Technology Handbook

Air Liquide
ENGINEERING & CONSTRUCTION

Value through technology

To all our customers,

We are pleased to share with you our most recent Technology Handbook. It provides a comprehensive overview of our portfolio of advanced technologies – some 64 of them, each designed to provide sustainable solutions to your business.

Our ambition is to be the partner of choice for the design, engineering and construction of state-of the-art production units worldwide. We work continuously to increase the value of our technologies and expand our knowledge to serve our customers better. Innovation is vital, and our internal technology experts and research networks work closely with our development teams and plant operators to develop ideas and new approaches that meet our clients' needs. We stay close to the markets and customers we serve, allowing us to develop our technological leadership for our customers' benefit.

A fundamental goal at Air Liquide Engineering & Construction is to provide our customers with competitive solutions that are safe and reliable. Our aim is to make sure that our customers can secure the best possible performance from their operations and make the most efficient use of natural resources.

We encourage you to contact us through our regional offices or one of our technology groups. Our experts and project leaders will be at your disposal and ready to offer additional information to help your business grow and prosper.

Air Liquide

A world leader in gases, technologies and services for Industry and Health

We are present in 80 countries with approximately 66,000 employees, serving more than 3.6 million customers and patients.

Oxygen, nitrogen and hydrogen have been at the core of the company's activities since its creation in 1902. They are essential small molecules for life, matter and energy. They embody Air Liquide's scientific territory.

Air Liquide's ambition is to lead its industry, deliver long-term performance and contribute to sustainability. The company's customer-centric transformation strategy aims to achieve profitable growth for the long term. It relies on operational excellence, selective investments, open innovation and a network organization implemented by the Group worldwide. Through the commitment and inventiveness of its people, Air Liquide is helping to deliver a transition in energy and the environment, provide changes in healthcare and digitization, and deliver greater value to all its stakeholders.

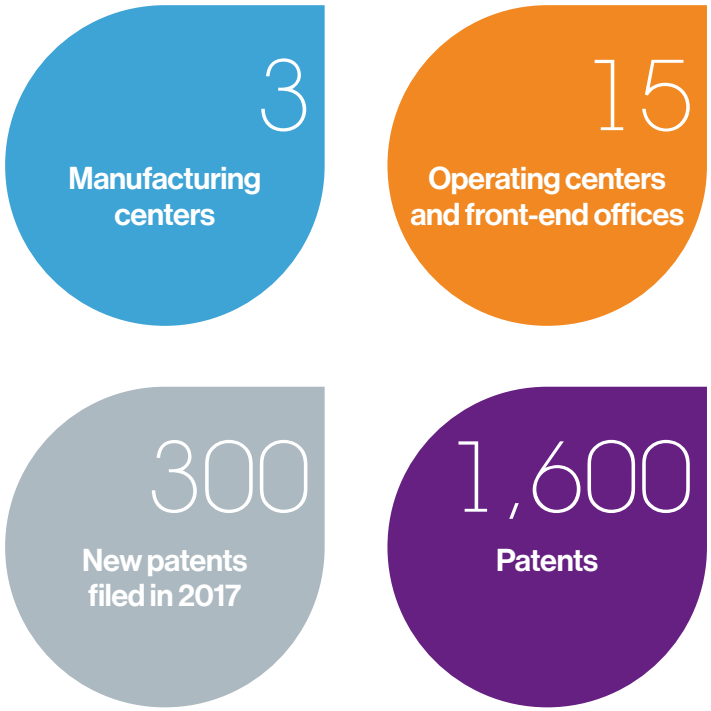
Air Liquide Engineering & Construction

A technology partner of choice

Air Liquide Engineering & Construction, the engineering and construction business of the Air Liquide Group, builds the Group's production units – mainly air gas separation and hydrogen production units – and supplies external customers with its portfolio of technologies. Its industrial gas, energy conversion and gas purification technologies enable customers to optimize the use of natural resources.

We cover the entire project life-cycle: from license engineering services / proprietary equipment, high-end engineering and design capabilities, as well as project management, commissioning and execution. Its exclusive and innovative technologies are contributing to the transition of the energy sector.

With more than 1,600 patents we are at work, connecting people and ideas everywhere to create advanced technologies to solve customer issues.



At the heart of innovation

Innovation is one pillar of the Air Liquide Group's strategy

Inventiveness, open-mindedness, sharing, agility and entrepreneurial mindset are fundamental features of our innovation approach.

Our Group innovation network is built on science, technologies, and dedicated investments. It is focused on developing new approaches and services for customers and patients, accelerated by digital transformation. It is part of an open ecosystem in which advances are rapidly shared across Air Liquide and with our external scientific partners and start-ups.

Innovation improves our customers' experience, contributes to growth and to the creation of a more sustainable world.

We innovate across all our areas of activity, balancing its drive for innovation with a commitment to preserve and maintain core products. By combining this pragmatic approach with technical creativity, our teams deliver unique solutions that make a real difference to our customers. Here are just a few examples of recent innovations.

Innovation in action

Cryocap™, CO_2 cold capture system

Cryocap™ enables the capture of CO_2 released during hydrogen production via a cryogenic process.
The first industrial deployment of this technology was made in Port-Jérôme, France, at the largest steam methane reforming hydrogen production unit operated by Air Liquide.

Cryogenic Technology Center

At our Cryogenic Technology Center in Vitry-sur-Seine, France, innovations related to cryogenic technology topics are developed, tested and demonstrated in an accelerated innovation cycle, thus being ready for early industrialization.

SMR-X, a zero steam hydrogen plant solution

SMR-X enables zero steam hydrogen production, with 4% natural gas fuel savings and 4% reduced CO_2 emissions compared to conventional installations.

A full portfolio of solutions for the LNG market

We offer customers a suite of highly efficient and proven LNG technologies based on our own proprietary processes using plate fin heat exchangers technology.

World's largest plants for industrial gas production

We have designed and assembled the largest single train air separation unit ever built. With a total capacity of 5,800 tons of oxygen per day (at mean sea level), the unit will supply industrial gases to the Secunda site for Sasol in South Africa. We have also designed and built units for the global-scale hydrogen production site in Yanbu Industrial City in Saudi Arabia with a total capacity of 340,000 Nm^3 per hour.

Gas POx contributing to clean air

Our natural gas partial oxidation technology (GasPOx) enables the reduction of carbon, NOx and CO emissions compared to conventional syngas solutions.
The technology has been successfully proven in a first reference project in Germany.

Our commitment to safety

We have one goal with respect to health, safety, the environment and security: to achieve zero accidents and zero environmental incidents.

We ensure that every action we undertake, from initial design to construction, reflects our goal of ensuring safety and protecting the environment.

In pursuit of this goal, we strive to:

- Provide a safe and secure work environment
- Prevent all injuries, damage to the environment and damage to property
- Identify and reduce risks and exposure to hazards in a sustainable way
- Improve our Health, Safety, Environment and Security performance continuously
- Enforce Air Liquide Life Saving Rules

Embodying a safety-first culture

- Our safety commitment applies not only to our employees, but also to our contractors, customers, adjacent facilities and local communities.
- We ensure that safety is the responsibility of everyone and is a part of the Air Liquide Engineering & Construction culture driven by our behavioral-based ACT (Actively Caring Together) program. In this way, we are all safety leaders, and all share a commitment to the golden rule of safety first.
- We will not hesitate to stop an activity of whatever nature (design, engineering, construction execution, or manufacturing) if it is not safe or if there is any suspicion that it may result in an accident or incident, now or in the future.

Our commitment to sustainability

We strive to contribute to a more sustainable world.

In line with Air Liquide's Corporate Sustainability Program and in order to contribute to a cleaner industry, transportation and enabling cleaner production, we offer a comprehensive portfolio of environmentally-optimized, efficient and easy-to-use solutions for our customers:

- Cryogenic CO_2 capture technology.
- Methanol production from CO_2 rich feedstock and hydrogen.
- Wide experience in the use of LNG, deployed as clean fuel. Our Liquefin™ technology offers 10% efficiency gain vs. state-of-the-art.
- Our SMR-X for export steam free H_2 production reduces natural gas use and CO_2 emissions by about 5% compared to conventional steam reforming.
- Our vast oleochemicals portfolio is a key-enabler to produce clean chemicals.

Supporting sustainability also involves actions in our own activities in engineering, manufacturing or on our sites to minimize environmental impact, leveraging new ways of digital transformation.

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AIR GASES

We have the experience, flexibility and capacity to provide a wide range of air separation units through standard plants, customized offerings and other cryogenic liquefaction technologies. Our strength lies in our ability to adapt our plants performances, safety and construction design philosophy to each project/customer specifics.

AIR GASES

Yango™ – Standard Air Separation Unit

Application

Steel making (basic oxygen furnaces, blast furnaces, electric arc furnaces), chemicals (ethylene oxide, ammonia, etc.)

Feedstock

Air + Energy (electrical or steam)

Product

Oxygen from 99.6% to 99.8% purity and up to 50 bar

Co-product

Nitrogen, liquid oxygen, liquid nitrogen, liquid argon, compressed dry air

Capacity

330 to 770 tpd

Economics

Specific energy: 400 to 600 kWh/t

Capex: 22 to 30 mm USD

Description

The Yango™ air separation unit is based on air compression, adsorption purification, cryogenic distillation of main components and internal compression of high pressure products.

Yango is a standardized, highly packaged ASU solution to support short-time-to-start-up projects.

Several process schemes are available to optimize both Capex and Opex depending on customer product requirements, energy cost and customer process integration potential.

Air Liquide Engineering & Construction offers optimized solutions in terms of construction strategy, operating philosophy and reliability.

References

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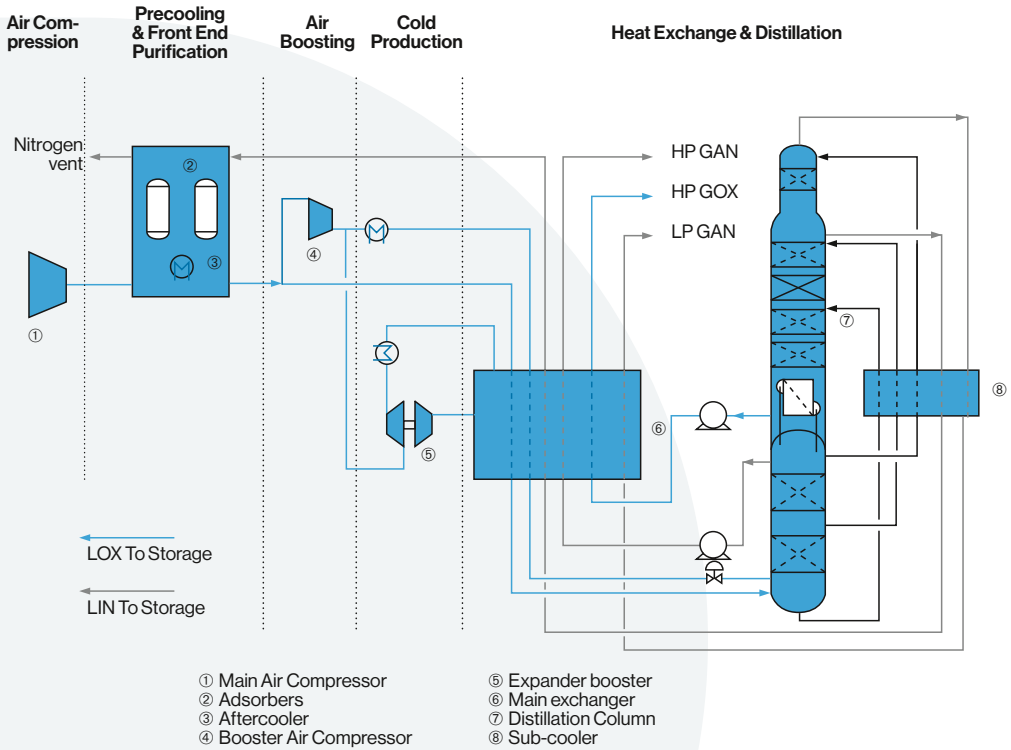
Contact

airgases@airliquide.com



Sigma – Standard Air Separation Unit

Application

Steel making (oxygen boosting, electric arc furnace), chemicals (ethylene oxide, etc.), glass, non-ferrous metals, waste water treatment, pulp and paper

Feedstock

Air + Energy (electrical)

Product

Oxygen up to 99.8% purity

Co-product

Nitrogen, liquid oxygen, liquid nitrogen, liquid argon, compressed dry air

Capacity

110 to 380 tpd

Economics

Specific energy: 280 to 460 kWh/t

Capex: 5 to 9 mm USD

Description

Sigma units are based on air separation with the following steps: air compression, adsorption, purification, cryogenic distillation of main components, internal compression.

Several process schemes are available to optimize both Capex and Opex depending on customer product requirements.

The Sigma units are designed to reduce construction and time to production with a highly packaged architecture.

Some liquid co-production could be available to refill backup liquid storages.

References

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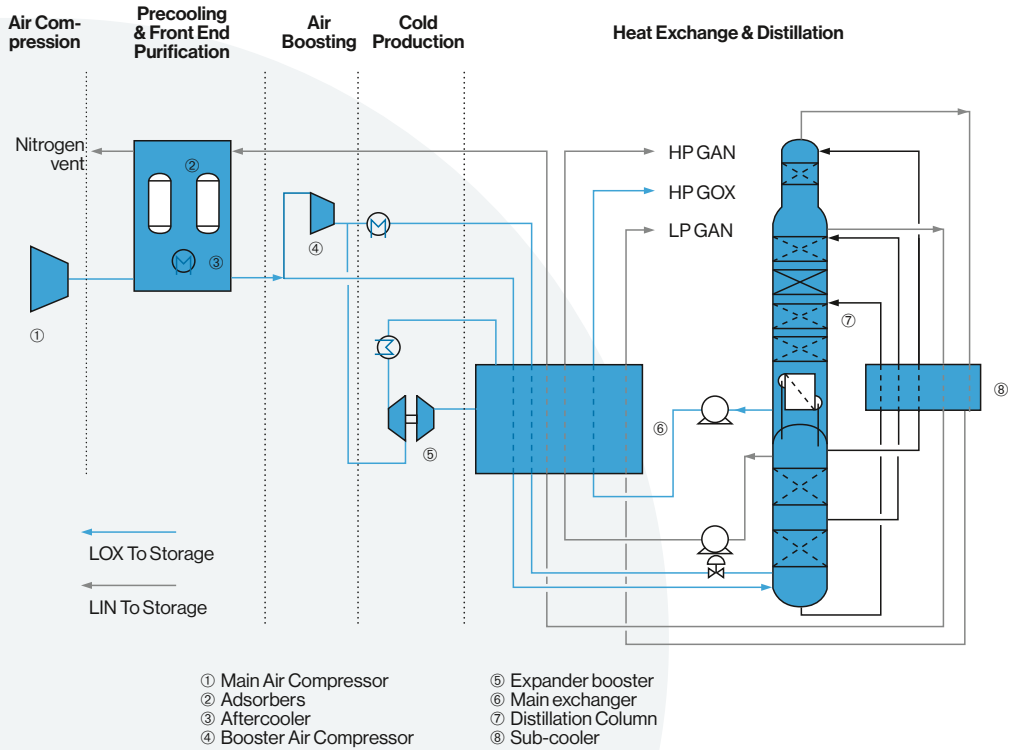
Contact

airgases@airliquide.com



AIR GASES

Vacuum Swing Adsorption (VSA) On-Demand Oxygen Generation

Application

Steel making, glass, pulp and paper, waste water treatment, mining

Feedstock

Air + Energy (electrical)

Product

Oxygen from 90% to 93% purity

Co-product

None

Capacity

40 to 130 tpd

Economics

Specific energy: 265 kWh/t

Capex: 1 to 6 mm USD

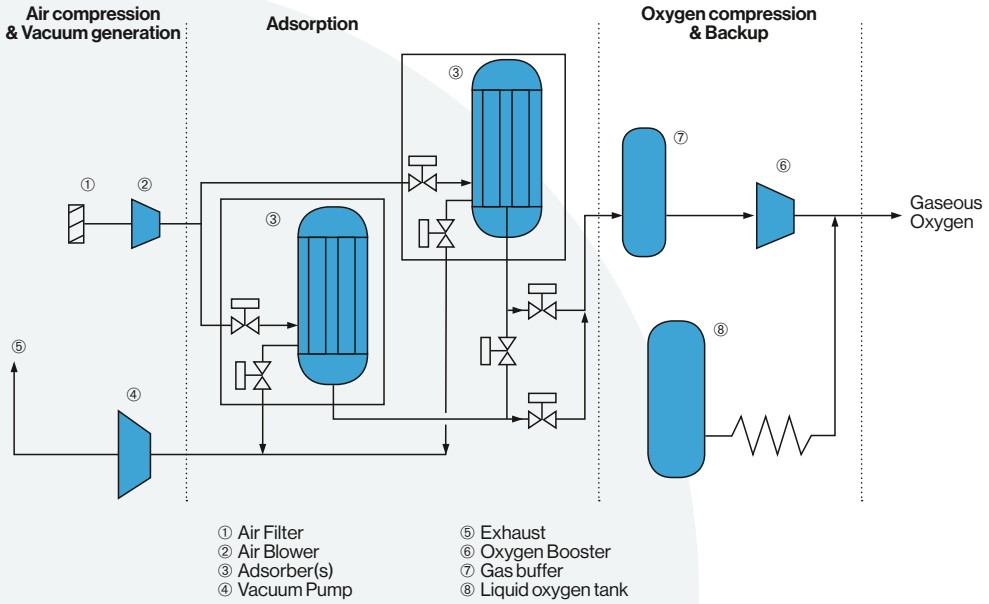
Description

VSA uses the process of air separation by adsorption. The basic principle of air separation by adsorption relies on the use of specific zeolite adsorbents for the selective adsorption of nitrogen over oxygen and argon.

Main features:

- Compact design layout
- Fully packaged and pre-tested skids
- Minimized schedule, erection and start-up times
- Automatic and unattended operation

Capitalization of more than 20 years of operating and maintenance experience.



References

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Contact

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Nitrogen Generation System

Application
LNG terminal, crude oil refinery, electronics

Feedstock
Air + Energy (electrical)

Product
Nitrogen (gaseous, liquid)
with 100 ppm to 1 ppb O_2

Co-product
LOX high purity

Capacity
500 Nm^3/h to 70,000 Nm^3/h
of nitrogen

Economics
Specific energy: 175 to 280 KWh/t

Capex: 2 to 11 mm USD

Description

This nitrogen generation system is based on air separation with the following steps: air compression, adsorption, purification, cryogenic distillation of main components.

Several process schemes are available to optimize both Capex and Opex depending on customer product requirements.

Some liquid co-production could be available to refill backup liquid storages.

Systems often include backup vaporizers and storage designed as per customer's requirements (availability and reliability).

These systems are safe, reliable and easy-to-operate and maintain.

References

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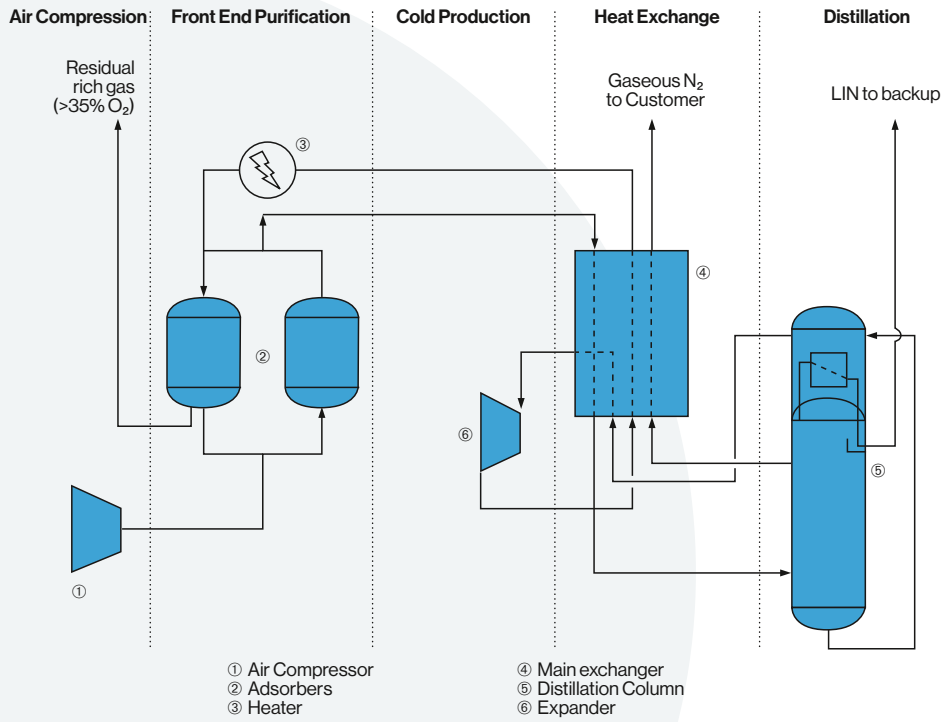
Contact

airgases@airliquide.com



AIR GASES

Large Air Separation Unit

Application

Steel making (basic oxygen furnaces, blast furnaces, electric arc furnaces), gas monetization (gas-to-methanol, -propylene, -liquids), coal gasification, chemicals (ethylene and propylene oxide, etc.), clean power (IGCC, oxycombustion)

Feedstock

Air + Energy (electrical or steam)

Product

Oxygen up to 99.8% purity and 100 bara

Co-product

Nitrogen, rare gases (Kr, Xe, He, Ne), liquid oxygen, nitrogen and argon, compressed dry air

Capacity

Up to 6,000 tpd

Economics

Specific energy: 160 to 500 kWh/t

Capex: 40 to 300 mm USD

Several processes are available to optimize economics depending on product requirements, energy cost and process integration.

Description

Large air separation units are based on adsorption purification, cryogenic distillation of main components and internal compression of high pressure products.

From the small standard of a few hundred tonnes per day to Mega ASU complexes (multi-train) of more than 15,000 tonnes per day, Air Liquide Engineering & Construction offers optimized solutions in terms of construction strategy, operating philosophy and reliability.

References

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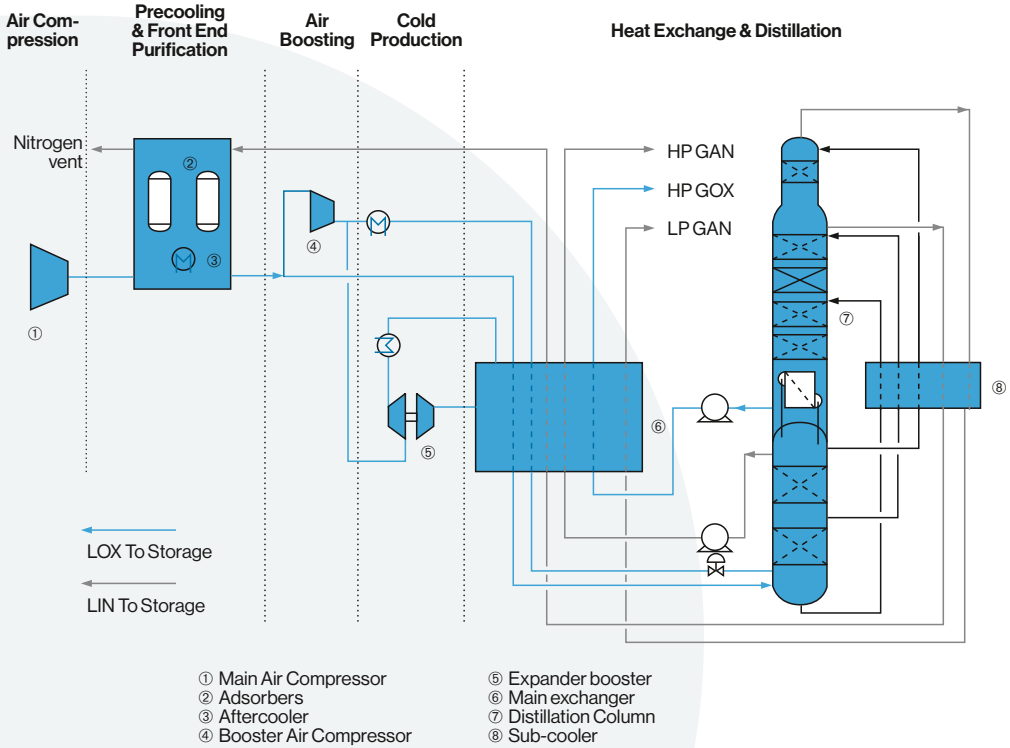
Contact

airgases@airliquide.com



RARE GASES

Our technologies for rare gases use the most efficient, safe and reliable processes to achieve optimal production or extraction of products. Our solutions are fully integrated into existing plants providing optimal cost and energy efficiencies.

