes:
- Closest cooperation with client representatives
- Optimization of export steam flows with regards to cost and efficiency
- Optimization of the integration of new units into existing site concepts
- Optimization of the generic plant concept, e.g. with regard to co-generation of complementary products such as CO, NH₃ or MeOH
- Optimization of project implementation schedule
- Optimization of plant pre-fabrication and modularization concepts
- Optimization of plant design with regard to multiple feedstock utilization
- Optimization of plant availability and reliability with regard to capital expenditure

In a nutshell the Lurgi Reformer® technology provides:
- Proven technology
- Highly customized design solutions
- Easy and smooth operation
- Superior firing and load control
- Best in class emission levels

The Lurgi Reformer® is especially outstanding due to:
- Top fired reformer box
- High energy efficiency
- Operational availability higher than 99 %
- High operational reliability ensured by 2 out of 3 voting systems
- Optimized turn-around cycles
- Low utility consumption
- Low maintenance costs
- Low overall capital expenditure
The generic process scheme comprises feed desulfurization, SMR, shift conversion and hydrogen purification.

The hydrocarbon feedstock is mixed with recycled hydrogen. Desulfurization comprises two process steps, organic sulfur compounds are converted to H$_2$S in the presence of a hydrogenation catalyst and H$_2$S is adsorbed.

The desulfurized feed is mixed with process steam at an optimized steam to carbon ratio and superheated prior to entering the primary reformer. In the presence of a catalyst the mixed feed is converted to a reformed synthesis gas containing H$_2$, CO$_2$, CH$_4$, N$_2$ and steam inside the tubes of the primary reformer.

The CO in the reformed synthesis gas is water gas shifted for increased hydrogen yields by means of sweet water gas shift process units such as high temperature shift or high temperature shift plus low temperature shift process units.

In the hydrogen purification unit, hydrogen is separated from the shift gas stream by pressure swing absorption or membrane units to provide continuous and constant hydrogen product flow rates.

The reformer box is heated by firing the off-gas from the hydrogen purification unit and by make-up process fuel with forced draught burners in the top section.

The combustion air required is routed by a combustion air fan to the burners after pre-heating. The hot flue gases exit the reformer box through a refractory-lined duct and are routed to the flue gas stack after excess heat being recovered in the heat recovery section.

Steam generated by waste heat of reformed gas from the SMR is utilized as process steam while the excess is exported.
To achieve an optimum customization of the Lurgi Reformer® plant design, Air Liquide Global E&C Solutions offers a full range of process options.

Pre-Reforming

For the conversion of higher-molecular hydrocarbons and optimization of overall energy efficiency, Air Liquide Global E&C Solutions offers tailor-made pre-reforming process units as an integral part of the hydrogen plant.

Autothermal Reforming

Pure autothermal reforming can be applied for syngas generation whenever light natural gas and oxygen are available as feedstocks. The desulfurized and optionally pre-reformed feedstock is reformed with steam to synthesis gas at high pressures using oxygen as reforming agent. The process yields carbon-free synthesis gas and offers great flexibility over a wide operating range. The synthesis gas is compressed by a single casing compressor with integrated recycle stage to the required battery limit pressure.

As the industry leader in autothermal reforming, we present a large number of plant references starting as early as the 1950s.

Combined Reforming

For heavy natural gases and oil-associated gases, the most economic way to produce synthesis gases is a combination of autothermal reforming and steam reforming. After desulfurization, a branch of the feed gas is processed in a steam reformer at high pressure and relatively low temperature. The reformed gas is then mixed with the bypassed feed gas and reformed to synthesis gas at high pressure in the autothermal reformer. This concept has become known as the Lurgi Combined Reforming process.

The main advantages of this Combined Reforming process is the feed gas bypass of the steam reformer and the low process steam consumption translating into reduced energy consumption as well as lower capital expenditure.
Success through Technology

Partial Oxidation

Air Liquide Global E&C Solutions proprietary Multi Purpose Gasification MPG® technology is suited for the non-catalytic partial oxidation of solids, gaseous or liquid feedstocks for the production of large quantities of synthesis gas. With over 45 years of active experience in gasification technologies and over 75 units on-stream, Air Liquide Global E&C Solutions is the right partner to maximize advantages of the MPG® technology due to:

- Maximum feedstock flexibility
- Extended guaranteed burner lifetimes
- Inherent plant safety by pressurized cooling water system
- Long reactor lifetimes due to moderate, uniform wall temperature profiles
- Sophisticated designs for boiler and quench configuration

In combination with raw gas shift and raw gas purification technologies, MPG® is the superior choice for large scale hydrogen plants based on heavy residue feedstocks such as oil sands, vacuum residues, visbreaker residues or asphalt.