RARE GASES

Krypton / Xenon

Application

Production of Krypton & Xenon mixture concentrated at > 98%

Feedstock

Liquid oxygen stream from a large Air Separation Unit (>3,000 tpd)

Product

Krypton + Xenon Mixture at > 98%

Co-product

None

Capacity

From 4,000 Nm^3/annum
up to 20,000 Nm^3/annum

Economics

Opex : small size

- Power: depending on the ASU integration : 500 kWh/h - 1000 kWh/h
- Cooling water + gaseous nitrogen (negligible quantity compared to ASU utilities)

Capex: small size

5 - 15 mm USD (EP)

Description

Liquid oxygen from ASU(s) is first treated in a primary module, named "Extraction cold box," which aims to remove contaminants such as N_2O and partially CnHm before entering in a first set of cryogenic separation to produce a pre-concentrated mixture.

The secondary module, named "Krypton-Xenon upgrader," treats the pre-concentrated mixture through a hydrocarbons purifier before entering into the final concentrated cryogenic separation in order to produce a krypton-xenon mixture enriched at > 98% (rest is oxygen).

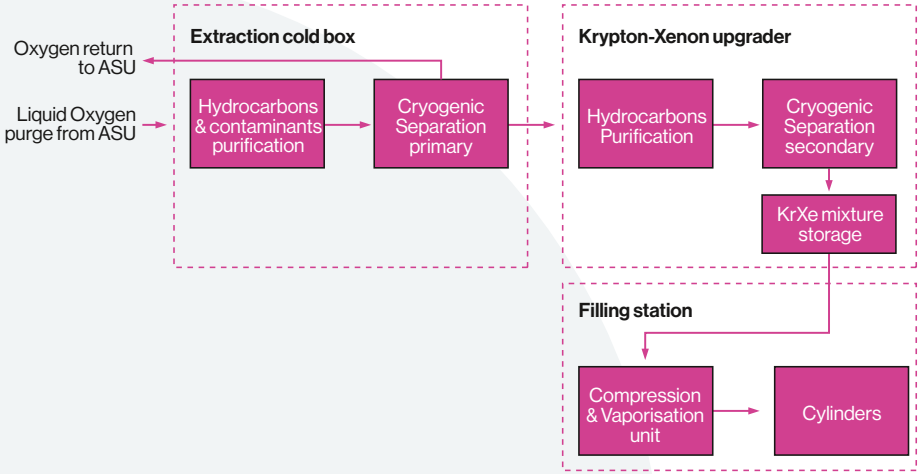
This concentrated cryogenic mixture (typically Kr 91%, Xe 7%, O_2 2%) is then compressed and vaporized to fill gas cylinders at 150 barg.

Final separation (pure Kr, pure Xe) is done outside the ASU plant in a dedicated laboratory.

Note: Krypton-Xenon production is economically favored for large ASU (>4000 tpd) or for multi ASUs due to the low Krypton and Xenon content in the air (resp. 1.1 ppm, 0.086 ppm).

Main features:

- Integration with ASU
- Low power consumption
- Pre-assembled packages or skid units to ease the erection



References

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Contact

raregases@airliquide.com

Helium Extraction and Liquefaction

Application

Pure liquid helium production and loading into ISO containers

Feedstock

Natural gas or impure helium gas extracted as non-condensable side-product from LNG units or impure helium gas extracted from nitrogen rejection units

Product

Liquid helium

Co-product

None

Capacity

Up to 20 tpd (one train)

Economics

The highly efficient process combined with the vapor recovery system allows for a very high helium recovery (> 99%).

Capex: 40 to 300 mm USD

Description

The impure helium feed gas is purified in a first section, where N_2, CH_4, H_2, CO, Ar, O_2, water and CO_2 are separated from helium.
It is composed of a cryogenic partial condensation unit, a hydrogen removal system and a Pressure Swing Adsorber (PSA) unit.

Then, the pure gaseous helium is cooled and liquefied via a helium cycle and the use of cryogenic expanders with a highly optimized cryogenic exchanger arrangement. Expanders are based on a proprietary technology using static gas bearing, ensuring high reliability and efficiency.

Liquid helium is continuously produced and stored in tanks. The unit is equipped with loading bays to fill ISO containers. All helium vapors from the containers are collected and recycled within the unit.

Contact

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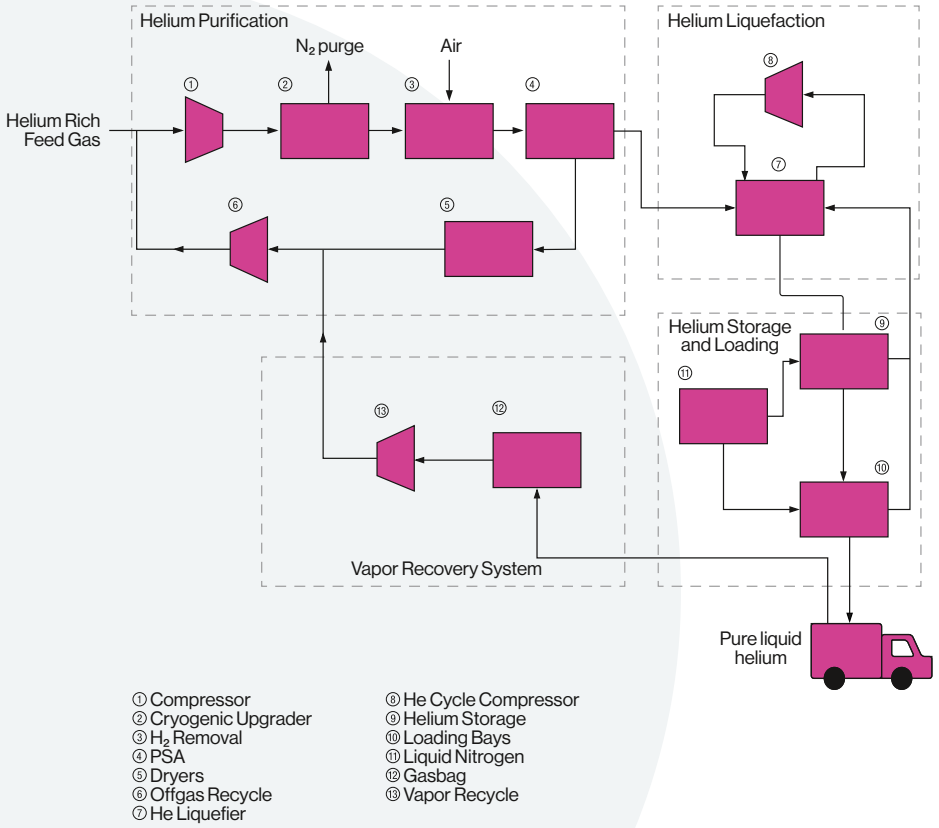
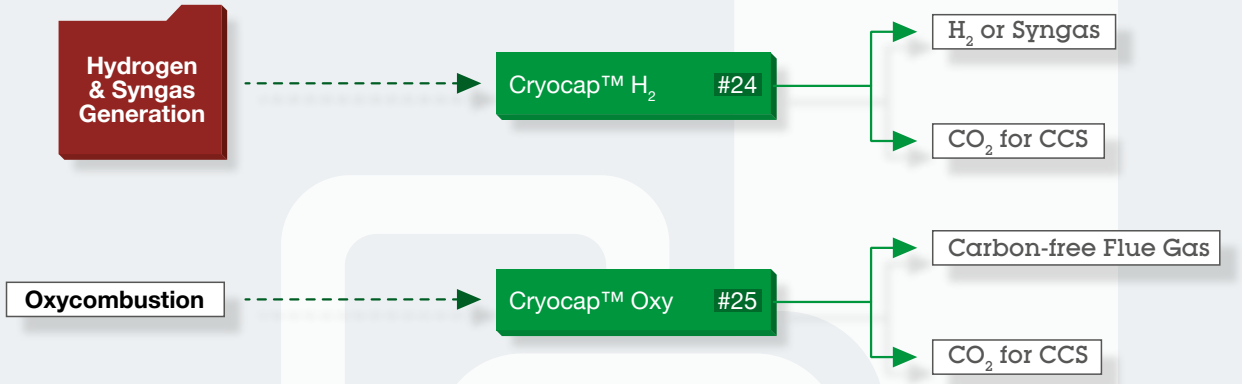


CO_2 CAPTURE

Cryocap™ is a technological innovation for CO_2 capture using a cryogenic process involving low temperatures, around -50°C, combined with membranes separation, that is unique in the world. It can be adapted to specific applications combining a variety of Air Liquide technologies: the capture of CO_2 produced by thermal power plants (Cryocap™ Oxy), or hydrogen production units (Cryocap™ H_2).

Overview


Hydrogen & Syngas Generation
Cryocap™ H_2 #24
H_2 or Syngas
CO_2 for CCS
Oxycombustion
Cryocap™ Oxy #25
Carbon-free Flue Gas
CO_2 for CCS

Cryocap™ H_2 – Cryogenic CO_2 Separation

Application

CO_2 capture from H_2 production plants

Feedstock

Offgas from H_2 plant

Product

CO_2

Co-product

H_2

Capacity

From 500 to 2,000 tpd

Economics

Opex + Capex:

- 45 USD/tonne of CO_2
- Increase H_2 production by 13% to 20%
- Cryocap™ H_2 offers the lowest costs for CO_2 production from H_2 plant (20% less capex than amines)

Description

The offgas is compressed, dried and sent to a cryogenic unit, where the CO_2 is separated from the other components by a combination of partial condensation and distillation. A pure and pressurized CO_2 flow is produced from the cold box.

The non condensed gases are recycled through a membrane system to recover H_2 and CO_2. Residual gas is sent to the burners of the reformer.

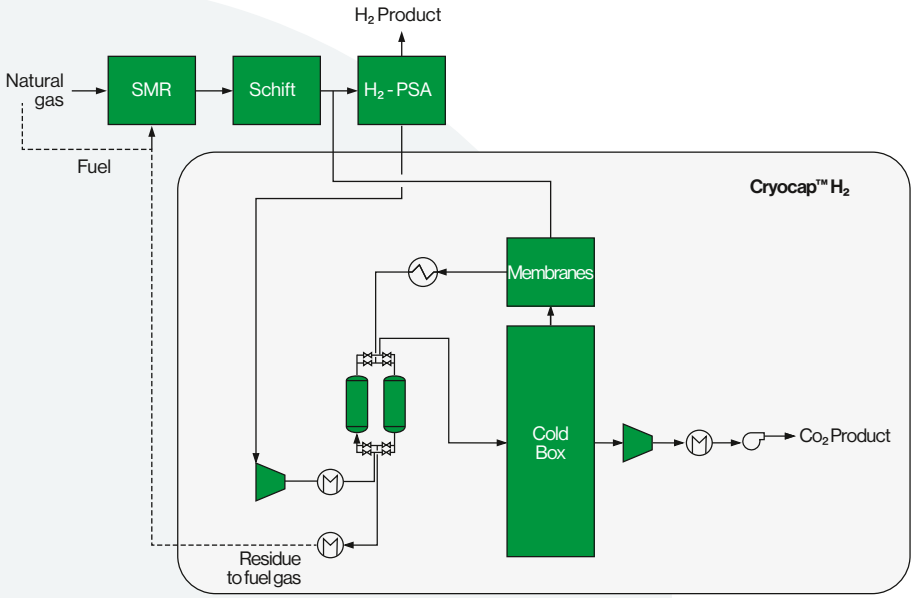
The CO_2 product is compressed up to supercritical pressure or liquefied and stored in liquid storage.

Food-grade quality can be achieved by an additional purification on a catalytic bed where all remaining hydrocarbons and alcohols are destroyed.

Cryocap™ H_2 can be installed for greenfield as well as brownfield H_2 plants.

Main feature:

• More than 98% of CO_2 recovery from syngas



Reference

1 (100 000 t/y)

Contact

cryocap@airliquide.com

CO_2 CAPTURE

Cryocap™ Oxy – Cryogenic CO_2 Separation for Oxycombustion

Application

CO_2 capture from power plants

Feedstock

Oxycombustion flue gas

Product

CO_2

Co-product

None

Capacity

From 1,000 to 15,000 tpd

Economics

Cryocap™ Oxy allows very high CO_2 recovery and near zero-emission to the atmosphere (SOx, particulate matters, NOx, Hg).

Capex: 40 to 300 mm USD

Description

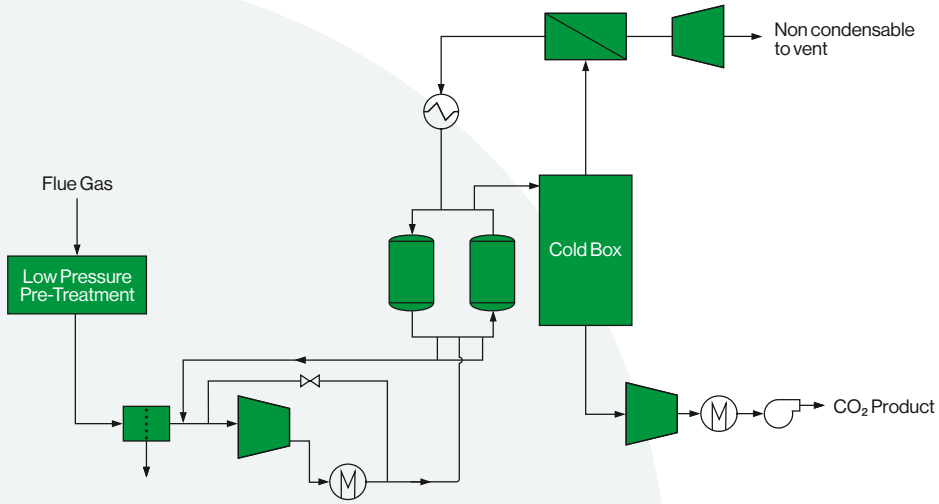
The flue gas issued from the boiler plant is first treated in a pre-treatment unit, which aims to cool the gas and remove the SOx, HF, HCl, most of the NOx, and the dust. Then the gas is compressed and dried before entering the cryogenic purification unit.

In the cold box, CO_2 is recovered by combination of partial condensation and distillations, which allow the removal of the heavy compounds such as NOx and the light elements such as O_2, Ar, N_2, NO and CO.

The CO_2 product is compressed, condensed and pumped up to supercritical pressure.

Main feature:

- More than 98% of CO_2 recovery from syngas



References

3 (from 25 000 to 1.2 million t/y)

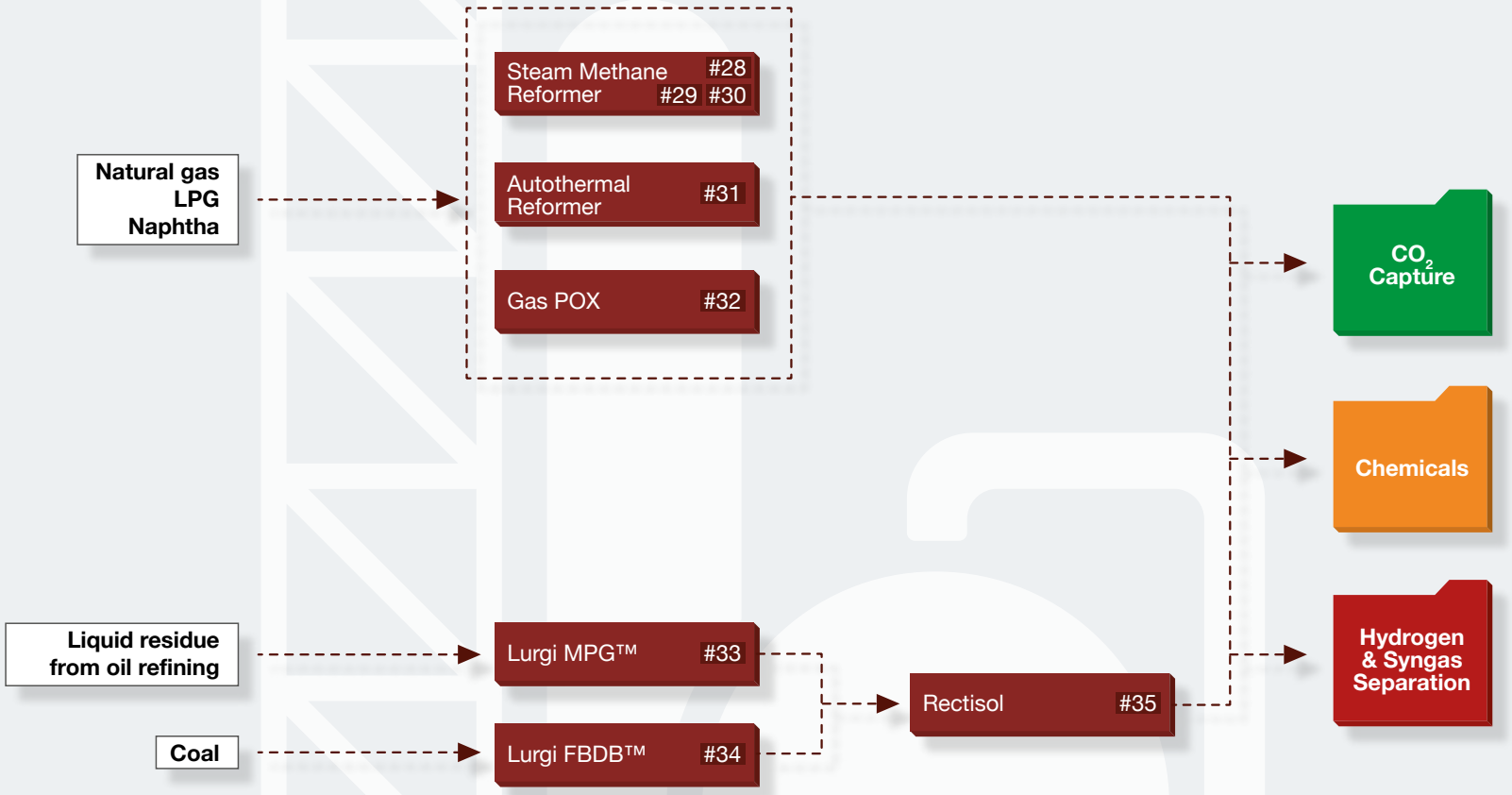
Contact

cryocap@airliquide.com

HYDROGEN & SYNGAS GENERATION

We are pushing technology limits in design and delivery of syngas plants, including the world's largest units. Our plants meet the needs of large, medium, and small customers with a wide range of possible steam export rates.

Overview


Natural gas
LPG
Naphtha
Steam Methane Reformer #28 #29 #30
Autothermal Reformer #31
Gas POX #32
Liquid residue from oil refining
Coal
Lurgi MPG™ #33
Lurgi FBDB™ #34
Rectisol #35
CO_2 Capture
Chemicals
Hydrogen & Syngas Separation

Steam Methane Reforming (SMR)

Application

Generation of syngas by steam reformation of methane rich hydrocarbon

Feedstock

LPG, naphtha, natural gas, refinery off-gas

Product

Hydrogen, carbon monoxide, syngas or a combination thereof

Co-product

Steam, optionally carbon dioxide

Capacity

Per SMR train:

- 15,000 - to 200,000 Nm^3/h H_2 plant
- 3,500 - 40,000 Nm^3/h CO plant
- Up to 350,000 Nm^3/h syngas

Economics

Opex:

H_2 plants (based on nat. gas feed & fuel):
Steam co-export ratio: 0.4 to 1.1 kg/Nm^3 H_2
Feed+Fuel: 14.5 to 15.3 MJ/Nm^3 H_2

HyCO plants (based on nat. gas feed & fuel):
H_2/CO product ratio: 2.6 to 4.2
Steam co-export ratio: 0.3 to 0.7 kg/Nm^3 [H_2+CO]
Feed+Fuel: 14.2 to 14.8 MJ/Nm^3 [H_2+CO]

Capex:

H_2 and HyCO plants (incl. purification):
25 to 370 mm USD

Description

Feedstocks are desulfurized, mixed with steam and pre-heated.

Optionally a catalytic pre-reforming step may be foreseen to convert the feed/steam mixture to a methane rich gas to improve efficiency of the SMR.

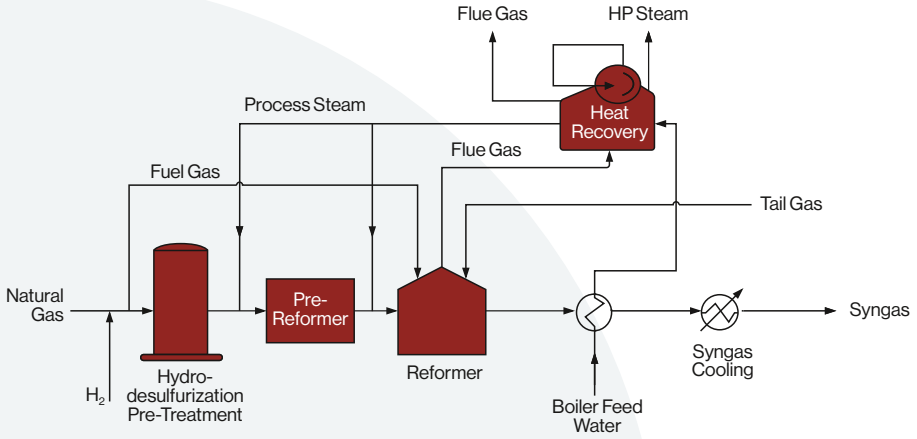
The main reforming reaction takes place in the proprietary top-fired steam reformer in which the feed/steam mixture is converted while passing catalyst filled and heated tubes at temperatures of 800 to 940 °C and pressures of 15 to 45 barg. Reformed gas leaving the reformer contains H_2, CO, CO_2 and unreacted components.

Efficiency of the process and composition of the reformed gas can be adjusted via the process parameters reforming pressure, temperature and steam to feed ratio.

In case H_2 yield should be increased or maximized a catalytic shift reactor may be added and fed with reformed gas to convert CO and steam to additional H_2 and CO_2.

In case a high CO yield is targeted CO_2 may be separated from reformed gas and recycled to the SMR. Additional import CO_2 may be added if available.

Suitable product purification technologies include: PSA and membrane for H_2, amine wash (aMDEA) for CO_2 removal and methane wash Cold Box for CO.



Main features:

- Flexibility in process design to optimize for best efficiency, lowest Capex or lowest total cost of ownership
- Optimized integration of refinery off-gases for H_2 production and recovery
- Best in class plant reliability and operability through operational feedback from Air Liquide's own plants.

References

> 140 (> 40 in last 20 years)

Contact

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Small-Scale Standard Hydrogen Plant

Application

Hydrogen production by steam reforming in a highly standardized and modularized plant

Feedstock

Natural gas, refinery off-gas, LPG, naphtha

Product

Hydrogen

Co-product

Steam

Capacity

15,000 - to 45,000 $Nm^3/h\ H_2$

Economics

Opex:

Feed+Fuel: 14.5 to 15.0 $MJ/Nm^3\ H_2$ (Figures based on nat. gas feed & fuel)

Capex:

25 to 60 mm USD

Description

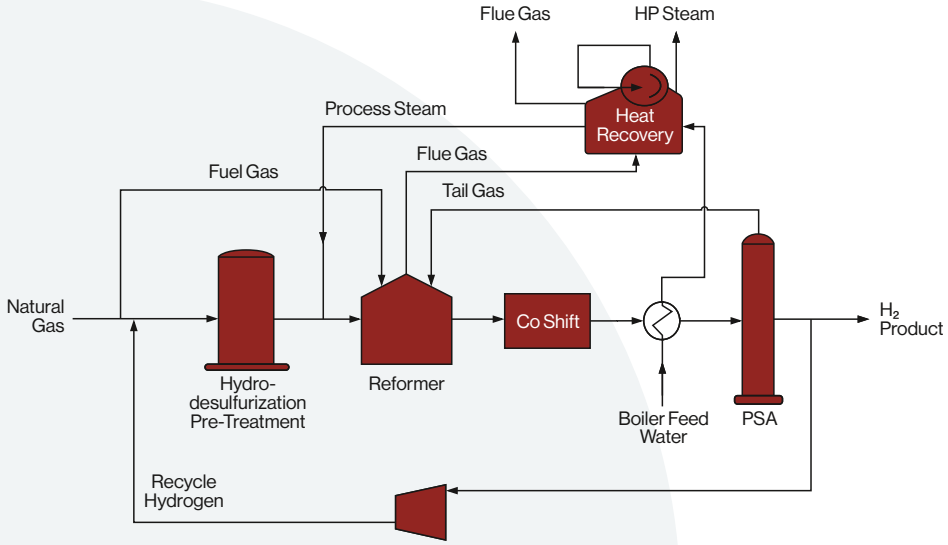
The small-scale standard H_2 plant product is based on hydrogen production via steam reforming of hydrocarbon feedstocks. Additionally a CO-shift and PSA unit are included to maximize the H_2 yield and purify the H_2. For more details regarding the process technology reference is made to the description of Steam Methane Reforming (SMR).

The small-scale standard H_2 plant product includes four different plant sizes with pre-defined equipment, piping arrangement and lay-out.

Its design is optimized for minimum total cost of ownership, but nevertheless allows for considerable process flexibility.
The product is suitable for receiving different types of feedstocks, its configuration may be selected for high or low steam co-product ratios with an option for high export steam quality. A pre-reformer may be included as well, particularly in combination with liquid feedstocks.

Main features:

- Design of standard plant allows for considerable process flexibility
- High degree of modularization to limit exposure during construction
- Compact plant layout and small foot-print
- Delivery time < 15 month FOB from project award



References

>20 (6 in last 10 years)

Contact

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SMR-X™ – Zero Steam Hydrogen Production

Application

Production of hydrogen in a radiative heat exchange steam methane reformer (SMR) without co-export of steam

Feedstock

Natural gas, refinery off-gas, LPG, naphtha

Product

Hydrogen

Co-product

None (optionally steam at low co-export ratio)

Capacity

Up to 100,000 Nm^3/h hydrogen

Economics

Opex:

Feed+Fuel: Appr. 13.6 MJ/Nm^3 H_2
(Figures based on nat. gas feed & fuel)

Capex:

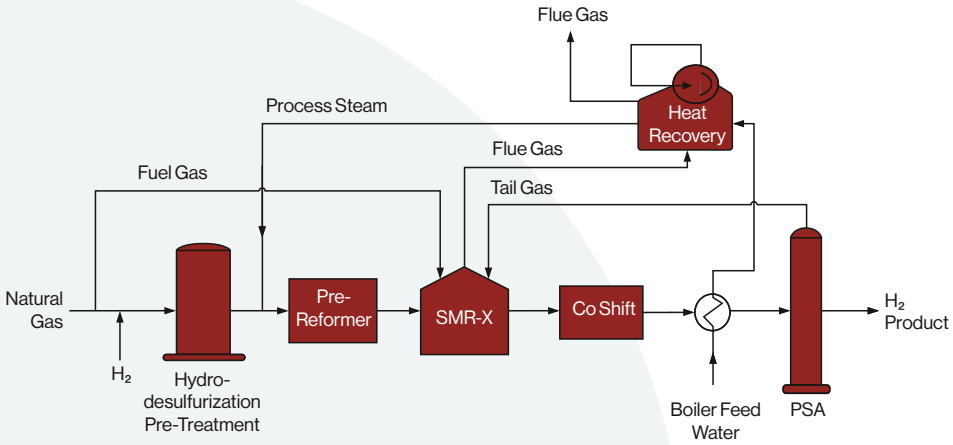
25 to 135 mm USD

Description

SMR-X technology is based on a new generation steam methane reformer furnace with additional heat recovery of the reformed gas leaving the reaction zone back to the catalyst bed.
To achieve this, the reformed gas passes via heat exchange tubes, located inside the main reformer tubes, before leaving the reformer.

Geometry and material of the internal heat exchange system is optimized for high efficiency and reliability. Consequently, utilization of SMR-X allows for a H_2 plant design with balanced steam production and consumption at superior overall process efficiency compared to conventional SMR technology. Also, highly efficient H_2 plant designs with very low steam co-export ratios are possible.

Furthermore, the plant's steam system is simplified and the reformer size of SMR-X is reduced compared to a conventional furnace, because approximately 20% of the required process heat is supplied by internal heat exchange.



Main features:

- H_2 plant de-coupled from steam host
- Highest efficiency of all available zero steam solutions
- >5% reduction of CO_2 emissions compared to conventional SMR based zero steam design
- Attractive plant Capex due to compact reformer design

Contact

hydrogen-syngas@airliquide.com

ATR – Autothermal Reforming

Application

Production of syngas by partial oxidation of gaseous hydrocarbon feed followed by a catalytic reforming conversion.

The syngas can be used as feedstock for different synthesis processes such as methanol or Fischer-Tropsch synthesis. Syngas components can be also separated to pure products (H_2, CO, CO_2)

Feedstock

Natural gas, refinery offgas, pre- reformed gas, Fischer-Tropsch tail-gas, LPG, Naphtha

Product

Syngas (H_2+CO)

Co-product

None

Capacity

Up to 1,000,000 Nm^3/h (dry) per reactor

Economics

Yield: 2.5- 4.0 Nm^3 syngas / Nm^3 natural gas (including fuel for fired heater)

Oxygen consumption: 0.15 - 0.25 kg O_2 / Nm^3 syngas

Capex: 160 to 280 mm USD

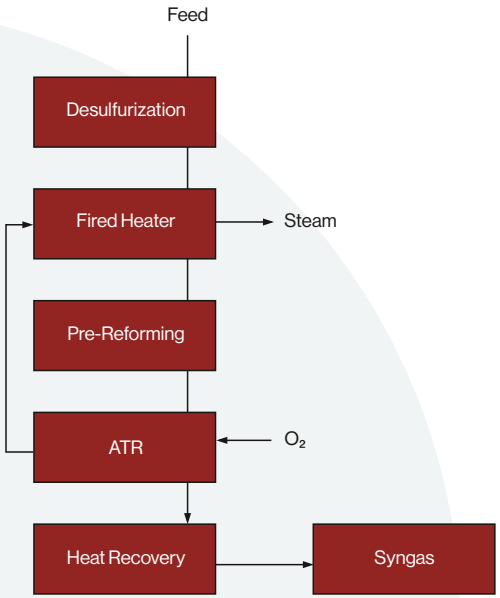
Description

Desulfurized feed gas is preheated and optionally pre-reformed prior to entering the ATR reactor. The gas is fed via the proprietary burner into a refractory lined reactor operating at 30 to 100 barg, where it reacts with oxygen and steam to form syngas. The syngas is further reformed via a Ni-based catalyst bed located in the same reactor. The syngas is cooled in a waste heat boiler producing high pressure steam.

Depending on the needed syngas properties of the downstream process this technology can be applied as stand-alone ATR or as a combination of SMR and ATR known as Combined Reforming.

Main Features:

- Provide large quantities of H_2-rich gas at lowest cost
- Compact reactor
- High pressure (up to 100 bar)



References

>30

Contact

hydrogen-syngas@airliquide.com

Gas POX – Natural Gas Partial Oxidation

Application

Production of CO, oxogas and syngas by partial oxidation of hydrocarbon feed in a refractory lined reactor

Feedstock

Natural gas, refinery offgas

Product

Syngas (H_2/CO < 1), oxogas, carbon monoxide

Co-product

Steam

Capacity

Up to 150,000 Nm³/h syngas

Economics

Oxygen consumption:
0.32 to 0.38 kg/Nm³ syngas (dry)

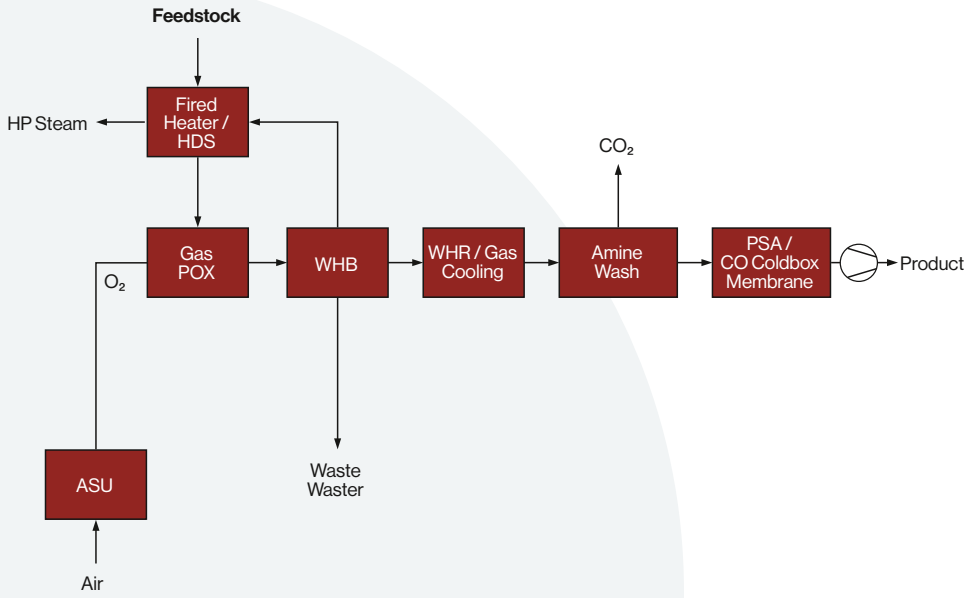
Capex:
10 to 100 mm USD

Description

Feed gas is desulfurized, mixed with steam and preheated in a fired heater.
Feed, steam and oxygen are fed from the proprietary burner to a refractory lined reactor operating at up to 100 barg, where H_2, CO and CO_2 are produced via partial oxidation.
Reformed gas is cooled down producing high pressure steam. CO_2 is removed from the syngas in an amine wash unit.
In case a high CO yield is targeted CO_2 may be separated from syngas and recycled to the POx. Additional import CO_2 may be added if available.
Suitable product purification technologies include: PSA and membrane for H_2, oxogas, amine wash (aMDEA) for CO_2 removal and partial condensation Cold Box for CO.

Main Features:

- Efficient technology for products with low H_2/CO ratio or for pure CO production
- Revamp of residue POx reactors allows for switching to more economic nat. gas feed
- Low CO_2 footprint



References

6

Contact

hydrogen-syngas@airliquide.com

Lurgi MPG™ – Multi-Purpose Gasifier

Application

Utilization of all kinds of liquid hydrocarbon residues from refinery or chemical processes for the production of syngas by non-catalytic partial oxidation

Feedstock

Typical feedstocks are residue from oil refining like: asphalt, bitumen, tar, visbreaker residue, hydrocracker residue, FCC residue, vacuum residue, coal tar, oil sand tar, etc

Product

Syngas (H_2 + CO)

Co-product

None

Capacity

Up to 200,000 Nm^3/h dry syngas per gasifier

Economics

Individual costs vary significantly depending on feedstock, size, location, integration in refinery, etc.

Oxygen consumption:
0 .7 Nm^3 O_2/kg feed

Capex: 180 to 400 mm USD

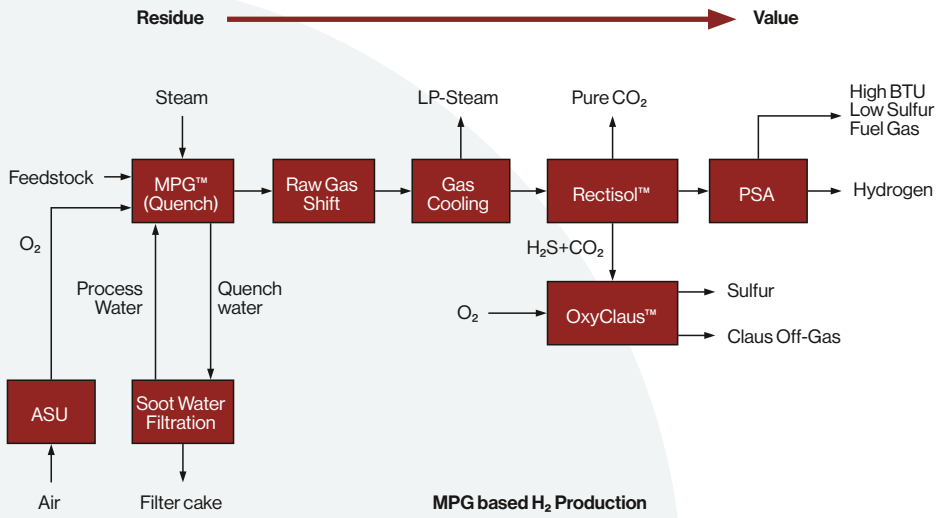
Description

The feedstock together with oxygen and steam is fed via the proprietary MPG-burner into the refractory lined entrained flow reactor operating at 30 to 100 barg, where it reacts in a non-catalytic partial oxidation at typically 1,200 to 1500 °C to form syngas. The syngas leaving the bottom of the reactor is cooled by quench or in a waste heat boiler, depending on feedstock characteristics and downstream usage.

The proprietary MPG-burner design allows a wide variety of feedstock properties to be handled safely and reliably, covering high viscosity and even occasional particles up to millimeter size. The pressurized water cooling of the burner insures safe operation under all conditions. The technology may also be adapted to the usage of slurries with solid content or bio-based syncrude.

Main Features:

- Valorization of residues capable of converting almost any liquid feedstock
- Highly tolerant to impurities
- High pressure



MPG based H_2 Production

Contact

hydrogen-syngas@airliquide.com

Lurgi FBDB™ – Fixed Bed Dry Bottom Coal Gasification

Application

Gasification of coal to produce syngas

Feedstock

Lumpy coal, especially suited for low-rank (high ash, high water) coal

Product

Syngas (H_2+CO), due to high CH_4 content particularly suited for the production of SNG (synthetic natural gas) or DRI (direct reduction of iron ore)

Co-product

Crude tar acids (phenols), sulfur, tar, oil, naphtha, ammonia

Capacity

40,000 to 120,000 Nm^3/h dry syngas per gasifier, typically more than 5 reactors per plant, largest plant 40 reactors at one site.

Economics

Individual costs depend strongly on location, coal quality, etc.

Yield:
2000 Nm^3 dry syngas / ton dry coal

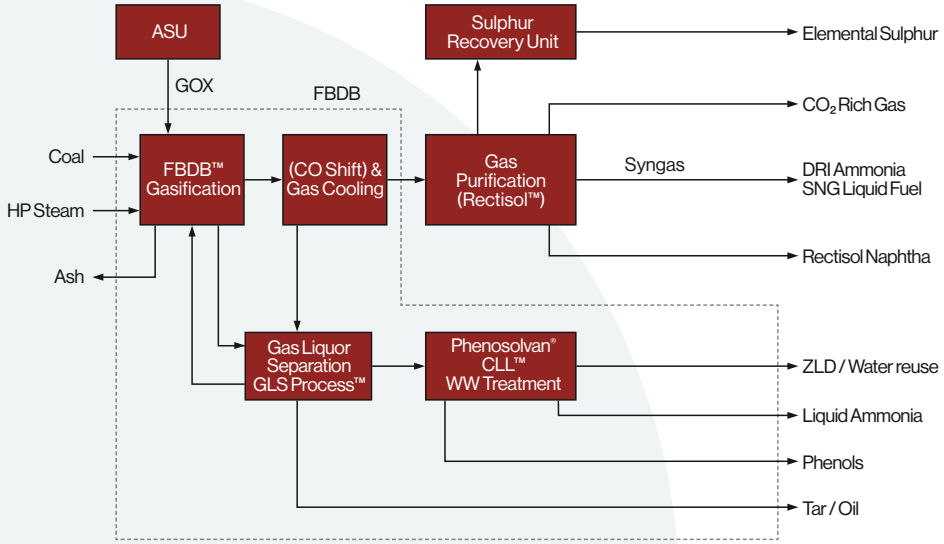
Capex:
420 to 650 mm USD
(cost base: 7 Mk+ in China)

Description

Coal is converted into syngas by reacting in a counterflow fixed bed with oxygen and steam. The raw syngas will be further processed (CO-shift, Rectisol™) to meet the downstream requirements of the processes. Side streams are further treated using proprietary technologies to produce valuable co-products, as well as to meet environmental specifications. Special water treatment allows for zero liquid discharge while minimizing water consumption.

Main Features:

- Robust technology that can be fed with coarse lumps, avoiding the need for grinding and drying
- Higher cold gas efficiency than entrained flow gasification
- Wide variety of coal possible
- Lower water consumption than entrained flow gasification



References

>100 gasifiers

Contact

hydrogen-syngas@airliquide.com

Rectisol™ – Syngas Purification

Application

Selective removal of acid gases (CO_2 and H_2S+COS) and of nearly all trace components (carbonyls, mercaptans, HCN...) from syngas of any gasification (coal, petcoke, residue, heavy oil,...) to meet highest specification reqirements for catalytic processes.

Feedstock

Raw syngas deriving from gasification of any carbon containing feedstock

Product

Clean/high purity syngas (H_2+CO) for catalytic processes, clean hydrogen

Co-product

H_2S rich gas for SRU, CO_2 offgas ready for storage/utililization

Capacity

100,000 to 1,000,000 Nm^3/h per train

Economics

Individual costs vary significantly depending on feedstock, size, purity request, etc.

Capex: 90 to 290 mm USD

Description

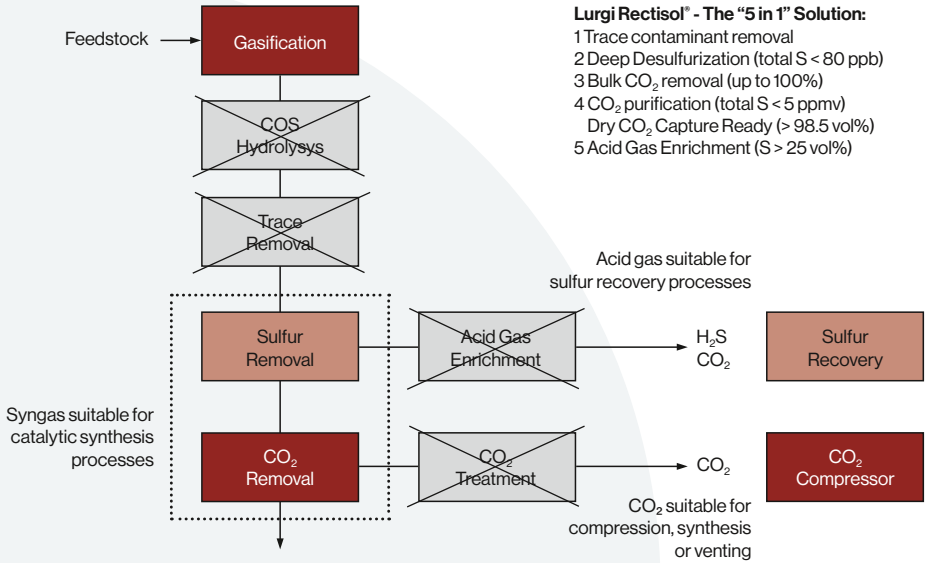
Acid gases in raw gases from any gasification are removed by absorption with a physical solvent (cold methanol). The rich solvent leaving the contactor is regenerated by flashing and stripping. Different process configurations are available to deliver a tailored solution optimized for Capex and Opex for a given syngas specification.

Rectisol™ is the leading process when it comes to the purification of gasification-based syngas for catalytic applications (production of SNG, methanol, ammonia, or Fischer-Tropsch) as well as hydrogen

Using inexpensive solvent in combination with optimized heat integration, the Rectisol process has extremely low operating costs and high availability.

Main Features:

- Highest level of purity for all contaminants
- Low Capex and Opex when compared to other purification process
- Low cost solvent
- CO_2 offgas meeting most stringent emissions requirements



Lurgi Rectisol® - The "5 in 1" Solution:
1 Trace contaminant removal
2 Deep Desulfurization (total S < 80 ppb)
3 Bulk CO_2 removal (up to 100%)
4 CO_2 purification (total S < 5 ppmv)
Dry CO_2 Capture Ready (> 98.5 vol%)
5 Acid Gas Enrichment (S > 25 vol%)

References

> 110 (> 35 since 2005)

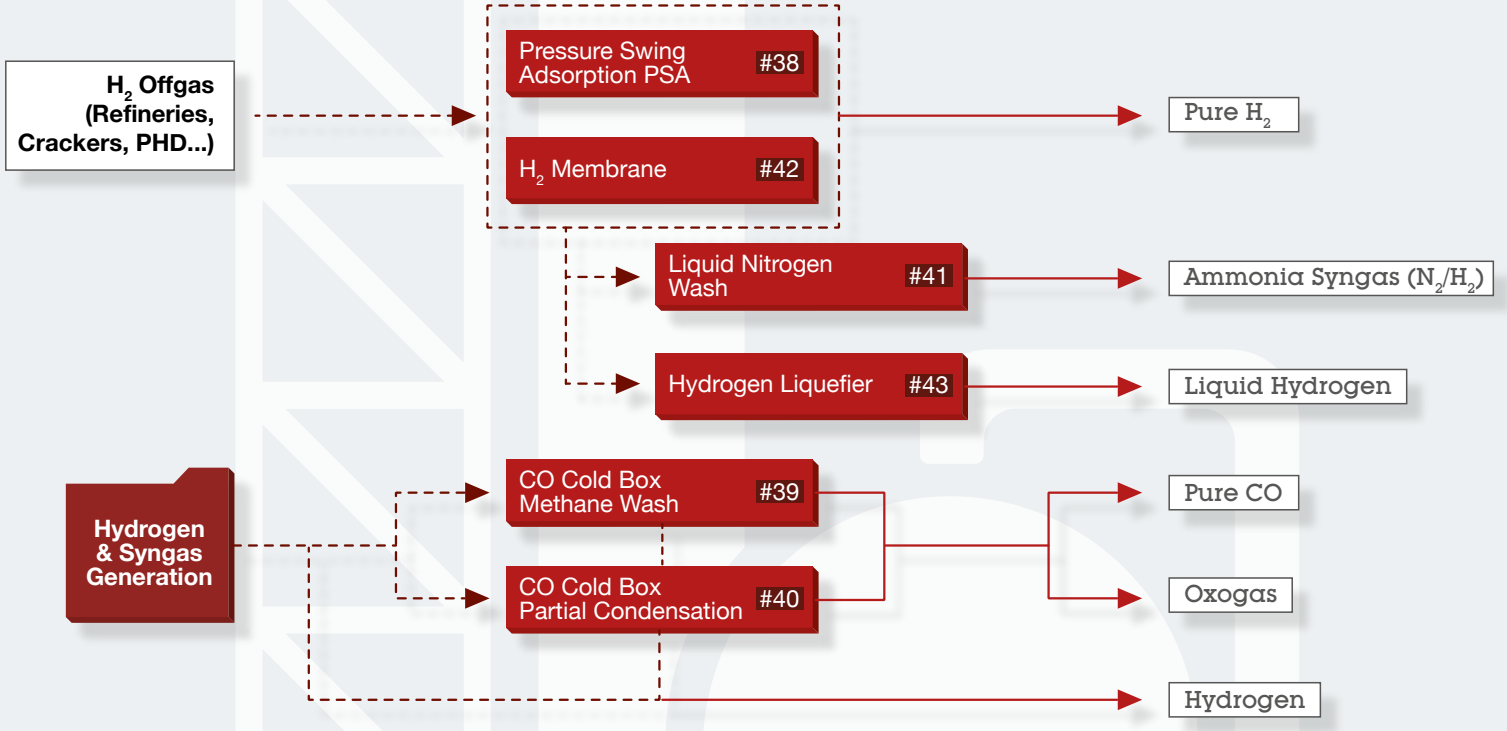
Contact

hydrogen-syngas@airliquide.com

HYDROGEN & SYNGAS SEPARATION

Leveraging on our vast technology portfolio, we have the means to combine various patented processes to address any Hydrogen & Syngas separation challenge. Our customers benefit from continuous improvements due to Air Liquide's own track record in its operational experience of such processes - from cryogenics to permeation to adsorption.