Water Gas Shift

Depending on the process optimization with regard to steam requirement, feedstock type and quality, and fuel valuation, Air Liquide Global E&C Solutions proposes the optimum solution for water gas shift systems:

For hydrogen plants designed for boiler mode operation by sweet water gas shift process units with upstream feedstock desulfurization:

- High temperature shift followed by a hydrogen purification
- High temperature shift followed by a low temperature shift and methanation process steps
- Medium temperature shift followed by a hydrogen purification

For hydrogen plants designed for quench mode operation by a raw gas shift process unit followed by a synthesis gas.

Hydrogen Purification

Depending on process conditions, required hydrogen quality and plant capacity, Air Liquide Global E&C Solutions offers three options for the hydrogen purification process step:

- Pressure swing adsorption (PSA) as the standard solution
- Low temperature shift plus downstream methanation process units for hydrogen plants with high hydrogen yields
- Membrane units for low capacity hydrogen units or hydrogen units with specific quality requirements
Lurgi Reformer®

The heart of the hydrogen plant is the Lurgi Reformer®. Air Liquide Global E&C Solutions advanced design combines outstanding operational characteristics with excellent maintenance features leading to superior operability and low investment and operating costs.

Distinct features of the Lurgi Reformer® proprietary design are:
- Large single train capacities of up to 1,000 tubes per train available
- Top fired reformer box for minimum number of burners
- Horizontal convection section for reduced maintenance efforts
- Cold header design for minimized thermal stress and refractory protection
- Flextube design for higher design and operating temperatures
- Counter-weight tube support design for minimized mechanical stress
- Horizontal or vertical waste heat recovery system designs available
- High modularization levels for increased quality of mechanical equipment, piping and instrumentation

CO₂ Capture

Our proven and worldwide recognized technology portfolio of CO₂ capture technologies include physical or chemical washes such as:
- Rectisol®
- MDEA
- Amine washes

Emission Control

Reflecting increased requirements of environmental regulations and clients or project policies, Air Liquide Global E&C Solutions offers a toolbox of technologies to lower the environmental impact of hydrogen plant operations which includes:
- State of the art noise abatement
- In-house portfolio of worldwide recognized CO₂ capture technologies
- Inherent plant safety by pressurized cooling water system
- Expertise in NOx reducing burner technologies
- Latest generation of selective catalytic reduction technologies (SCR) to minimize nitrous oxide flue gas emissions

Lurgi Reformer®
Air Liquide Global E&C Solutions is setting best in class standards with regards to plant availability and reliability by:
- Integrating design experience from over 110 Lurgi Reformer® units and over 1 million hours of operation in more than 30 Air Liquide hydrogen plants.
- Conducting extensive availability studies during the design phase of each project.
- Typical designs resulting in on-stream factors larger than 99 % for normal operation.
- Proven designs for turn-around cycles of up to 5 years.

Hydrogen Quality

The hydrogen produced is of high purity 99.9 – 99.999 vol. %, with low impurity levels, such as a CO content below 10 vol. ppm.

Utility Consumption

For a Lurgi Reformer® based medium sized hydrogen plant utilizing light natural gas as feedstock, typical consumption figures per 1,000 Nm³ hydrogen product amount to:

<table>
<thead>
<tr>
<th>Component</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed and Fuel</td>
<td>400 – 420 Nm³</td>
</tr>
<tr>
<td>Make-up BFW</td>
<td>1.0 – 1.5 t</td>
</tr>
<tr>
<td>Cooling Water</td>
<td>2.5 – 3.0 Nm³</td>
</tr>
<tr>
<td>Electricity</td>
<td>approx. 17 kWh</td>
</tr>
<tr>
<td>Export Steam</td>
<td>0.60 – 0.90 t</td>
</tr>
</tbody>
</table>

Typical consumption figures vary depending on hydrogen quality, customization and optimization of the plant design and export steam valuation.

Load Control

- Fully automatic blend and change of various feedstocks.
- Fully automatic load changes up to 3 % capacity per minute.
- Operation at minimum steam to carbon ratios.

Firing Control

- Peaks of PSA tail gas flow and composition are compensated by fuel gas.
- Stable reformed gas temperature ensured.
- Minimum oxygen content in the flue gas ensured.
Cost Efficiency

Lurgi Reformer® technology is the result of optimization and customization processes with regard to capital and operational cost.