Overview


H_2 Offgas (Refineries, Crackers, PHD...)
Pressure Swing Adsorption PSA #38
H_2 Membrane #42
Pure H_2
Liquid Nitrogen Wash #41
Ammonia Syngas (N_2/H_2)
Hydrogen Liquefier #43
Liquid Hydrogen
Hydrogen & Syngas Generation
CO Cold Box Methane Wash #39
CO Cold Box Partial Condensation #40
Pure CO
Oxogas
Hydrogen

Pressure Swing Adsorption (PSA) Hydrogen Purification

Application

Recovery and purification of pure hydrogen from different H_2-rich streams

Feedstock

Raw hydrogen from SMR, POX, cryogenic purification, methanol plant purge gases, ethylene off-gas, styrene offgas, gasification, ammonia plant, CCR, and other offgases or any combination of the above

Product

Hydrogen up to 99.9999% purity

Co-product

None

Capacity

5,000 to 200,000 Nm^3/h

Economics

H_2 recovery rate: 60 to 90%

Opex: Feed+Fuel: Appr. 13.6 MJ/Nm^3 H_2 (Figures based on nat. gas feed & fuel)

Capex: 1 to 5 mm USD

Description

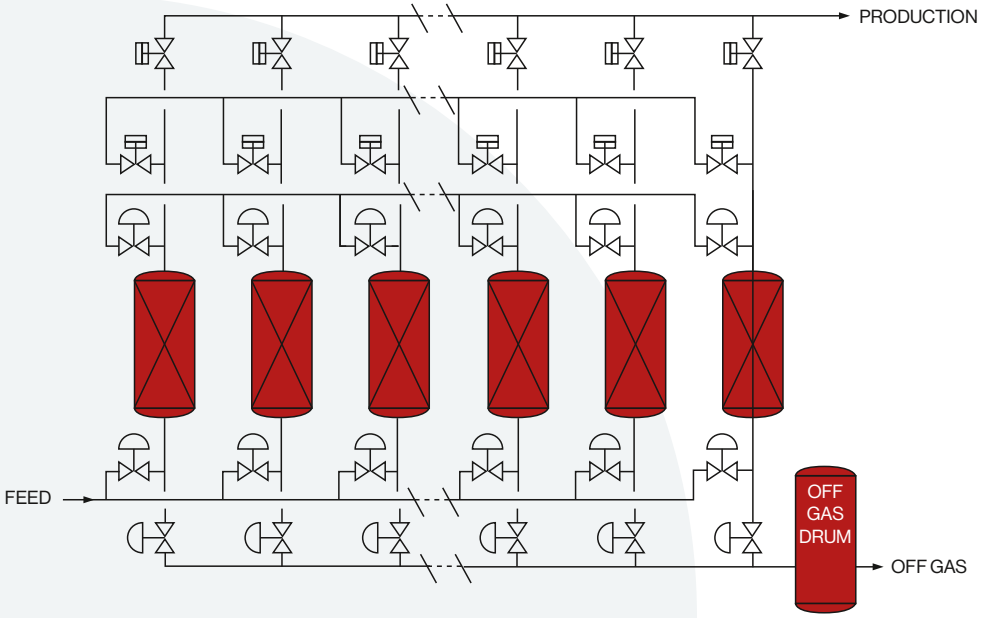
Pure H_2 product is delivered at a pressure close to feed pressure (pressure drop across PSA could be as low as 0.5 bar) and impurities are removed at a lower pressure (typical PSA offgas pressures range from 1.1 to 10 bara).

The PSA tail-gas, containing impurities, can be sent back to the fuel system (SMR burners or refinery fuel network) with or without the need of a tail-gas compressor. Operation is fully automatic.

PSA units use the most advanced adsorbents on the market and patented high efficiency cycles to provide maximum recovery and productivity. Typical on-stream factors are >99.9%.

Turndown can be as low as 25%.

PSA units are compact, fully skid- mounted and pre-tested units designed for outdoor and unmanned operation.



References

>70 (in operation or under construction)

Contact

hydrogen-syngas@airliquide.com

CO Cold Box – Methane Wash

Application

Carbon monoxide (CO) production or ratio-adjusted synthesis gas production from synthesis gas for use in chemical industry

Feedstock

Synthesis gas from natural gas, naphtha or coal/residue.

Product

CO up to 99.99% purity

Co-product

Hydrogen, oxogas, methane, LNG

Capacity

Up to 34 000 Nm^3/h (1 020 tpd) CO

Economics

Opex: Specific energy:
300 to 600 kWh/tonne

Capex: Economics are highly dependent on the type and quality of feedstock (coal, Naphtha or natural gas), as well as the required CO purity and pressure (MDI/TDI, PC, AcAc, MEG, etc.) and of the required scope of supply

Description

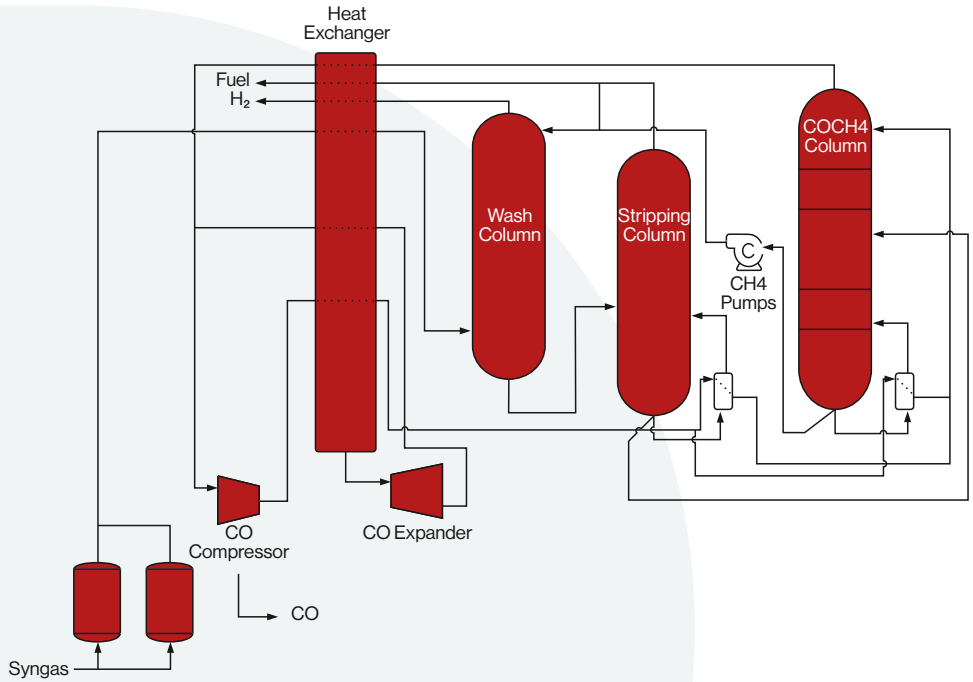
Methane Wash process is based on cryogenic separation technology using the difference in boiling points of the main components from the synthesis gas.

Feed gas is pretreated to remove impurities which will freeze at cryogenic temperatures encountered in the process. It is then cooled down in heat exchangers and washed with liquid methane before being purified step by step through distillation columns.

Every cryogenic process is tailor-made to fit the customer's specifications and other requirements on co-products.

Main Features:

- Greatest number of references in CO/N_2 separation
- Highest safety standards for all Cold Boxes
- In-house technology for highly safe, highly reliable & highly efficient CO expander
- High CO recovery



References

32 (latest 2016)

Contact

hydrogen-syngas@airliquide.com

CO Cold Box – Partial Condensation

Application

Carbon monoxide (CO) production or ratio-adjusted synthesis gas production from synthesis gas for use in chemical industry

Feedstock

Synthesis gas from natural gas/naphtha or coal/residue gasification.

Product

CO up to 99.99% purity

Co-product

Hydrogen, oxogas, methane, LNG

Capacity

Up to 55 000 Nm^3/h (1 650 tpd) CO

Economics

Opex:

Specific energy: 18 to 100 kWh/tonne

Capex:

Economics are highly dependent on the type and quality of feedstock (coal, Naphtha or natural gas), as well as of the required CO purity and pressure (MDI/TDI, PC, AcAc, MEG, etc.) and of the required scope of supply

Description

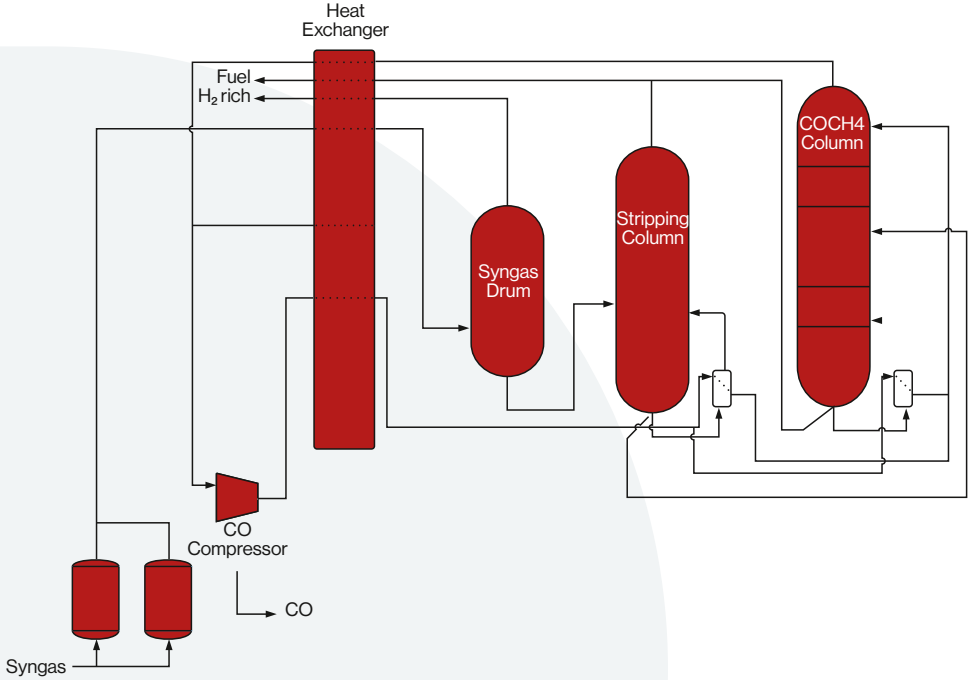
Partial Condensation process is based on cryogenic separation technology using the difference in boiling points of the main components from the synthesis gas.

Feed gas is pretreated to remove impurities which will freeze at cryogenic temperatures encountered in the process. It is then partly condensed in heat exchangers and flashed in a syngas drum before being purified step by step through distillation columns.

Every cryogenic process is tailor-made to fit the customer's specifications and other requirements on co-products.

Main Features:

- Greatest number of references in CO/N_2 separation
- Highest safety standards for all cold boxes
- Low specific energy consumption for wide range of feedstock



References

17 (latest 2017)

Contact

hydrogen-syngas@airliquide.com

Liquid Nitrogen Wash

Application

Production of pure synthesis gas for ammonia plants

Feedstock

Raw hydrogen
(from Amine Wash / Rectisol™)

Product

Pure ammonia synthesis gas with a stoechiometric N_2/H_2 ratio of 1:3

Co-product

Methane, LNG

Capacity

Up to 230 000 Nm^3/h (2 100 tpd)

Economics

Opex:

- LIN: 0 to 0.02 tonne/tonne of syngas
- Power: 0 to 900 kWh/tonne of LNG (if LNG co-production)

Capex:

Economics are highly dependent on the co-product requirements and required scope of supply

Description

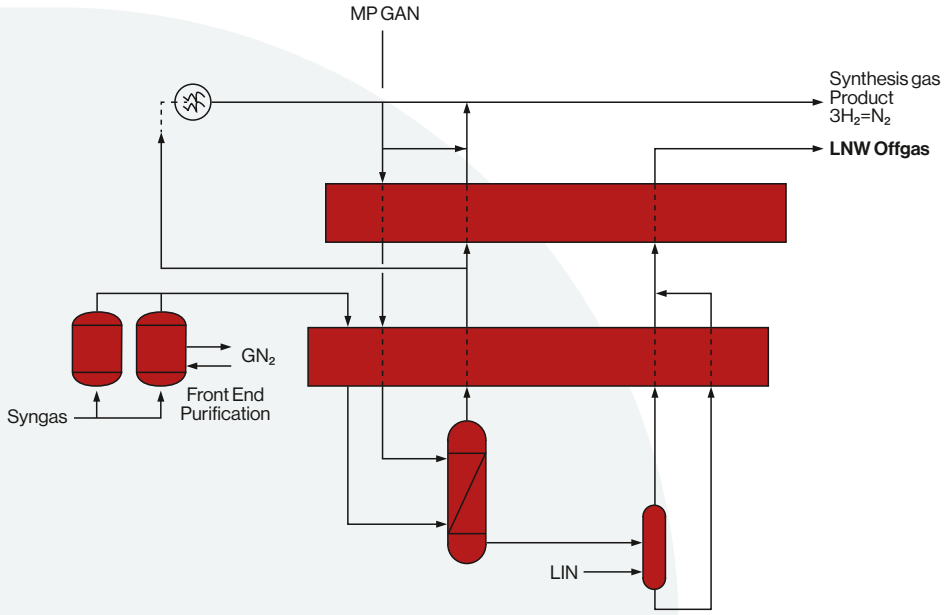
Raw hydrogen and high pressure nitrogen are fed to the liquid nitrogen wash unit.
Both streams are cooled down against product gas.

Raw hydrogen is fed to the bottom of the nitrogen wash column and condensed nitrogen liquid is fed to the top. Trace impurities, like methane, argon and carbon monoxide, are removed and recycled as fuel gas.

To establish the desired H_2/N_2 ratio, high pressure nitrogen is added to the process stream.

Main Features:

- Highest safety standards for all Cold Boxes
- Low specific energy consumption for Methane / LNG co-production



References

49 (latest 2015)

Contact

hydrogen-syngas@airliquide.com

Hydrogen Separation Membranes

Application

Recovery of hydrogen in refinery or chemical plants purge gas
H_2 / CO ratio adjustment

Feedstock

Any purge gas streams with hydrogen concentrations >20 % (vol).

Product

Hydrogen (>99% vol achievable)

Co-product

None

Capacity

Membrane systems are truly scalable with virtually no upper capacity limit Largest system referenced by Air Liquide: 124 membrane cartridges

Economics

Opex:

- Dependant on feedstock quality
- Hydrogen recovery > 98%
- 50% + turndown capabilities

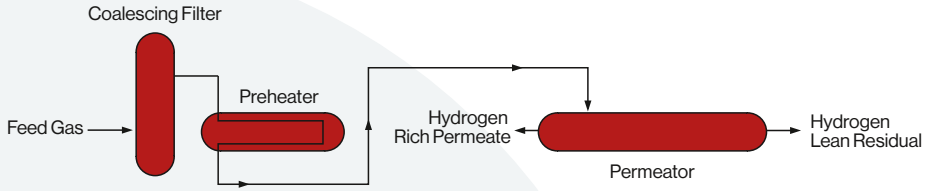
Capex:

1 mm to 10 + mm USD

Description

Our membranes operate on the basis of selective permeation. Each membrane is composed of millions of polymeric hollow fibers similar in size to the diameter of a human hair. The "fast gases," or gases with a higher permeation rate, permeate through the membrane into the hollow interior and are channeled into the permeate stream. Simultaneously, the "slower gases" flow around the fibers and into the residue stream. As a result, the fibers have the ability to selectively separate a fast gas like hydrogen from carbon monoxide, methane, heavier hydrocarbons and other slower gases

The process begins when pressurized feed gas is routed to the coalescing filter to remove contaminants and protect the membranes' fiber from liquid aerosols and particulates. Feed gas is then preheated before entering the membranes. The membranes then separate the feed into the hydrogen-rich permeate and hydrogen-lean residue. The separation of permeate and residual gas is driven by the hydrogen partial pressure difference between the feed gas and permeate gas, as well as our advanced polymer material. The non-porous hollow fiber membranes selectively allow faster molecules to permeate the membrane wall while slower, bulkier molecules remain on the high pressure side.



Main Features:

- No moving parts
- Skid mounted systems cartridge design for simple installation
- Estimated payback period of less than a year
- High permeability membranes for compact, low capital system design
- Unrestrained turndown capabilities
- Linear scale up for all size systems
- Hollow fiber membranes offer higher area to volume efficiency resulting in better packing efficiency, smaller footprint and reduced weight and module count.

Contact

hydrogen-syngas@airliquide.com

Hydrogen Liquefier

Application

Liquefaction of all kinds of H_2 stream for the filling of H_2 liquid storages which ease transportation of H_2 molecules

Feedstock

Many sources : natural gas, coal, or electrolyse

Product

Liquid hydrogen

Co-product

None

Capacity

Up to 50 TPD

Economics

Opex:
Less than 10kWh/kg LH_2

Description

Hydrogen to be treated may come from different sources. Accordingly, source warm purification upstream cold purification and liquefier by itself may be required.

Hydrogen is precooled thanks to N_2/MR cycle and the use of turbo-expander together with cryogenic exchangers.
The liquefier uses BAHX (widely used in cryogenic gas liquefaction).

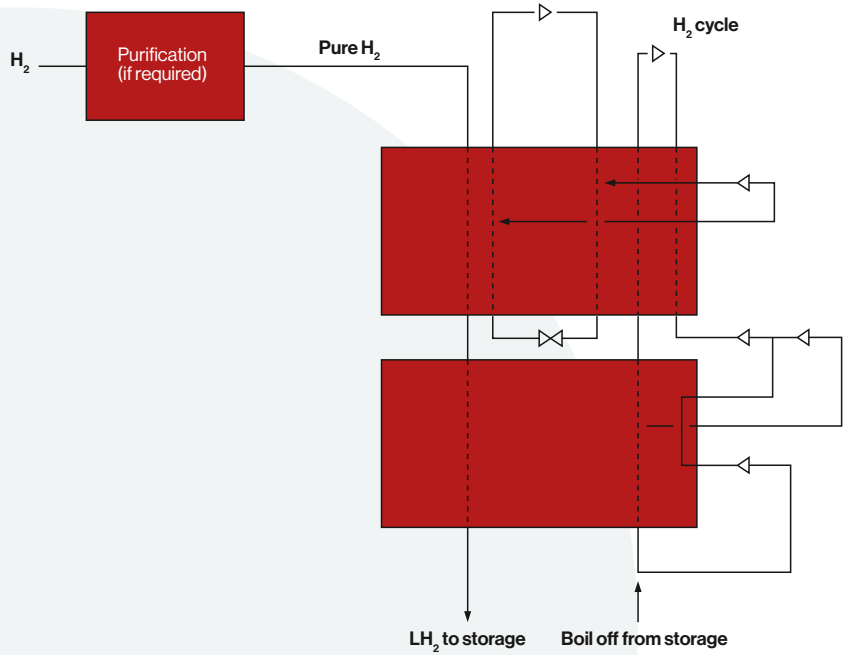
Then it is cooled and liquefied thanks to a H_2 cycle and the use of cryogenic expanders together with a highly optimized cryogenic exchangers' arrangement. The particularity of hydrogen liquefaction is the use of catalyst to convert ortho-hydrogen into para-hydrogen in order to reduce boil-off in storage.

Boil-off from LH_2 storage is sent back into H_2 cycle, in order to recover molecules.

Downstream infrastructure (storages, loading bays, etc.) can also be supplied.

Contact

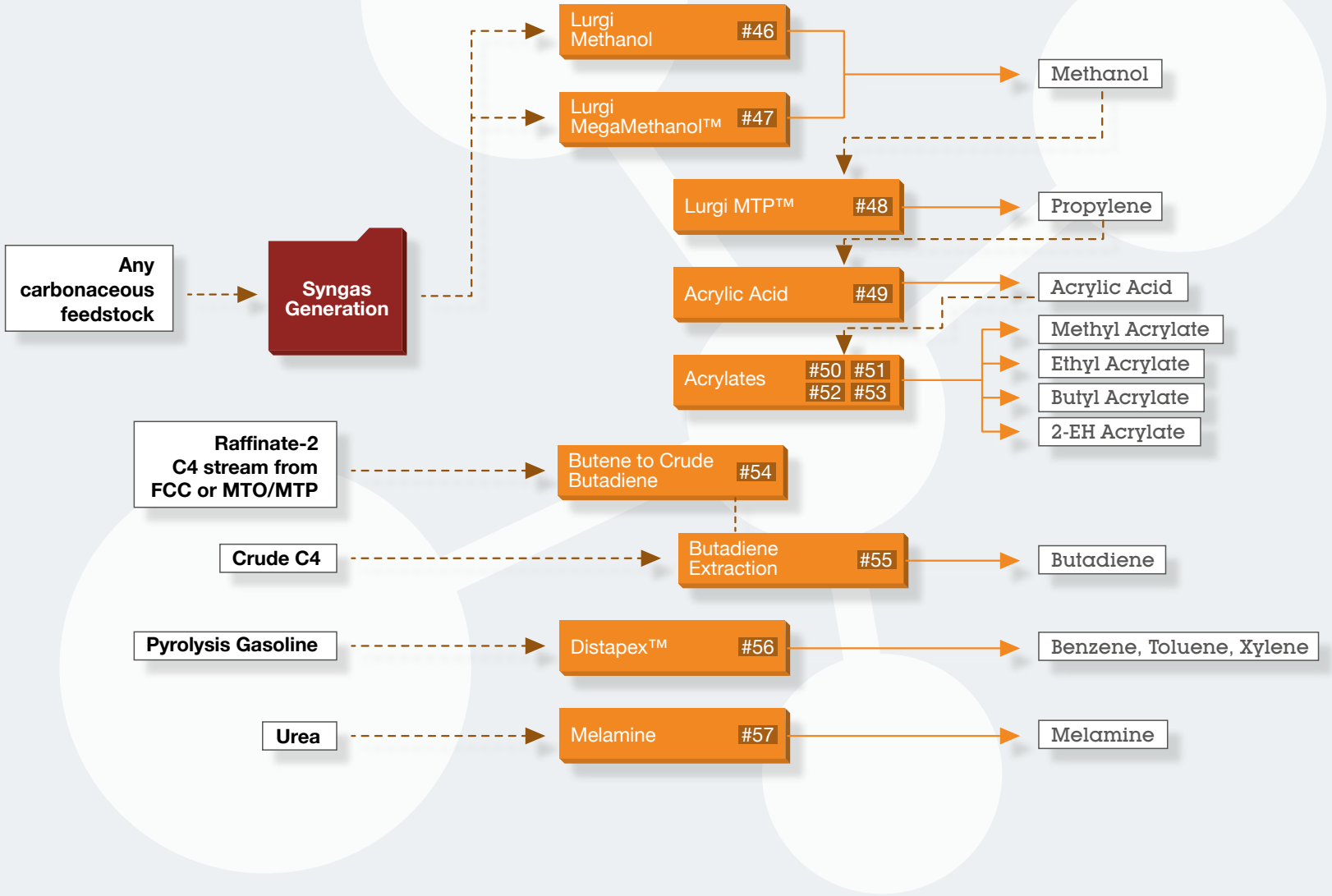
hydrogen-syngas@airliquide.com



CHEMICALS

Using our expertise and patents in catalytic conversion and purification techniques, we provide technology to produce or to separate valuable intermediate chemicals from syngas and other feedstock.
Our experience and continuous development of our products ensures well referenced safe and reliable technology for our customers that can be tailored to meet their specific needs.

Overview


Any carbonaceous feedstock
Syngas Generation
Lurgi Methanol #46
Lurgi MegaMethanol™ #47
Methanol
Lurgi MTP™ #48
Propylene
Acrylic Acid #49
Acrylic Acid
Acrylates #50 #51 #52 #53
Methyl Acrylate
Ethyl Acrylate
Butyl Acrylate
2-EH Acrylate
Raffinate-2 C4 stream from FCC or MTO/MTP
Butene to Crude Butadiene #54
Crude C4
Butadiene Extraction #55
Butadiene
Pyrolysis Gasoline
Distapex™ #56
Benzene, Toluene, Xylene
Urea
Melamine #57
Melamine

CHEMICALS

Lurgi™ Methanol

Application

Medium-scale production (< 1 million tpa) of methanol from synthesis gas derived from all kinds of carbonaceous material

Feedstock

Natural gas or synthesis gas (H_2+CO)

Product

Methanol in the required specification (AA, IMPCA, etc.)

Co-product

None

Capacity

Up to 3,500 tpd

Economics

Natural gas consumption:
29 MMBTU (LHV)/tonne (this includes energy for the process, all utilities and the ASU that produces 0.4 - 0.5 tonne O_2/tonne methanol)

Capex:
250 to 500 mm USD

Description

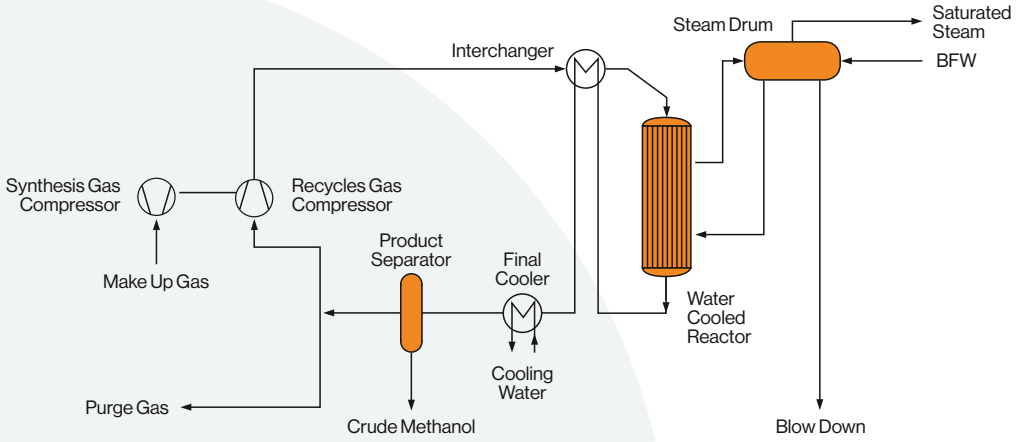
In the LP methanol unit (either with integrated gas generation based on natural gas or downstream of a coal gasification unit) syngas is converted over a copper catalyst in water-cooled reactor to produce raw methanol.

Unconverted synthesis gas is recycled back to the synthesis loop to enhance yield and carbon efficiency.

Raw methanol leaving the synthesis loop is further distilled to meet the required specification.

Main Features:

- Simple to operate over full catalyst life time
- Optimized heat transfer preventing temperature peaks in the methanol reactor
- Flexible integration with any syngas generation



Note: scheme represents only the methanol synthesis unit

References

>40

Contact

chemicals@airliquide.com

CHEMICALS

Lurgi MegaMethanol™

Application

Large scale production (> 1 million tpa) of methanol from synthesis gas derived from all kinds of carbonaceous material

Feedstock

Natural gas or synthesis gas (H_2+CO)

Product

Methanol in the required specification (AA, IMPCA, etc.)

Co-product

None

Capacity

2,500 to 7,000 tpd
10,000 tpd (GigaMethanol)

Economics

Natural gas consumption:
29 MMBTU (LHV)/tonne (this includes energy for the process, all utilities and the ASU that produces 0.4 - 0.5 tonne O_2/tonne methanol)

Capex:
400 to 1100 mm USD

Description

In the Lurgi MegaMethanol™ unit (either with integrated gas generation based on natural gas or down-stream of a coal gasification unit) syngas is converted over a copper catalyst in a two-stage reactor system (water-cooled followed by gas-cooled) to produce raw methanol. Unconverted synthesis gas is recycled back to the synthesis loop to enhance yield and carbon efficiency.

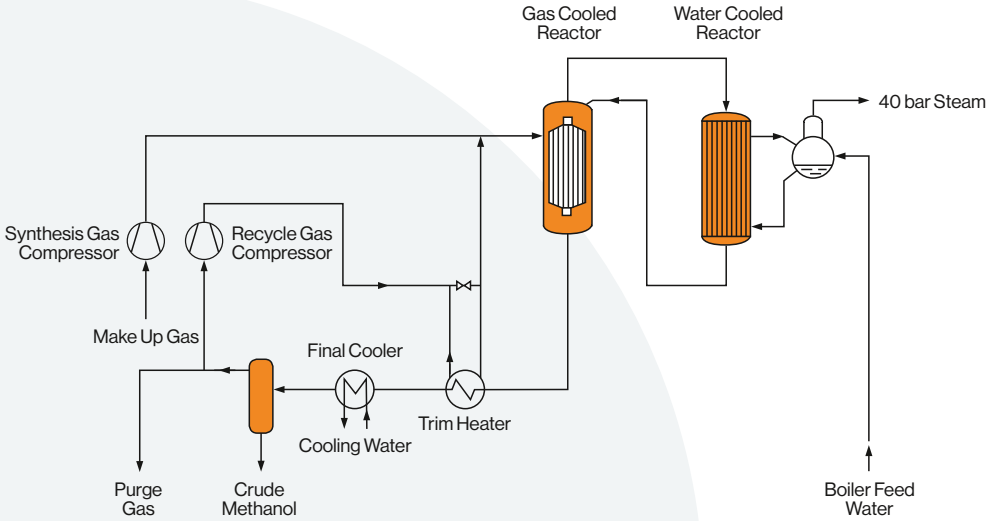
Raw methanol leaving the synthesis loop is further distilled to meet the required specification.

Due to high energy integration of the unit and the low recycle ratio in the synthesis loop, Lurgi MegaMethanol™ yields the lowest production cost.

Our most recent design (GigaMethanol) can produce up to 10,000 tpd in one single train.

Main Features:

- Methanol loop with minimized recycle ratio resulting in reduced piping and equipment
- Process intensification through interstage condensation possible
- Best referenced technology in the 5000 mtpd class



Note: scheme represents only the methanol synthesis unit

References

9 in operation (5 gas based, 4 coal based),
4 in construction (2 gas based, 2 coal based).

Contact

chemicals@airliquide.com

CHEMICALS

Lurgi MTP™ – Methanol-to-Propylene

Application

This on-purpose production of propylene from methanol is a way to produce propylene independently from crude oil and/or natural gas liquids. Hence, it supports the utilization of land-locked coal or natural gas reserves as feedstock for petrochemical processes

Feedstock

Methanol

Product

Polymer-grade propylene

Co-product

Gasoline and LPG

Capacity

500 to 1,500 tpd

Economics

Yield:
3.5 tonnes methanol/tonne propylene

Capex:
250 to 500 mm USD

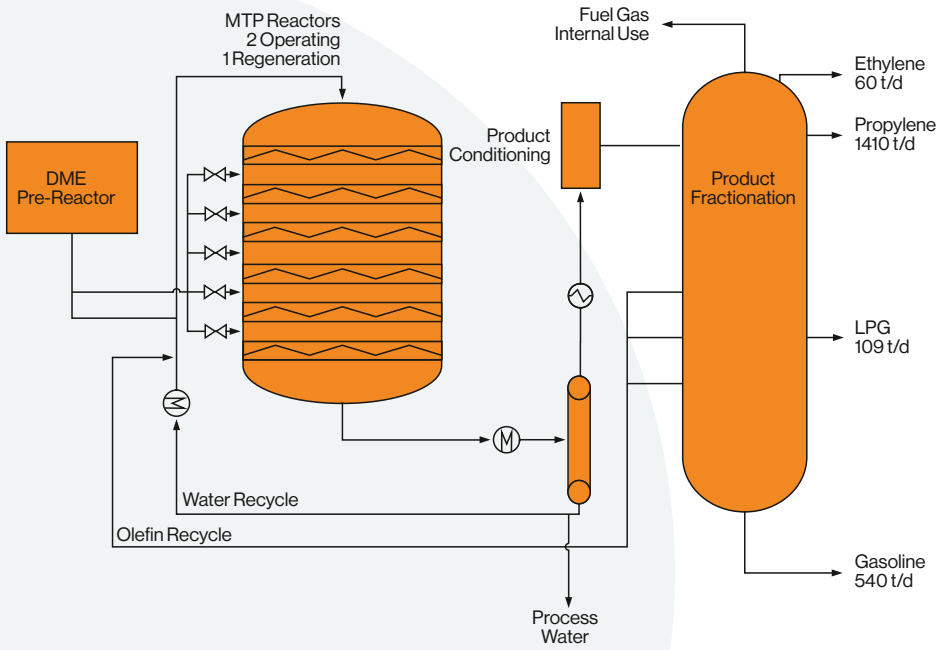
Description

In a first step, methanol is converted into dimethyl-ether (DME) which is, together with recycled hydrocarbon streams, the feedstock for the fixed-bed MTP reactor filled with proprietary zeolite catalyst. The effluent from the MTP reactor is cooled and enters a separation sequence similar to the one applied in steam-crackers. During this sequence, the effluent is separated into different hydrocarbon streams which are partially recycled to the reactor in order to maximise the propylene yield. The last step of the separation sequence yields polymer-grade propylene.

Compared to crude-based processes (naphtha cracking, metathesis, PDH) the MTP process has the lowest cash cost.

Main Features:

- Focus on propylene product
- Lowest cash cost
- High integration potential with methanol and other technologies



References

3 in operation (all coal based), first natural gas based plant in engineering stage.

Contact

chemicals@airliquide.com

CHEMICALS

Lurgi / Nippon Kayaku Acrylic Acid

Application

The combined Lurgi/Nippon Kayaku technology produces ester-grade acrylic acid (EAA). Main uses are adhesives, paints and coatings (acrylic esters)

Feedstock

Propylene

Product

Ester-grade acrylic acid

Co-product

None

Capacity

Up to 20 t/h (single train)

Economics

Capex: 200 to 300 mm USD

Description

Reaction: Acrylic acid (AA) is produced by catalyzed oxidation of propylene in a two-stage tubular fixed-bed reactor system.
The reactors are cooled by circulating molten heat transfer salt. The heat of reaction is used to produce steam.

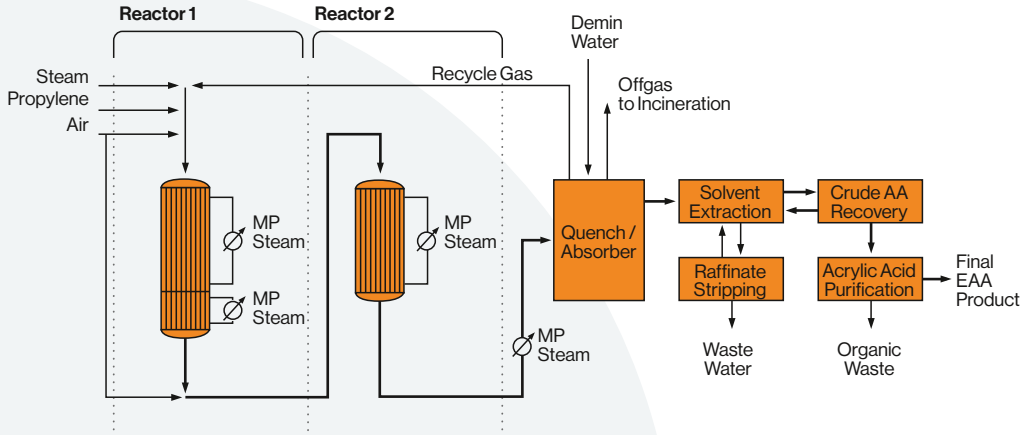
Quench: The AA is recovered from the reactor product gas in a quench tower.
The AA solution is routed to an extractor. Uncondensed gases are sent to an offgas treater to recover the remaining AA. A side draw from the offgas is sent to incineration. Overhead gas is recycled to the first reactor.

Solvent extraction: Liquid-liquid extraction is used to separate water and AA. The solvent is recovered and recycled. In a first step, water and acetic acid are removed to achieve a crude AA to be further purified in the next process steps. The extractor bottom is sent to the raffinate stripper to recover remaining solvents.

Crude AA recovery: In this section, solvent and acetic acid are removed from crude AA using two columns.

Raffinate stripping: The raffinate stripper recovers solvents from the wastewater streams.

The Lurgi/Nippon Kayaku technology combines high performance catalysts with highest acrylic acid yields and outstanding catalyst longevity with an optimized process. With low raw material and energy consumption, low environmental impact and high onstream time, this technology exhibits competitive production costs.



Acrylic acid purification: Crude AA is purified in the ester grade AA column. To maximize AA recovery, dimer is converted to AA in a dedimerizer.

References

1

Contact

chemicals@airliquide.com

CHEMICALS

Methyl Acrylate (Synthomer Licensed)

Application

Production of methyl acrylate (MA) by the esterification reaction of acrylic acid with methanol (MeOH). The methyl acrylate is used mainly for adhesives, paints and coatings

Feedstock

Acrylic acid, methanol

Product

Methyl acrylate

Co-product

None

Capacity

Up to 4 t/h

Economics

Process configuration is optimized resulting in low raw material consumption, optimized energy integration and low utility requirements. Environmental impact minimized. On stream times exceeding 8,000 hours per year could be achieved

Description

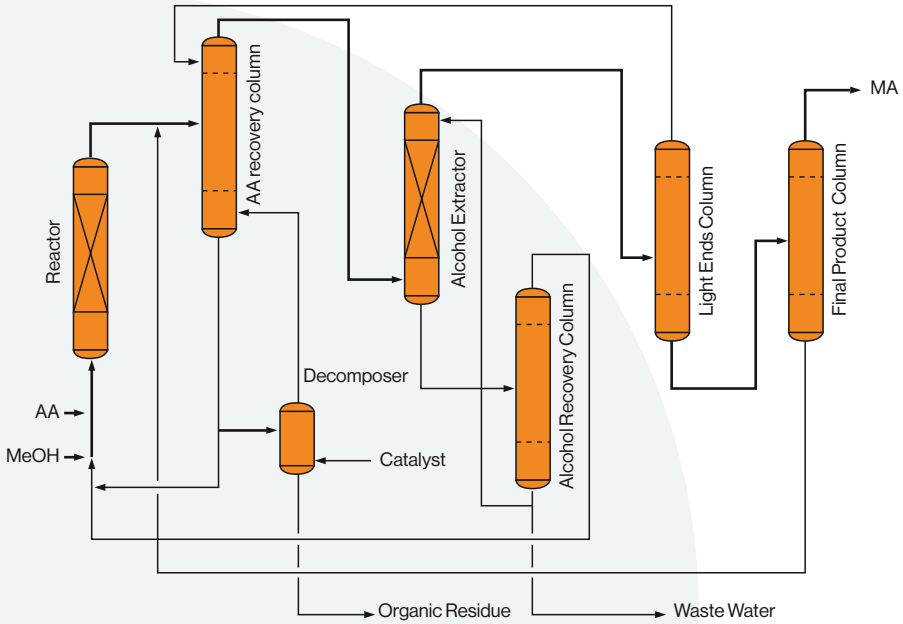
The reaction is catalyzed in a fixed bed reactor by means of a strong acid solid catalyst (ion-exchange resin).

The reactor effluents are routed to the fractionation section to separate unreacted acrylic acid from crude methyl acrylate, process water and methanol. Further purification of the crude methyl acrylate takes place in the alcohol extractor and the light ends column where process water and methanol, as well as other light ends, are removed. The final product column separates high boiling components to be routed to the AA recovery section and the purified MA product can be send to storage.

In the AA regeneration section acrylic acid is recovered to be recycled to the reactor. The high boiling components are routed to the decomposer where they could partly be converted back to methanol, methyl acrylate and acrylic acid to be recycled. Remaining unconverted components are discharged to battery limit for further treatment.

The bottom product of the alcohol extractor is routed to the methanol regeneration section to recover methanol to be recycled to the reactor. The water is partly reused in the process as well as routed to battery limit for further treatment.

Methyl acrylate is prone to polymerization. In order to minimize polymerization effects, an inhibitor injection system is foreseen at critical locations in the plant.



References

1

Contact

chemicals@airliquide.com

Ethyl Acrylate (Synthomer Licensed)

Application

Production of ethyl acrylate (EA) by the esterification reaction of acrylic acid with ethanol (EtOH). The ethyl acrylate is used mainly for adhesives, paints and coatings

Feedstock

Acrylic acid, ethanol

Product

Ethyl acrylate

Co-product

None

Capacity

Up to 4 t/h

Economics

Process configuration is optimized resulting in low raw material consumption, optimized energy integration and low utility requirements. Environmental impact minimized. On stream times exceeding 8,000 hours per year could be achieved

Description

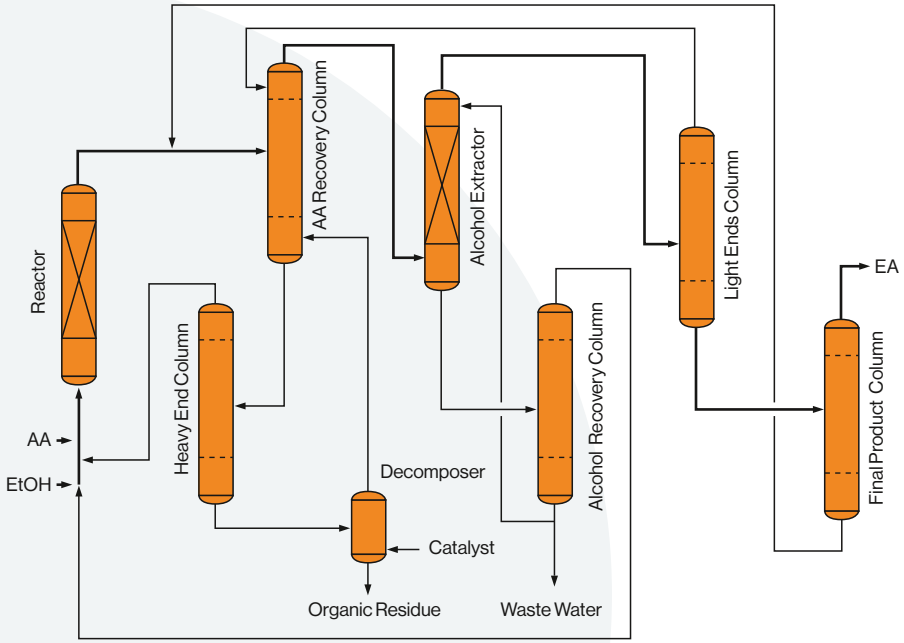
The reaction is catalyzed in a fixed bed reactor by means of a strong acid solid catalyst (ion-exchange resin).

The reactor effluents are routed to the fractionation section to separate unreacted acrylic acid (AA) from crude ethyl acrylate, process water and ethanol. Further purification of the crude ethyl acrylate takes place in the alcohol extractor and in the light ends column where process water and ethanol as well as other light ends are removed. The final product column separates high boiling components to be routed to the AA recovery section and the purified EA product can be sent to storage.

In the AA regeneration section the acrylic acid is recovered and recycled to the reactor. The high boiling components are routed to the decomposer where they are partly converted back to ethanol, ethyl acrylate and acrylic acid to be recycled. Remaining unconverted components are discharged to battery limit for further treatment.

The bottom product of the alcohol extractor is routed to the EtOH regeneration section to recover ethanol to be recycled to the reactor. The water is partly reused in the process as well as routed to battery limit for further treatment.

Ethyl acrylate is prone to polymerization. In order to minimize polymerization effects, an inhibitor injection system is foreseen at critical locations in the plant.



References

1

Contact

chemicals@airliquide.com

CHEMICALS

Butyl Acrylate (Synthomer Licensed)

Application

Production of butyl acrylate (BA) by the esterification reaction of acrylic acid (AA) with butanol (BuOH). The butyl acrylate is used mainly for adhesives, paints and coatings

Feedstock

Acrylic acid, butanol

Product

Butyl acrylate

Co-product

None

Capacity

Up to 20 t/h

Economics

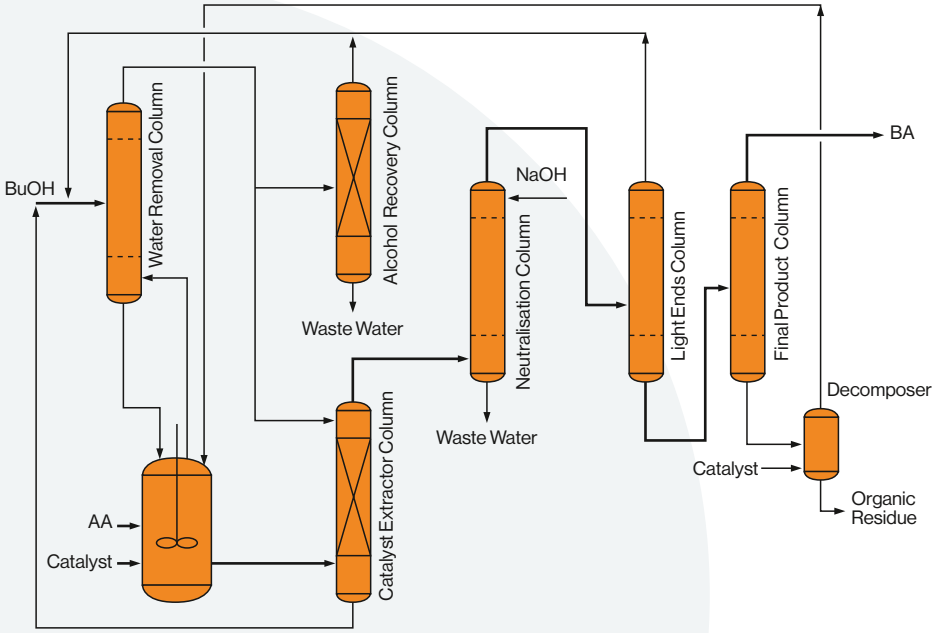
Process configuration is optimized resulting in low raw material consumption, optimized energy integration and low utility requirements. Environmental impact minimized. On stream times exceeding 8,000 hours per year can be achieved

Description

The reaction is catalyzed by means of para-toluene sulphuric acid (PTSA). A four stage reactor system ensures the conversion. The process water generated by the reaction is continuously removed from the reactor system. Process water, unconverted butanol and acrylic acid leaving the reactor system are separated in the dehydration columns. The organic phase (mainly butanol and AA) is recycled. The liquid crude BA and the catalyst are routed to the catalyst extraction column where the catalyst is extracted by means of process water and is recycled to the reactors. Residual acrylic acid in the crude BA is neutralized in the neutralization column by means of a caustic soda solution.

In the purification section light ends are removed from the crude BA and recycled back to the reactor system. In a second step high boiling components are separated and the final pure BA product is generated to be sent to storage. The high boiling components are transferred to the decomposer where they could partly be converted back to mainly BA to be recycled to the reactor section. Remaining unconverted components are discharged to battery limit for further treatment.

Butyl acrylate is prone to polymerization. In order to minimize polymerization effects, an inhibitor injection system is foreseen at critical locations in the plant.



References

1

Contact

chemicals@airliquide.com

CHEMICALS

2-Ethylhexyl Acrylate (Synthomer Licensed)

Application

Production of 2-ethylhexyl acrylate (2EHA) by the esterification reaction of acrylic acid with 2-ethylhexanol (2EHOH). The 2EHA produced is used mainly for adhesives, paints and coatings

Feedstock

Acrylic acid, 2-ethylhexanol

Product

2-ethylhexyl acrylate

Co-product

None

Capacity

Up to 5 t/h

Economics

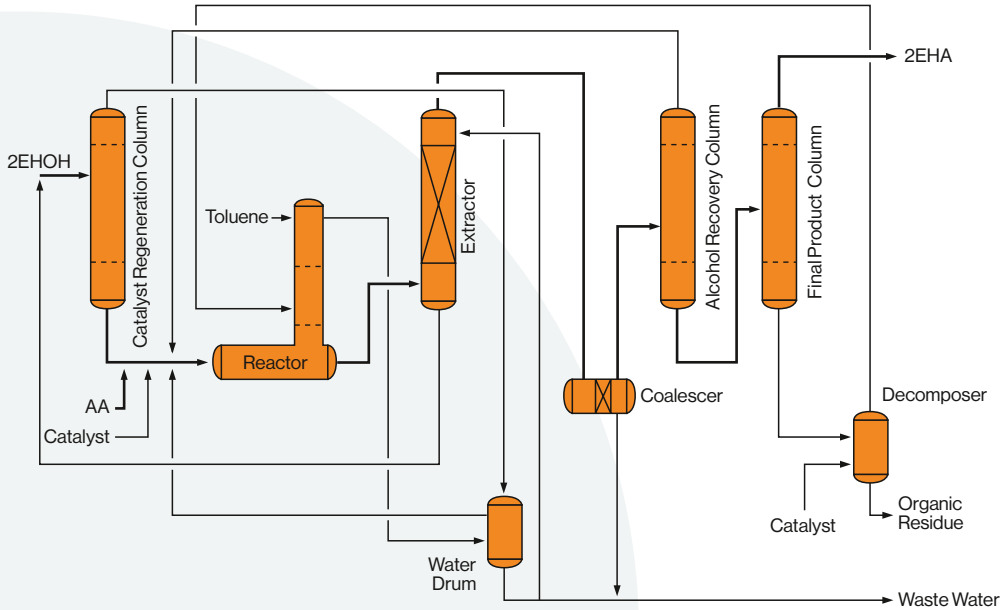
Process configuration is optimized resulting in low raw material consumption, optimized energy integration and low utility requirements. Environmental impact minimized. On stream times exceeding 8,000 hours per year could be achieved

Description

The reaction is catalyzed by means of para-toluene sulphuric acid (PTSA).
A three stage reactor system ensures the conversion. The process water generated by the reaction is removed continuously by an azeotropic distillation step with a carrier agent. The reactor effluent which contains the reacted 2EHA, non-reacted 2EHOH and PTSA is routed to the extraction section where the PTSA catalyst is extracted by means of process water and recycled to the Catalyst Regeneration Column.
Additional 2EHOH is introduced via this column into the process and the extraction water is separated. The recovered PTSA catalyst and the preheated 2EHOH is routed to the first reactor.