The Lurgi Reformer® offers reduced capital expenditure due to:
- Top fired designs
- Multiple tube rows limiting the number of burners
- Large single train plant capacity
- High level pre-fabrication and modularization

Lurgi Reformer® design results in reduced operating cost due to:
- High operating pressures at the Lurgi Reformer® outlet
- High feed preheating temperatures
- Completely maintenance free catalyst tube inspection system

Advanced Hydrogen Management

Advanced hydrogen management systems are the key to hydrogen plant efficiency and availability. The Lurgi Reformer® features the most sophisticated control systems resulting in exceptionally high on-stream factors.

PRO-EN™ Services

Profitability enhancement services are the backbone of hydrogen optimization and management solutions. Customized, proprietary state of the art simulation software offers industry-leading hydrogen optimization studies that are customized to meet client and project needs and budgets.

Design Tools

Air Liquide Global E&C Solutions applies state-of-the-art plant engineering and software tools such as 3D modeling. Computational Fluid Dynamics (CFD) models are used to generate optimized design solutions at different scales: from the distribution piping to the full furnace using a dedicated in-house 3D tool. In addition, our multi-scale computational approach helps creating new mathematical models for complex fluid designs.
Operational Excellence

References

The benefit of long years of engineering experience for steam reforming plants is available and applied in order to achieve optimum results.

- Plant capacities up to 250,000 Nm³/h hydrogen production
- Worldwide more than 30 hydrogen reference plants
- Worldwide more than 110 Lurgi Reformer® reference plants
- Over 120 years of engineering experience

Intelligent Solutions

Around 4,000 employees are working for Air Liquide Global E&C Solutions world-wide. More than 15% are engaged in finding technological solutions in the company’s technology and R&D units. After all, each client and each project have their own specific design and operational conditions calling for intelligent and integrated concepts. The aspects of feedstock availability and quality are discussed in multidisciplinary teams of experts to optimize solutions with best-in-class engineering practices.

Process optimizations require concrete numerical data, computer assisted simulation results and considerable experience. This expertise is indispensible when decisions have to be made. Air Liquide Global E&C Solutions contributes to every project the know-how accumulated in more than 50 years of engineering experience for synthesis gas plants.
Competence in Project Execution

Air Liquide Global E&C Solutions execution centers around the world allow for a fast and efficient support of clients and projects in their respective location. Modern communication structures, fast know-how transfer and the complete service portfolio are the key to success for our clients and projects.

Scope of Services

Air Liquide Global E&C Solutions provides technology solutions executed in full-service operating centers worldwide. Our activities cover all phases of synthesis gas projects from financing through design, procurement, start-up services and operation including:

- Consulting services
- Market studies
- Conceptual studies
- Feasibility studies
- Product marketing
- Financing
- Investment analysis
- Contracting
- Value engineering
- Authority engineering
- Basic and detail engineering
- Global sourcing
- Construction
- Construction supervision
- Start-up services
- Operation and maintenance
- Technical services

In addition, project management consulting services are offered to provide comprehensive project management and associated services for large scale synthesis gas projects.
Air Liquide is the world leader in gases for industry, health and the environment, and is present in 80 countries with 46,200 employees. Oxygen, nitrogen, hydrogen and rare gases have been at the core of Air Liquide’s activities since its creation in 1902. Using these molecules, Air Liquide continuously reinvents its business, anticipating the needs of current and future markets. The Group innovates to enable progress, to achieve dynamic growth and a consistent performance.

Innovative technologies that curb polluting emissions, lower industry’s energy use, recover and reuse natural resources or develop the energies of tomorrow, such as hydrogen, biofuels or photovoltaic energy… Oxygen for hospitals, homecare, fighting nosocomial infections… Air Liquide combines many products and technologies to develop valuable applications and services not only for its customers but also for society.

A partner for the long term, Air Liquide relies on employee commitment, customer trust and shareholder support to pursue its vision of sustainable, competitive growth. The diversity of Air Liquide’s teams, businesses, markets and geographic presence provides a solid and sustainable base for its development and strengthens its ability to push back its own limits, conquer new territories and build its future.

Air Liquide explores the best that air can offer to preserve life, staying true to its Corporate Social Responsibility and sustainable development approach.

In 2011, the Group’s revenues amounted to €14.5 billion, of which more than 80% were generated outside France. Air Liquide is listed on the Paris Euronext stock exchange (compartment A) and is a member of the CAC 40 and Dow Jones Euro Stoxx 50 indexes.

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