In the coalescer section water is removed from the extracted crude 2EHA.
The following purification section separates unreacted alcohol which is recycled to the reaction section. Furthermore, high boiling components are removed and the final pure 2EHA product is generated to be sent to storage. The high boilers are discharged to the heavy end decomposer where they are partly converted back to 2EHA and 2EHOH and recycled to the reactor section. Remaining unconverted components are discharged to battery limit for further treatment.

2EHA is prone to polymerization.



In order to minimize polymerization effects, an inhibitor injection system is foreseen at critical locations in the plant.

References

1

Contact

chemicals@airliquide.com

Butene-to-crude Butadiene (Mitsubishi BTcB Process)

Application

The BTcB process produces crude butadiene by oxidative dehydrogenation of butenes.

The process offers the option for an on-purpose production of 1,3-butadiene in grassroot plants as well as an enhancement of 1,3-butadiene yield in existing naphtha cracker or refinery facilities.

Feedstock

Raffinate 2 from naphtha cracker
Butene rich C4 from FCC units
C4 by-product of MTO/MTP units

Product

1,3-butadiene

Co-product

None

Economics

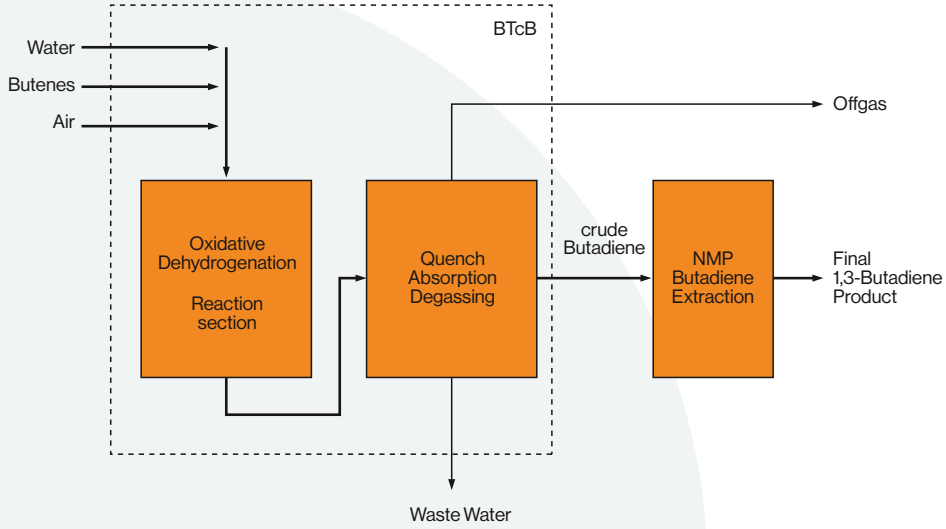
Contact us for more information

Description

The butene rich feedstock is oxidatively dehydrogenated in a fixed bed reactor using air and steam. After quenching the reactor effluent, remaining oxygen, oxygenates and other impurities are removed.

The produced crude butadiene is routed to a BASF NMP butadiene extraction unit for further purification to generate the final high purity 1,3-butadiene product.

The Mitsubishi BTcB process combines high conversion rates and high selectivity while operating at mild reaction conditions.



References

1 pilot plant

Contact

chemicals @airliquide.com

CHEMICALS

Butadiene Extraction (BASF NMP Licensed)

Application

Recovery of 1,3 butadiene from a crude C4 stream from olefins plants by extractive distillation

Feedstock

Crude C4

Product

1,3 butadiene

Co-product

None

Capacity

6 to 35 t/h

Economics

Utility consumption:
(per tonne butadiene)

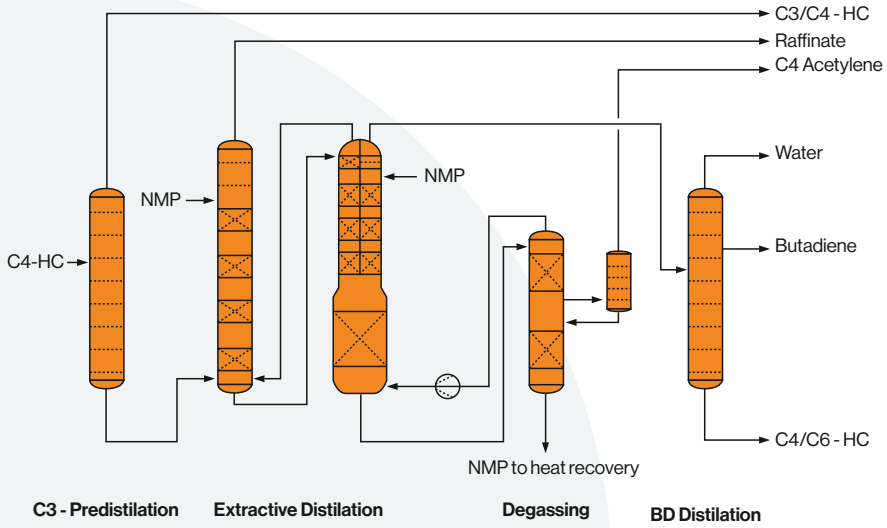
- Steam: 1.7 t/t
- Electricity: 150 kWh/t
- Water, cooling: 150 m^3/t

Capex: 80 to 110 mm USD

Description

In the pre-distillation tower methyl acetylene, propadiene and other light components are separated from the C4 cut feedstock which then enters the bottom section of the main washer column while NMP solvent enters at the top. C4 raffinate consisting of butanes and butenes is drawn off as overhead product. The loaded solvent is sent to the rectifier. In the first compartment of the divided wall column, the less soluble butenes are separated and recycled to the main washer while C4 acetylenes are separated from crude butadiene in the second compartment. The solvent from the rectifier is sent to the degassing tower where hydrocarbons are stripped from the solvent and than recycled to the rectifier by a compressor.

The side stream of the degassing tower containing diluted C4 acetylenes is fed into a scrubber to recover NMP solvent.
After further dilution with raffinate or other suitable materials, the C4 acetylene stream is discharged to battery limits for further processing. The crude butadiene withdrawn as overhead product from the second compartment of the rectifier is sent to the butadiene column for final purification.
The butadiene product is withdrawn as liquid side product.



Ecology: NMP biodegrades readily and has low toxicity to aquatic life. Compared to other technologies, this process is much more eco-friendly.
In addition the BASF SELOP selective hydrogenation process can be offered for further treatment of the C4 Acetylene stream to increase the 1.3 Butadiene yield.

References

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Contact

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CHEMICALS

Distapex™ – Aromatics Extractive Distillation

Application

Recovery of aromatics from a heart-cut feedstock by extractive distillation

Feedstock

Pyrolysis gasoline

Product

Benzene

Co-product

None

Capacity

Up to 40 t/h

Economics

Recovery rate: > 99.5%

Utility costs: 8.8 USD/tonne

Utilities (per tonne benzene):
- Steam, tonne: 0.7
- Electricity, kWh: 8
- Water, cooling, m^3: 19
- Solvent loss, kg: 0.01

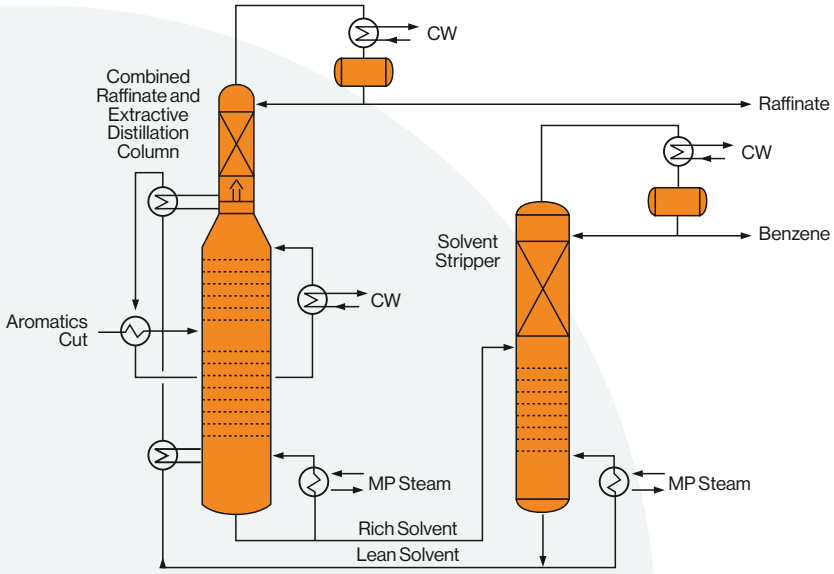
Capex: 40 to 80 mm USD

Description

The aromatics in the feedstock are separated by extractive distillation using N-methylpyrrolidone (NMP) as a solvent. The raffinate product containing the non-aromatics leaves the extractive distillation column via the top. The loaded solvent is routed to a stripper column where the final aromatic product is recovered at the column top and routed to battery limit. The lean solvent is recycled to the extractive distillation column.

Ecology: Due to the unique properties of NMP, the process has an excellent ecological footprint and requires medium pressure steam only.

The Distapex™ process requires a minimum number of equipment items and is especially renowned for reliability and availability as well as low operating costs.



References

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Contact

chemicals @airliquide.com

CHEMICALS

Lurgi/Edgein Melamine

Application

The Lurgi/Edgein low pressure technology produces melamine from urea in a catalytic vapor-phase reaction. Main uses are laminates, adhesives and coating.

Feedstock

Urea

Product

Melamine

Co-product

None

Capacity

Up to 7,5 t/h in a single train

Economics

Consumption per metric ton of melamine:

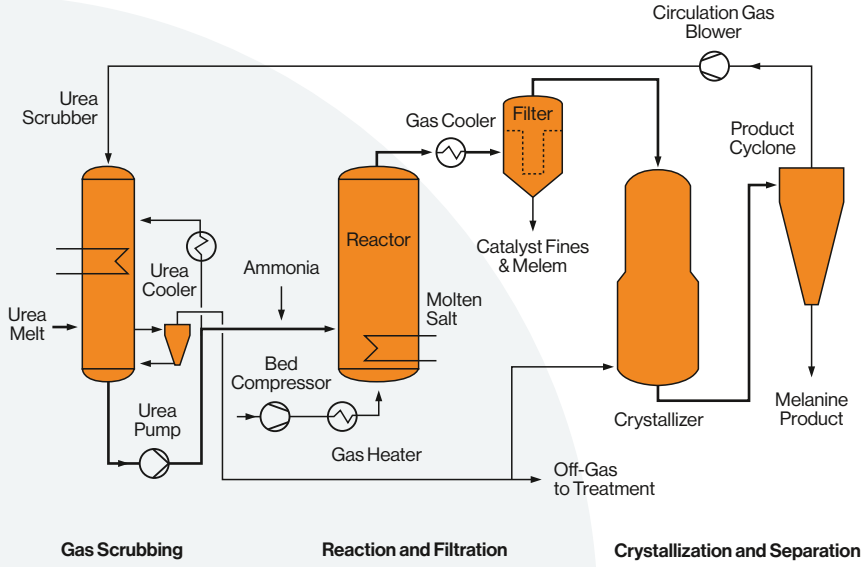
- Urea melt: 3.15 tons, net value 1.5 tons
- Ammonia: 0.3 tons
- Catalyst: 4 kg
- HP steam: 0.5 tons
- Electrical power: 1300 kWh
- Natural gas: 15.5 GJ (ca. 397 Nm³)
- Cooling water: 33 tons
- No quench water required (no waste water)

Capex: 185 mm USD

Description

Molten urea is fed to a fluidized bed reactor using a silica/aluminum oxide catalyst.
The fluidization is accomplished with an ammonia /CO_2 mixture to process off-gas.
The required heat for the reaction is provided by circulating molten salt through internal heating coils. The gaseous reactor effluent is cooled to a level that the by-products and the catalyst fines can be removed in a filtration step. The solid melamine particles are generated by desublimation in a crystallizer and are finally separated by a cyclone. The off-gas is recycled to a urea washing tower where it is scrubbed with molten urea before being partially recycled as fluidizing gas to the reactor and as quench gas to the crystallizer section. Surplus on off-gas can be recycled to the upstream urea plant or a separate off-gas treatment unit.

The melamine produced with the Lurgi/Edgein technology is characterized by an excellent quality, with small particle sizes and a uniform particle size distribution exceeding the standard requirements for the downstream applications.



References

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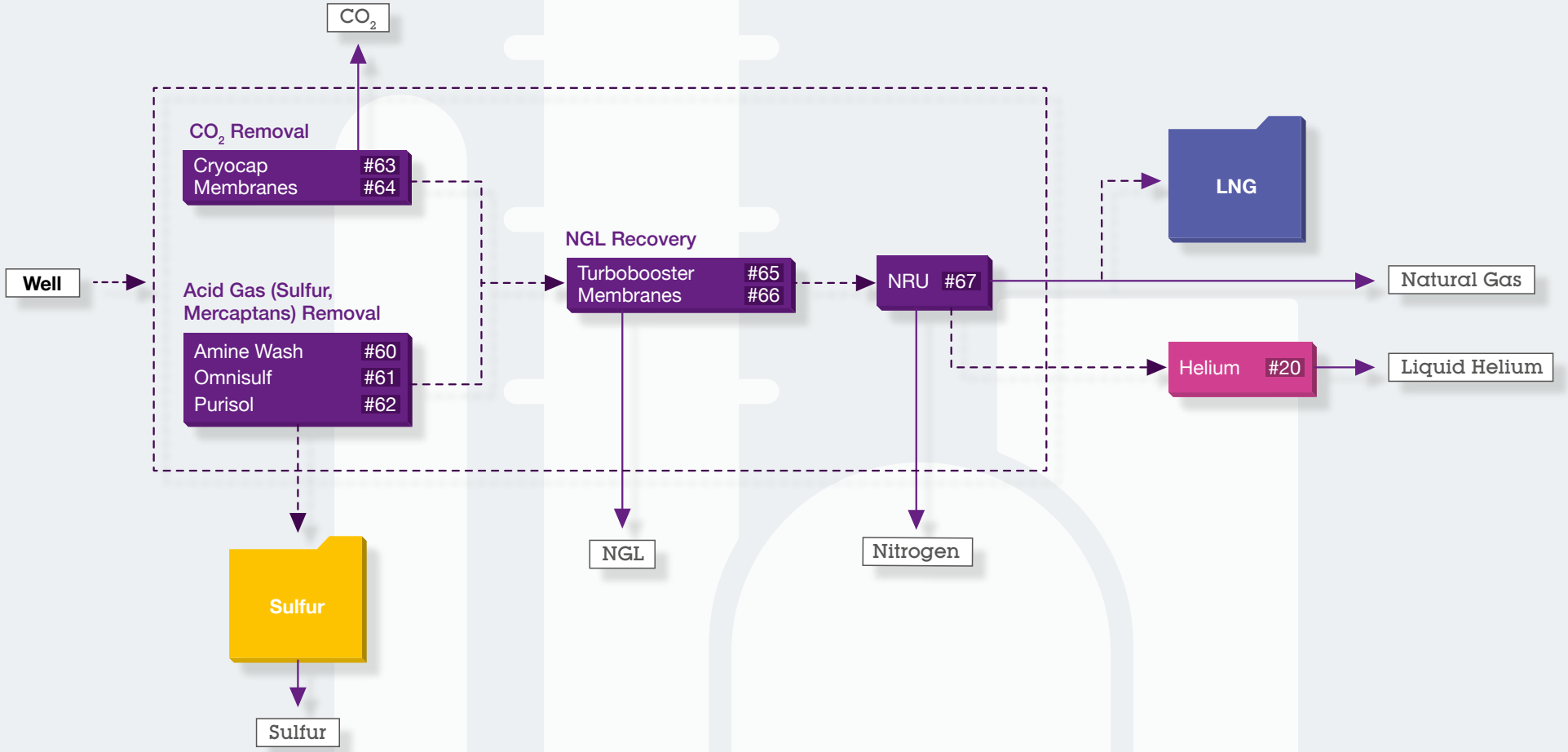
Contact

chemicals @airliquide.com

NATURAL GAS TREATMENT

Raw natural gas needs to be treated to meet pipeline and liquefaction specifications. We offer a full range of technologies to remove any kind of contaminant, offering clients a reliable and cost-effective solution tailored to their needs.

Overview


CO_2
CO_2 Removal
Cryocap #63
Membranes #64
Well
Acid Gas (Sulfur, Mercaptans) Removal
Amine Wash #60
Omnisulf #61
Purisol #62
NGL Recovery
Turbobooster #65
Membranes #66
NRU #67
LNG
Natural Gas
Helium #20
Liquid Helium
Sulfur
Sulfur
NGL
Nitrogen

Acid Gas Removal – Amine Wash

Application

Removal of acid gases (CO_2, H_2S, COS, light mercaptans) from natural gas, associated gases and unconventional gas sources

Feedstock

Natural gas

Product

Sweet natural gas

Co-product

Acid gases

Capacity

Up to 1,500,000 Nm^3/h

Economics

Economics are highy dependent on feedstock and requirements (high efficiency or low Capex).

Contact us for more information

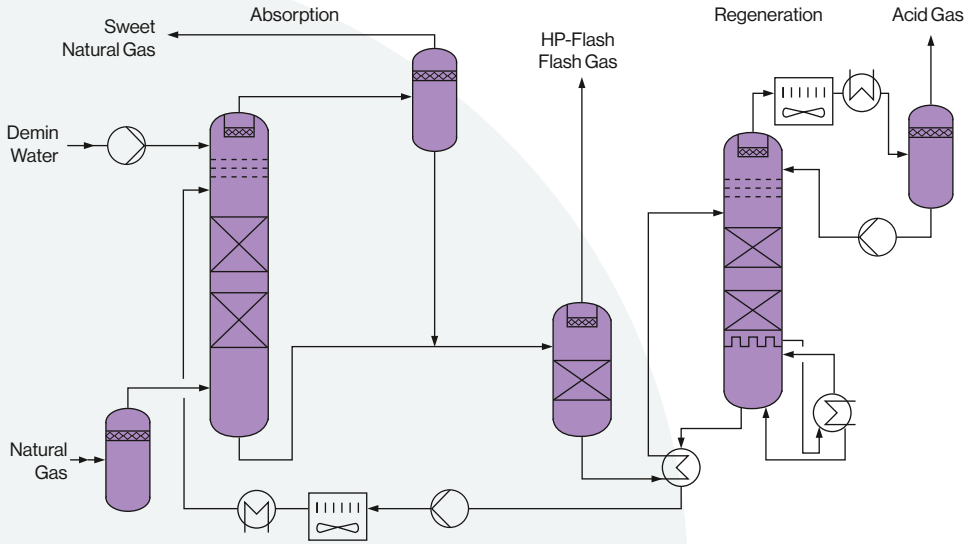
Description

Acid gases contained in raw gases are removed by absorption with a chemical or a mixture of chemical and physical solvent. The rich solvent leaving the contactor is regenerated by flashing and stripping.

The process configuration and solvent selection will be tailored according to feedstock and sweet gas application.

Air Liquide Engineering & Construction can offer very energy-efficient processes such as the BASF OASE® purple or formulated MDEA for pipeline or liquefied natural gas specifications.

This process presents the advantage of very low hydrocarbon co-absorption.



References

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Contact

gas-treatment@airliquide.com

Acid Gas Removal – OmniSulf™

Application

Sweetening and processing of natural gas by removing CO_2, H_2S, COS, mercaptans, water and mercury to pipeline or LNG specifications as well as production of liquid elemental sulfur while minimizing SO_2 emissions to the atmosphere to meet most stringent environmental regulations

Feedstock

Raw natural gas, associated gas

Product

Dry sweet gas, sulphur (99.9+% purity)

Co-product

None

Capacity

Up to 1,500,000 Nm^3/h

Economics

Economics are highly dependent on feedstock and requirements (high efficiency or low Capex).

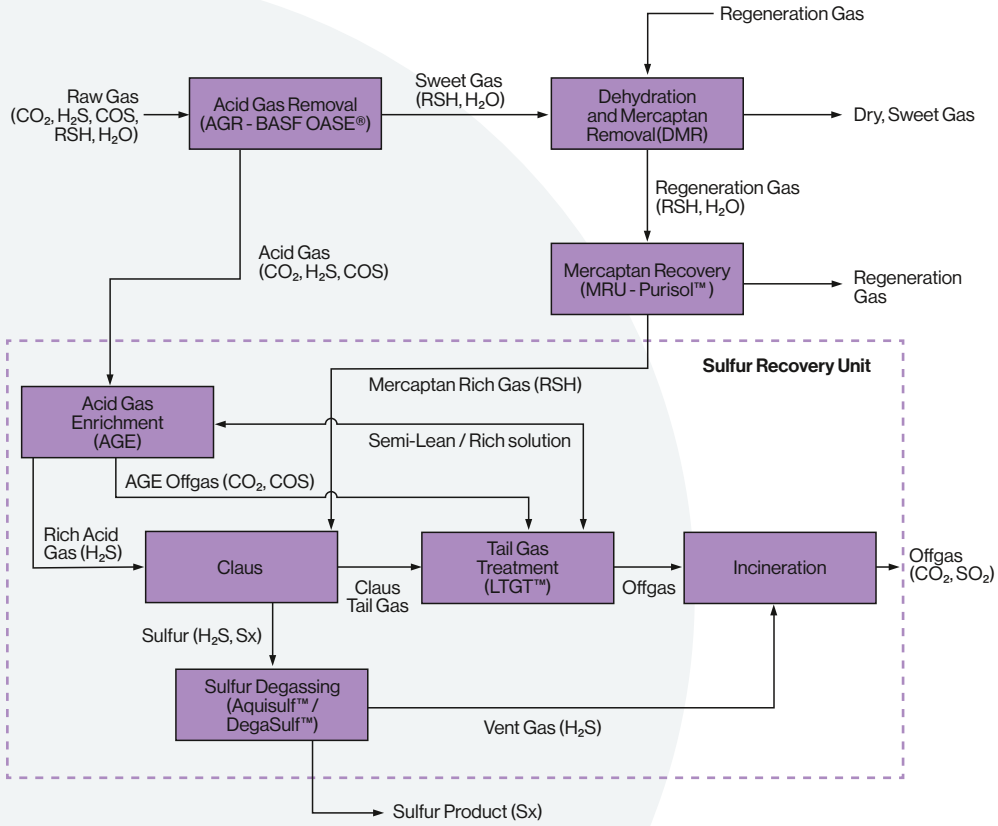
Contact us for more information

Description

The OmniSulf™ technology encompasses the following proprietary key processes:

Acidic components are removed using BASF's OASE® technology and the cleaned gas is routed to a dehydration and mercaptan removal unit (DMR) that removes moisture and mercaptans with multi-layered bed of specialized zeolitemolecular sieves. If necessary, mercury is removed from the sweet gas with impregnated activated carbon. Mercaptans are recovered from the regeneration gas with the Lurgi Purisol™ technology. All gas streams containing sulfur are routed to a sulfur recovery unit (SRU). Elemental sulfur is produced in the Claus process (equipped with a Lurgi Multi-Purpose Burner) followed by a Lurgi tail gas treatment (LTGT™) unit combined with an acid gas enrichment system to boost sulfur recovery and reduce SO_2 emissions. The liquid sulfur product is degassed to H_2S concentrations below 10 ppm by applying the Aquisulf™ technology.
Offgases are incinerated before being released to the atmosphere.

The OmniSulf™ technology can be tailored for gas reinjection.



Contact

gas-treatment@airliquide.com

Acid Gas Removal – Purisol™

Application

Highly selective removal of acid gases (H_2S, mercaptans, etc.) from natural gas and process gases

Feedstock

Natural gas, regeneration gas, process gas

Product

Clean sulfur free gas

Co-product

Sulfur rich gas for SRU

Capacity

50 000 - 500 000 Nm^3/h

Economics

Individual costs vary significantly depending on capacity and purity request

Opex: This process has typically very low Opex due to the high selectivity and easy regeneration as well as a stable solvent with low losses due to high boiling point

Capex: 3 to 40 mm USD

Description

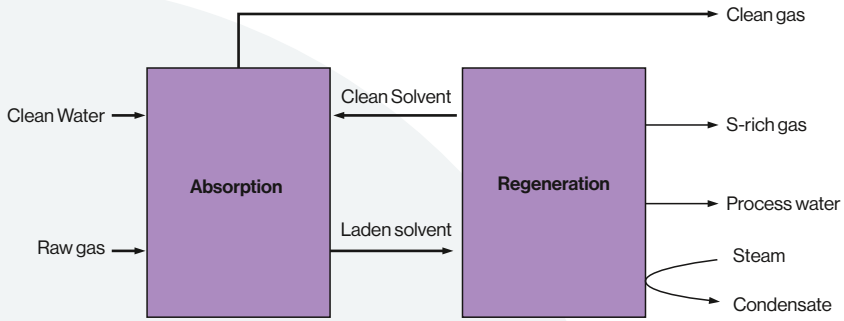
The Purisol™ process uses a highly selective, non-toxic, non-corrosive, easily available solvent (N-Methyl-2-Pyrrolidone, NMP) for the physical absorption of the undesired acidic components of a feed gas or process gas, like H_2S and mercaptans. The process requires very low Opex due to several features. Taking advantage of the very high selectivity towards H_2S and mercaptans compared to CO_2 and hydrocarbons allows a low circulation rate. The process is operated at ambient temperature and thus does not need high cooling duty. Regeneration of the solvent is done by flashing and heating. Because of the high boiling point of the solvent, losses are extremely low.

A typical application is the cleaning of periodically released regeneration gases of natural gas treatment to a clean fuel gas. Here an additional feature is to provide a continuous flow of sulfur rich gas to the Claus process by using the buffering function of the set up.

The process can be modularized and also easily be integrated into existing plants.

Main Features :

- Non-toxic, non-corrosive solvent, easily available solvent
- Smooth and peakless gas to Claus process



Contact

gas-treatment@airliquide.com

NATURAL GAS TREATMENT

CO_2 Removal – Cryocap™NG

Application

Removal of CO_2 from natural gas, associated gases and unconventional gas sources

Feedstock

Natural gas with high CO_2 content (> 35%)

Product

Natural gas

Co-product

CO_2 (under pressure)
NGL (possible)

Capacity

Up to 1,000,000 Nm^3/h

Economics

Separation cost:
less than 1 USD/MMBTU

Capex savings:
> 50% vs. amine absorption (at high CO_2 content)

Contact us for more information.

Description

The CO_2 rich natural gas is first dried and sent to a cold box where it is cooled down and sent to a distillation column.

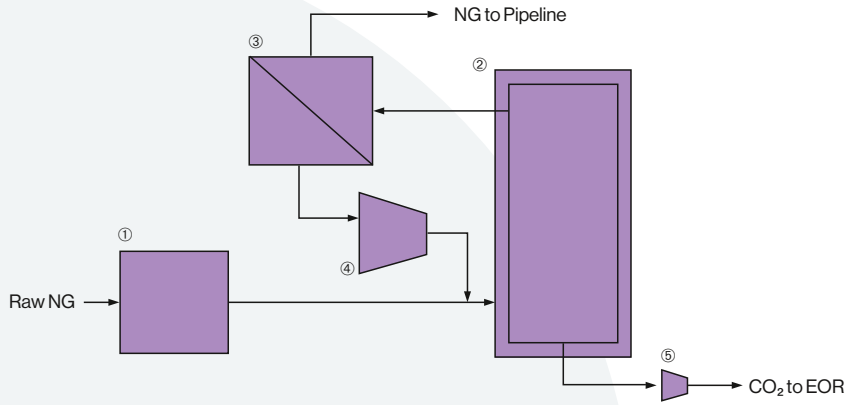
High CO_2 partial pressure favors the CO_2 partial condensation and thus makes its separation from natural gas even easier.
The non-condensable gas is enriched in methane and sent to a membrane for final purification.

The CO_2 purity of the product corresponds to pipeline specifications, generally 1 to 10 mol%.
The permeate stream of the membrane enriched in CO_2 is sent back to the cold box. The CO_2 and heavy hydrocarbons condense in the cold box and are collected at high pressure. NGL recovery is possible with almost no additional cost.

Cryocap™ NG is tolerant to a few % H_2S.
Cryocap™ NG also allows for H_2S bulk removal from NG.

Contact

gas-treatment@airliquide.com



① Simple Pre-treatment (Dehydration, Mercury removal)
② Cold Box
③ Membrane stage
④ Recycle Compressor
⑤ CO_2 product Compressor

CO_2 Removal – Membranes

Application

CO_2 removal from natural gas

Feedstock

Natural gas with moderate to high acid gas content

Product

Sweet natural gas

Co-product

Acid gases

Capacity

Up to 500,000 Nm^3/h

Economics

Economics are highly dependent on feedstock and requirements (high efficiency or low Capex).

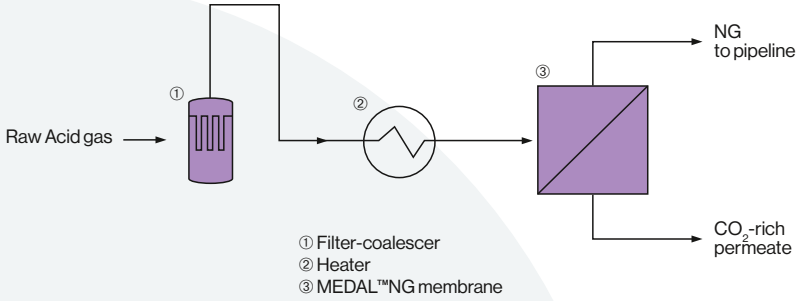
Contact us for more information.

Description

Air Liquide Engineering & Construction offers a vast portfolio of gas separation membranes for natural gas treatment: the natural gas product is recovered as a high-pressure retentate while the impurities are concentrated in the low pressure permeate. This includes bulk CO_2 removal with the highly selective MEDAL™ NG, as well as HC dewpointing, bulk CO_2 removal and dehydration with PEEK-SEP™ suite of products.

Main Features:

The hollow-fiber type offers more compact and robust membrane solutions to meet pipeline specifications. Air Liquide membrane technology is characterized by higher resistance to hydrocarbons and higher selectivity, compared to cellulose acetate products, offering higher methane recovery, lower investment and operating costs.



Contact

gas-treatment@airliquide.com

Natural Gas Liquids Recovery – Turbo-booster

Application

NGL (C2+) recovery from natural gas, associated gases and unconventional gas sources

Feedstock

Lean or Rich Natural gas

Product

Ethane, LPG, condensates, natural gas

Co-product

LNG, crude helium

Capacity

Up to 1,000,000 Nm^3/h

Economics

Increased NGL recovery with significant reduction in capital and/or operating costs as compared to open-art technologies.

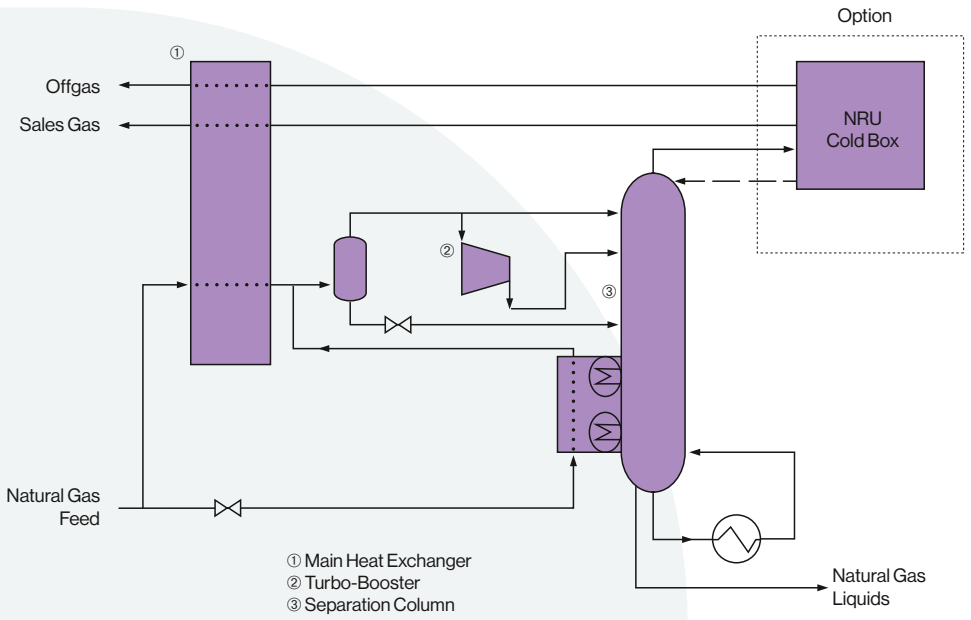
Contact us for more information.

Description

Air Liquide Engineering & Construction offers open-art or proprietary natural gas liquids technologies (NGL) for high efficiency C_2 recovery (>98%), high propane recovery (99+%) and low energy consumption. Air Liquide know-how and operational expertise of key technology components (heat exchangers, turbo-expander) allow for robust and reliable solutions. Additionally, Air Liquide can combine NGL recovery with its nitrogen rejection technology and expertise in cryogenics to provide overall optimized NGL/ NRU plants.

Contact

gas-treatment@airliquide.com



Natural Gas Liquids Recovery – Membranes

Application

NGL recovery from rich gas and fuel gas conditioning (including dewpointing and BTU value adjustment)

Feedstock

Natural gas, associated gases, unconventional gas sources, refinery off-gas, flared gas

Product

Treated natural gas, NGL

Co-product

Fuel gas

Capacity

Up to 100,000 Nm^3/h

Economics

Air Liquide membrane solutions are characterized by low investment and operating costs that can translate into short payback periods.

Contact us for more information.

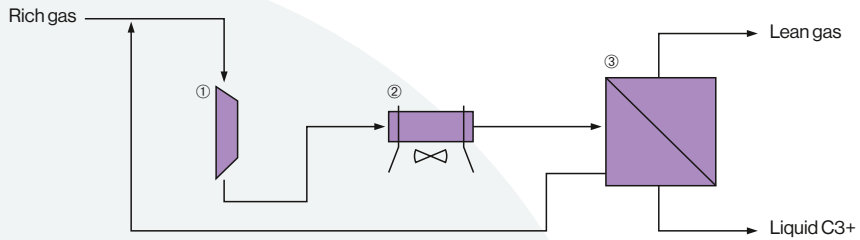
Description

Thanks to outstanding mechanical properties of the PEEK-SEP™ membranes, liquid C3+ can be recovered at high pressure whereas the residual gas is produced as a low pressure permeate. The membrane system is simple and reliable, and does not require extensive feed gas pre-treatment beyond an inlet coalescing filter.

PEEK-SEP™ membranes can also be used as a pretreatment stage upstream of MEDAL™ NG (CO_2 removal units) to optimize the performance and reduce overall footprint and weight as compared to traditional pre-treatment schemes. Other applications of the PEEK-SEP™ membranes include hydrocarbon dewpointing (the treated gas is produced at high-pressure) and nitrogen removal for BTU value adjustment purposes.

Air Liquide's membrane solutions represent a robust and compact option to unlock the use of low quality fuel gas and the monetization of valuable Natural Gas Liquids (NGL) contained in rich gas sources such as flared gas, refinery off-gases or fuel gas networks.

When the feed gas is rich in heavy hydrocarbons, typical refrigeration plants can be attractive when sufficient NGL liquid product can be recovered. Air Liquide POROGEN PEEK-SEP™ membranes provide alternative solutions to recover NGLs even when the amount of NGLs is too low to allow for economic recovery by traditional means.



① Feed Compressor
② Air Cooler
③ Peek-Sep™ Membranes

Contact

gas-treatment@airliquide.com

NATURAL GAS TREATMENT

Nitrogen Rejection Unit

Application

Removal of nitrogen from natural gas, associated gases and unconventional gas sources

Feedstock

Natural gas with high nitrogen content

Product

Natural gas, nitrogen

Co-product

LNG, liquid nitrogen, crude helium

Capacity

Up to 1,000,000 Nm^3/h

Economics

Economics are highy dependent on feedstock and requirements (high efficiency or low Capex).

Contact us for more information.

Description

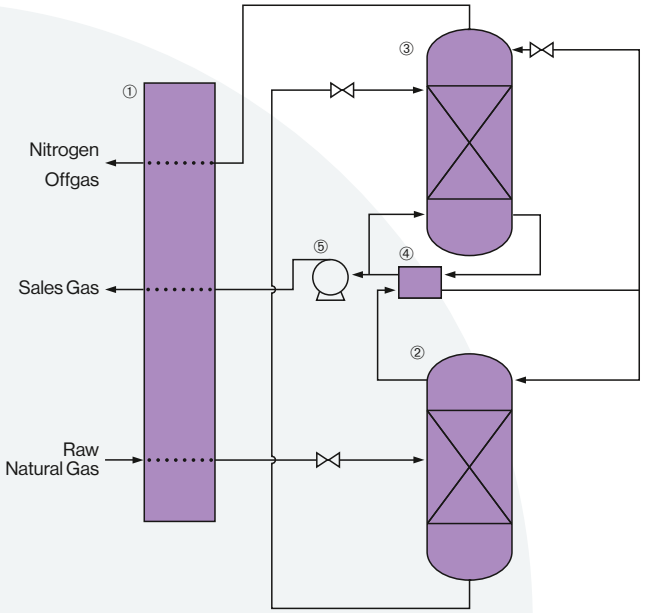
Natural gas feed is partially condensed, then methane and nitrogen are separated into a system of distillation column(s). Depending on the feed composition and pressure, the system can include one to three distillation columns. The process scheme selection is done according to project-specific parameters such as feed evolution with time and product specifications. Air Liquide Engineering & Construction offers a wide range of solutions, such as the ability to treat any N_2/CH_4 mixtures (5-90%), high efficiency, flexibility and recovery (>99% methane), minimization of greenhouse gas emissions to the atmosphere (methane in N_2 vent << 1%). Capex optimization and operation flexibility are allowed thanks to proprietary design and Air Liquide operational feedback.

References

>15

Contact

gas-treatment@airliquide.com



① Main Heat Exchanger
② High Pressure Column
③ Low Pressure Column
④ Condenser/Reboiler
⑤ Sales Gas Product pump

SULFUR

Hydrogen sulphide removed in the Natural Gas Cleaning or Crude Oil Refining can be converted into pure sulfur product using proven Claus technology. Over the years, we have developed a highly efficient and reliable burner system and further technologies to boost this traditional process, making it more efficient, less costly and more environmentally friendly.

SULFUR

Oxynator™ / OxyClaus™ for Sulfur Recovery Units (SRU)

Application

Oxygen enriched SRU operation for
- Capex / plot space savings for new SRU
- SRU debottlenecking and revamps

Feedstock

Acid gases, Oxygen

Product

Bright yellow sulfur, up to 99.9% purity

Co-product

None

Capacity

Up to 600 tpd sulfur

Economics

Opex :

Pure oxygen requirement:

Approx. 0.15 - 0.4 ton O_2 / ton sulfur

(depending on enrichment level and feed gas composition)

Capex :

Oxynator™: less than 0.5 mm USD

OxyClaus™ : up to 35% less than conventional SRU with same capacity

Description

In a conventional Sulfur Recovery Unit ambient air is used to oxidize part of the hydrogen sulfide (H_2S) in the acid gases to sulfur dioxide (SO_2). By enriching the combustion air to the Claus unit with pure oxygen more feed gas can be processed in the SRU without violation of pressure drop or residence time constraints.

Air Liquide Engineering & Construction provides the most suited oxygen enrichment technology depending on client's requirements.

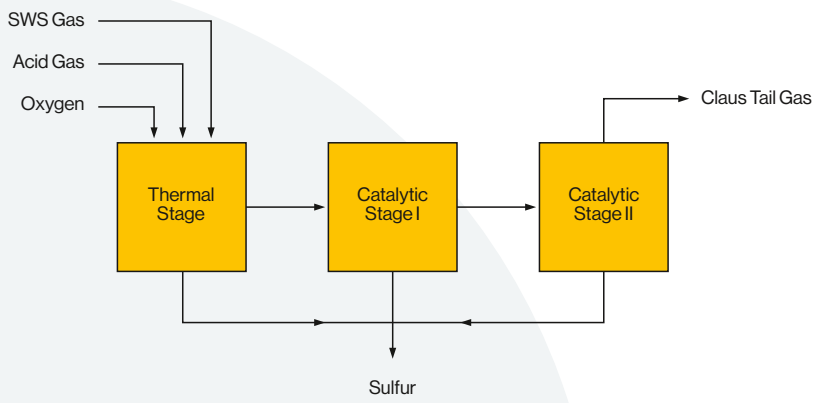
Oxynator™ for low-level enrichment (<28% O_2 in air)

Low-level oxygen enrichment is a very cost effective option to increase SRU capacity up to 125% as there is usually no modification required on existing SRU equipment. Air Liquide uses its patented Oxynator™, a compact swirl type mixer, for safe and efficient oxygen mixing.

The oxygen is injected into the combustion air upstream of the Claus burner.

OxyClaus™ for high-level enrichment (<60% O_2 in air)

Capacity increase to 200% can be achieved by using the well known Lurgi OxyClaus™ process that can safely handle high levels of oxygen. In the specially designed Lurgi OxyClaus™ burner the oxygen is directly injected into the flame via dedicated oxygen lances. The hot oxygen flame is surrounded by a cooler acid gas – air flame shielding the refractory from exposure to high temperature.



Main Features:

- Integration with ASU
- Low power consumption
- Pre-assembled packages or skid units to ease the erection

References

>40

Contact

sulfur@airliquide.com

SULFUR

Sulfur Recovery Unit

Application

Recovery of sulfur from acid gas streams containing hydrogen sulfide (H_2S)

Feedstock

Acid gases from sweetening units and sour-water strippers

Product

Bright yellow sulfur with up to 99.9% purity

Co-product

None

Capacity

Up to 1,000 tpd

Economics

Sulfur recovery: >95%
Operating costs can be considered negligible if credit is given for steam produced in SRU.

Capex: 10 to 100 mm USD

Description

The acid gases are burnt sub-stoichiometrically with air in a refractory lined furnace. Resulting mixture of H_2S and SO_2 reacts to form elemental sulfur which is removed from the process through condensation. In subsequent catalytic stages, typically two or three, the conversion to sulfur is promoted further yielding a sulfur recovery of 94.5% – 97.5% for the Claus unit.

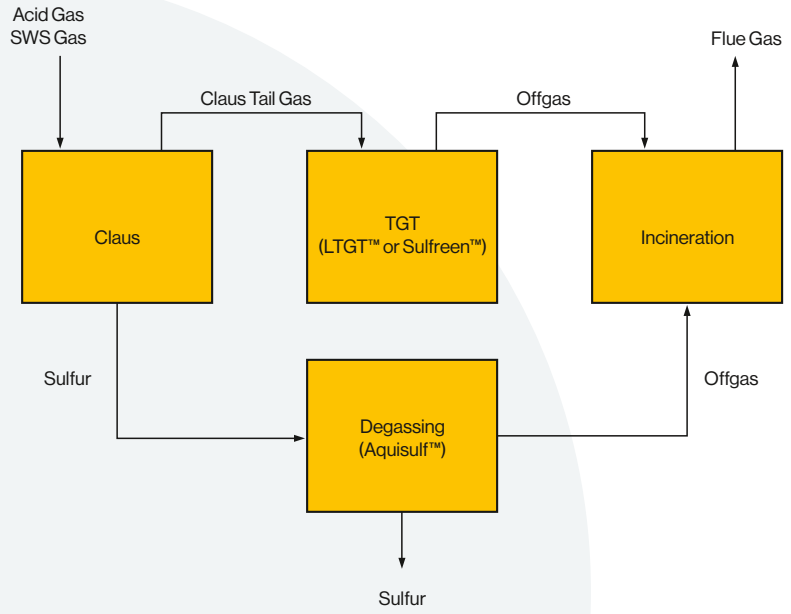
Two tail gas treatment (TGT) options are available to boost the sulfur recovery further.

1) Sulfreen™: A sub-dewpoint; catalytic purification of the Claus tail gas for an overall sulfur recovery of up to 99.5%.

2) LTGT™: Claus tail gas is purified in a wet-scrubbing process. Due to the recycling of the H_2S rich stream to the Claus unit, total sulfur recovery can be increased to 99.9%.

In the degassing section, the H_2S content of the liquid sulfur is decreased to less than 10 ppm. For this the catalytically promoted Aquisulf™ technology can be employed.

Offgas from tail gas treatment and degassing is incinerated and released to the atmosphere.



References

>170 Claus plants (4 to 1,000 tpd)
>60 tail gas treatment processes
>50 Aquisulf™ in operation

Contact

sulfur@airliquide.com

SULFUR

Emission-Free Sulfur Recovery Unit

Application

Recovery of sulfur from acid gas streams containing hydrogen sulfide (H_2S) with 100% sulfur recovery

Feedstock

Acid gases from acid gas removal unit and sour-water strippers

Product

Bright yellow sulfur with up to 99.9% purity

Co-product

None

Capacity

Up to 1,000 tpd

Economics

Capex: 25% less than conventional amine-wash tail gas treatment

Sulfur recovery: 100%

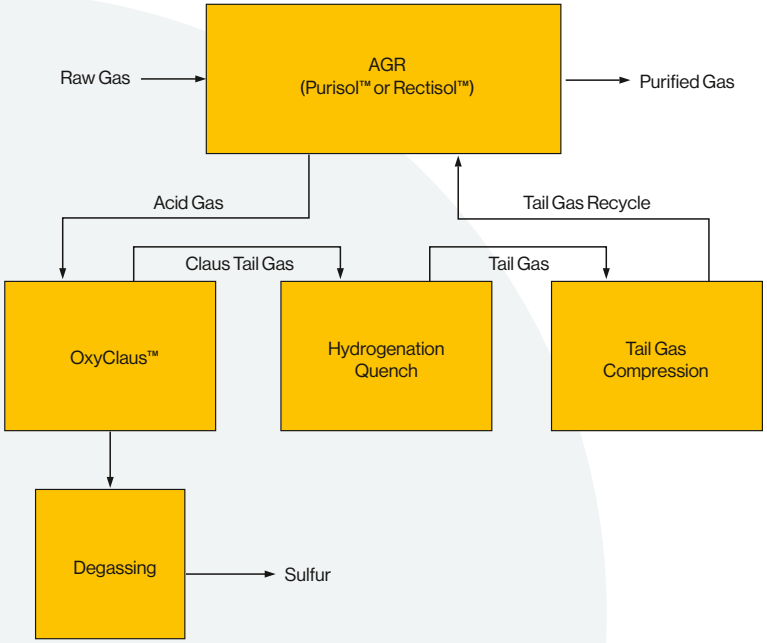
Contact us for more information.

Description

Raw gas is desulfurized in an AGR and the removed acid gas is sent to the emission-free SRU for sulfur recovery. The oxygen based Claus process is employed to recover sulfur from the acid gas in elemental form. The recovered sulfur is degassed and is then available as a sellable product.

Claus tail gas is hydrogenated and cooled before being compressed and routed back to the AGR. Here it is desulfurized and the H_2S is recycled together with the acid gas back to the Claus unit. Other valuable components inside the tail gas, like H_2 and CO end up in the purified gas. With this recycle a sulfur recovery rate of 100% is achieved. The sulfur emissions to the atmosphere in the overall complex are significantly reduced.

OxyClaus™ is used in this concept because this reduces the process gas volume and therefore lowers not only investment cost plus operating cost but also the amount of inert gas sent to AGR.



References

3 emission-free SRUs have been designed, two are in operation.

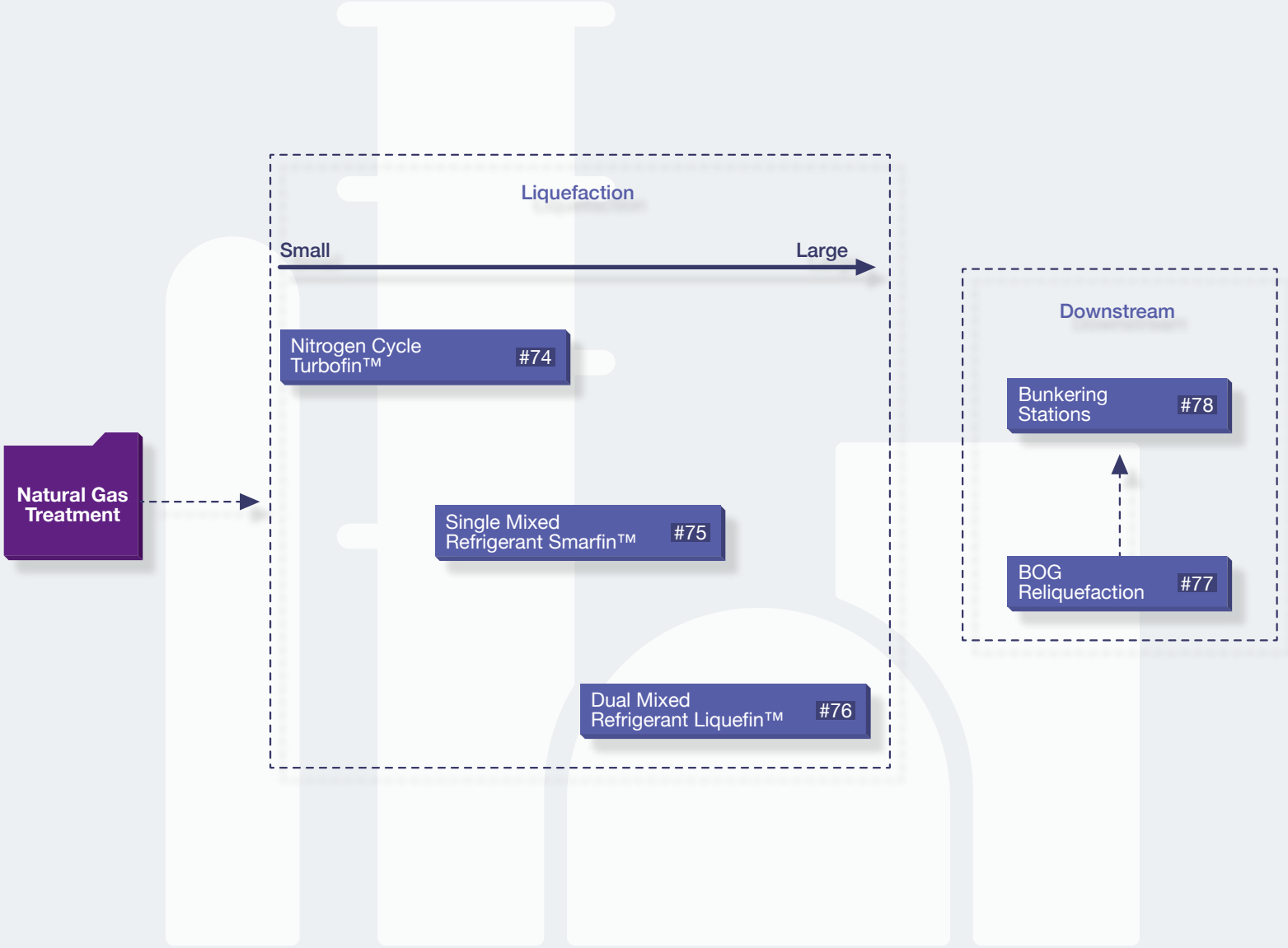
Contact

sulfur@airliquide.com

LNG

As an expert in cryogenics and a pioneer in the field of Liquefied Natural Gas, we have extensive experience in equipping plants of all sizes with LNG technology. Our modularized designs are easy to construct and our robust liquefaction technology based on cold boxes helps reduce costs.

Overview


Liquefaction
Small
Large
Nitrogen Cycle Turbofin™ #74
Natural Gas Treatment
Single Mixed Refrigerant Smarfin™ #75
Dual Mixed Refrigerant Liquefin™ #76
Downstream
Bunkering Stations #78
BOG Reliquefaction #77

LNG

Turbofin™ (Nitrogen Refrigerant Cycle)

Application

Liquefaction of natural gas for small scale plants serving power applications (peak shaving, remote power) or fuel (marine, truck, rail, etc.)

Feedstock

Natural gas

Product

LNG

Co-product

NGLs, depending on feedstock composition

Capacity

Up to 0.25 Mtpa

Economics

Opex: Typically 450 kWh/ton of LNG

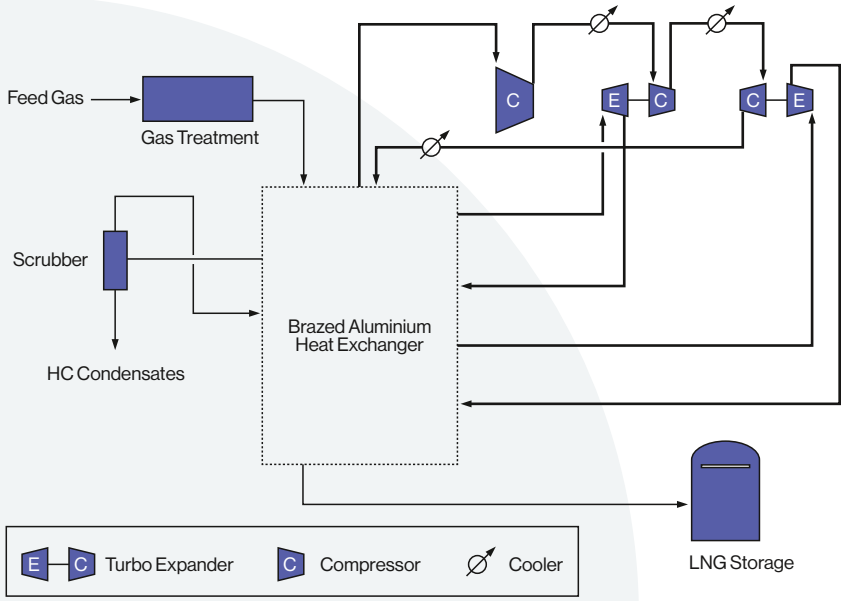
Description

The process consists of three main modules: pre-treatment of natural gas (NG), liquefaction and LNG storage and loading (truck, trailer, bunkering barge, etc.).

1) The pre-treatment consists mainly of CO_2 and H_2O removal. It is either a simple Temperature Swing Adsorption (TSA) cycle or a combination of amine wash with TSA depending on the CO_2 content in the feed gas.

2) The liquefaction process is based on a nitrogen cycle (closed loop): N_2 is first compressed and boosted. After being cooled down through a Brazed Aluminum Heat Exchanger, it is expanded releasing N_2 at low pressure and low temperature. Cold N_2 (T<-165°C) is then re-injected into the main Heat Exchanger to cool down the NG and convert it to LNG which is sent to storage. Warm N_2 is then recycled through the cycle compressor.

3) Storage can either be fabricated for small volumes (vacuum insulated) or site erected flat bottom tanks for larger needs, depending on the applications considered.
The loading station can be adapted to truck, trailer, or maritime. Regasification is added downstream of the storage for peak shaving facilities.



Main Features:

- Cost effective especially for small scale plant
- Non-hydrocarbon refrigerant improving safety
- Simplicity of operation

References

90

Contact

lng@airliquide.com

LNG

Smartfin™ (Single Mixed Refrigerant Cycle)

Application

Liquefaction of natural gas for mid scale plants serving LNG for mid-size export terminals and peak shavers

Feedstock

Natural gas

Product

LNG

Co-product

NGLs, depending on feedstock composition

Capacity

Up to 1.5 Mtpa

Economics

Opex: Typically 350 kWh/ton of LNG

Description

Smartfin™ is a single mixed refrigerant type of process optimized with the use of Brazed Aluminium Heat Exchangers (BAHX).

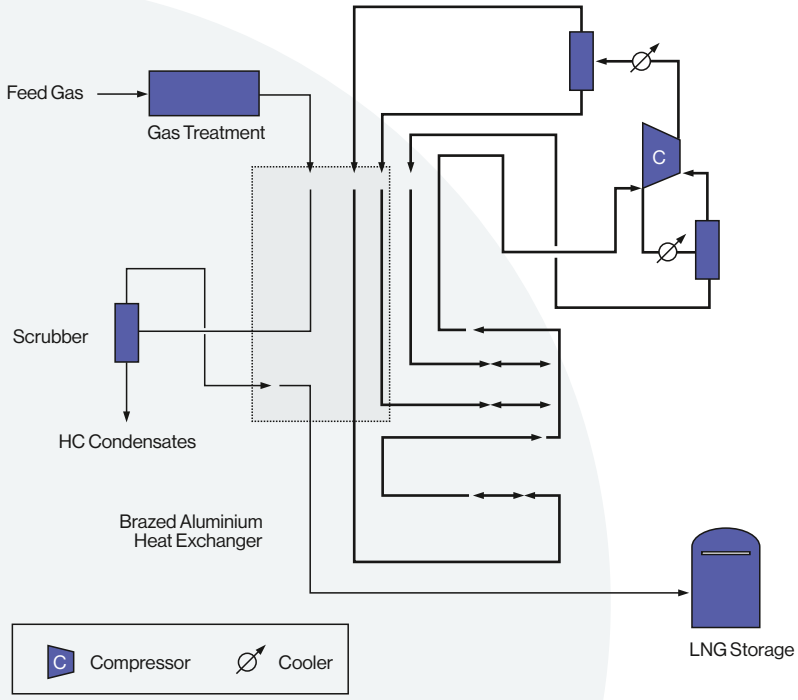
The refrigeration cycle is filled with a mixture of hydrocarbons and nitrogen.

The refrigerant is compressed and separated in liquid and gaseous streams. Lightest fractions of the refrigerant are sent to the cold end of the main heat exchanger, cooled down and sent back to the compressors after being vaporized through the main BAHX. Heaviest fractions are let down and vaporized at an intermediate level in the main BAHX.

The optimization of the mixed refrigerant cycle consists of taking advantage of the vaporization temperature difference between generated refrigerant streams to optimize the natural gas liquefaction heat exchange profile. In addition, the heavy hydrocarbons removed from the process can be recovered and sold as NGL.

Main Features:

- Efficient Process
- Reduced number of rotating machines
- Flexibility of Operation



References

17

Contact

lng@airliquide.com

LNG

Liquefin™ (Dual Mixed Refrigerant Cycle)

Application

Liquefaction of natural gas for mid and large scale plants serving LNG export terminal

Feedstock

Natural Gas

Product

LNG

Co-product

Natural Gas Liquids

Capacity

1 to 5+ Mtpa

Economics

Opex: Less than 300 kWh/ton of LNG

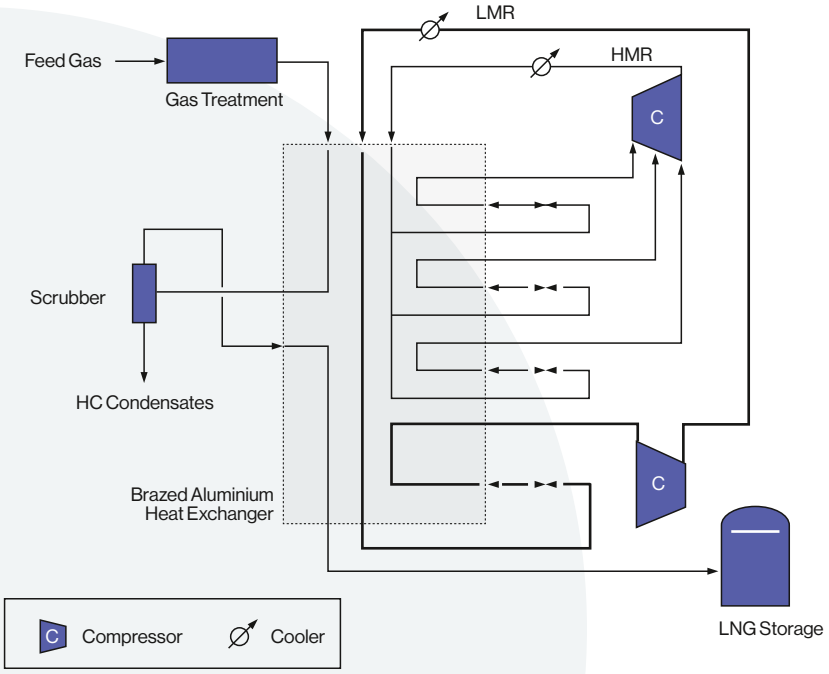
Description

Liquefin™ is a Dual Mixed Refrigerant type of process optimized with the use of Brazed Aluminium Heat Exchangers (BAHX).

Each of the two refrigeration cycles is using a dedicated mixture of refrigerant.

The first cycle is filled with a fluid composed of relatively heavy components (HMR, an ethane and propane mixture). The second cycle uses a fluid made of lighter components (LMR, a nitrogen, methane and propane mixture). Each HMR and LMR fluid is compressed through a compressor, cooled and introduced in the Cold Box under a single phase. The HMR is then let down in several stages, generating the cooling duty that pre-cools the Natural Gas (NG) and condenses the LMR at about -70°C.
No phase separation of LMR is necessary which means a simpler scheme and a better operability. The LMR is then also let down, generating the cold duty that allows for NG liquefaction and sub-cooling at about -160°C.

The proprietary Main Cryogenic Heat Exchanger is a Cold Box mainly composed of compact multi-fluid BAHX and vessels.



Main Features:

- The most efficient liquefaction process
- Low capital cost
- Modular design, lowering construction risk.

Contact

lng@airliquide.com

LNG

Boil-Off Gas Reliquefaction Units

Application

Reliquefaction of Boil-Off Gas (BOG) on import & bunker terminals

Feedstock

Boil-Off Gas

Product

Reliquefied Boil-Off Gas

Capacity

2 to 40 T/h

Economics

Typical power consumption
400 to 800 kWh/ton

Description

A boil-off gas (BOG) reliquefaction unit allows recovery of BOG emitted from LNG storage by reliquefying it.

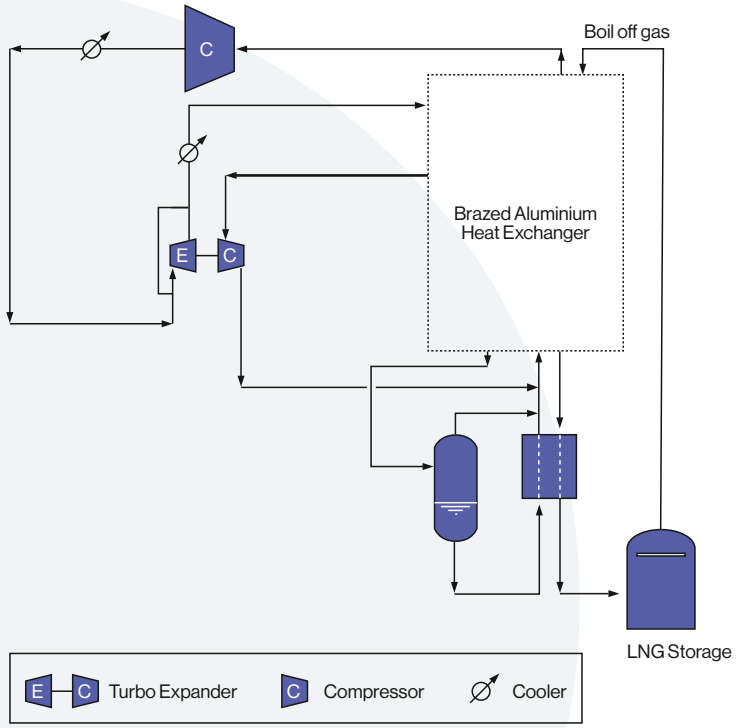
Several systems are proposed, either using liquid nitrogen or nitrogen expansion cycle as cooling agent.

Typical reliquefaction capacity is in the range 2-40 tons per hour.

Such units avoid BOG flaring, and debottlenecking of LNG export terminals. They can also reduce the cost of terminal by avoiding investment in BOG compressors

Contact

lng@airliquide.com



LNG

Bunkering Stations

Application

LNG as bunker fuel

LNG for truck distribution

LNG for remote power generation

Feedstock

Liquid natural gas

Product

Liquid natural gas / natural gas

Co-product

None

Capacity

500 to 10,000m³ storage capacity

Economics

Opex: N/A

Description

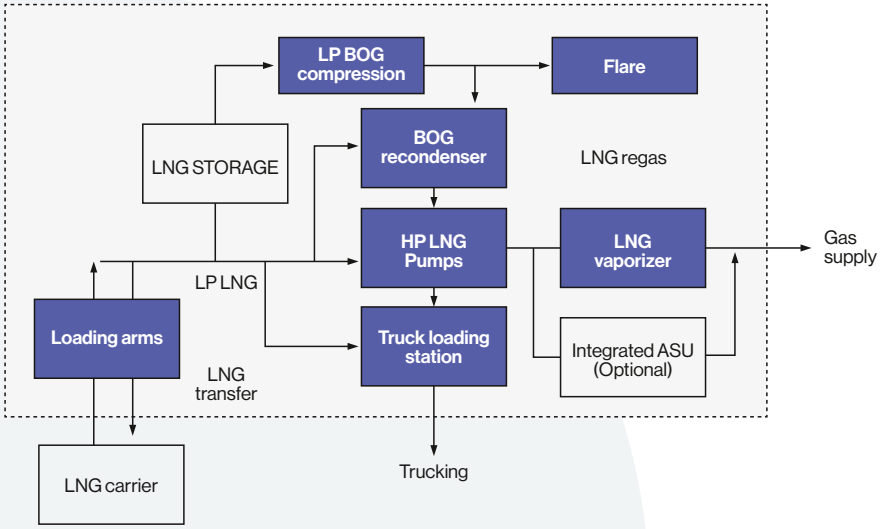
A distribution hub is used to import small quantities of LNG and distribute them to various downstream users such as ships, trucks, or power plant.

A set of several vacuum insulated tanks with a maximal capacity of 1000 m³ each are used, minimizing site work and allowing phasing of the capacity.

A proprietary boil-off gas management (BOG) system ensures that no gas is lost during operation of the hub and that the fuel remains as dense and low pressure as possible during the storage.

Equipments ensuring the interface with ship (loading arm) and trucks (proprietary Turbo-Bay) are included in the scope of supply. LNG pumps, transfer lines, metering device and regasification system (if needed) are also provided.

Downstream infrastructure (LNG trucks, refueling station, regas satellite station) can also be supplied.



Main Features:

- Proprietary BOG management technology without need for BOG compressors
- Proprietary transfer systems

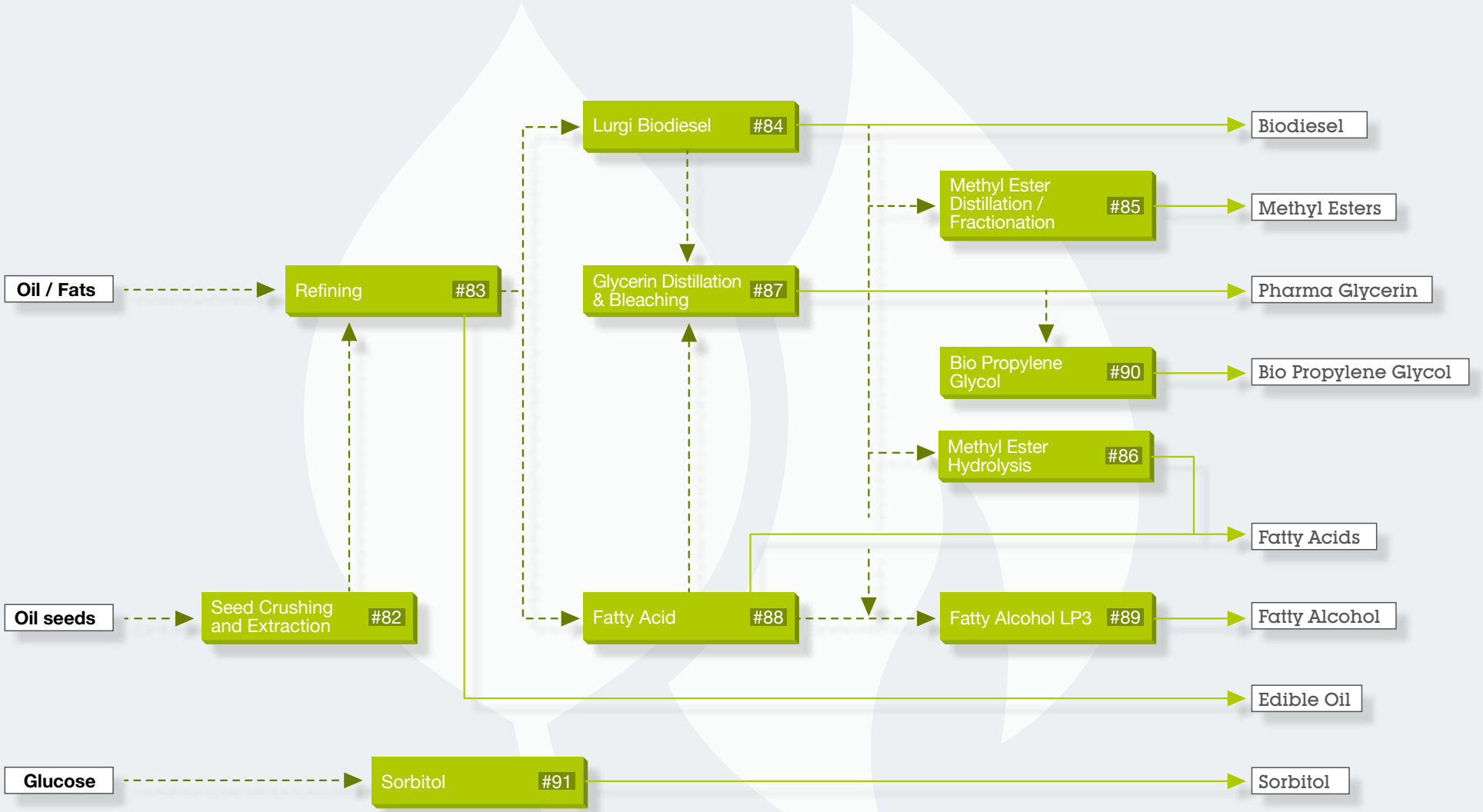
Contact

lng@airliquide.com

GREEN CHEMICALS & FUELS

Our leading edge technologies provide complete system processing, from seed crushing and oil extraction to oil refining for a wide range of downstream applications. Air Liquide Engineering & Construction green chemicals & fuels technologies create value for the food, cosmetics, detergents, surfactants and pharmaceutical industries through our comprehensive offering.

Overview


Oil / Fats
Refining #83
Oil seeds
Seed Crushing and Extraction #82
Glucose
Sorbitol #91
Lurgi Biodiesel #84
Glycerin Distillation & Bleaching #87
Fatty Acid #88
Methyl Ester Distillation / Fractionation #85
Bio Propylene Glycol #90
Methyl Ester Hydrolysis #86
Fatty Alcohol LP3 #89
Biodiesel
Methyl Esters
Pharma Glycerin
Bio Propylene Glycol
Fatty Acids
Fatty Alcohol
Edible Oil
Sorbitol

GREEN CHEMICALS & FUELS

Seed Crushing and Extraction Lurgi Sliding Cell Extractor

Application

Production of crude edible oils

Feedstock

Oil seeds (soybean, canola/ rapeseed, sunflower, palm kernel...)

Product

Crude edible oils for use in food or technical applications after refining

Meal for animal feed

Co-product

Crude lecithin

Capacity

Up to 5,000 tpd

Economics

Economics are highly dependent on the type of feedstock and required meal quality.

Capex: 25 to 100 mm USD

Description

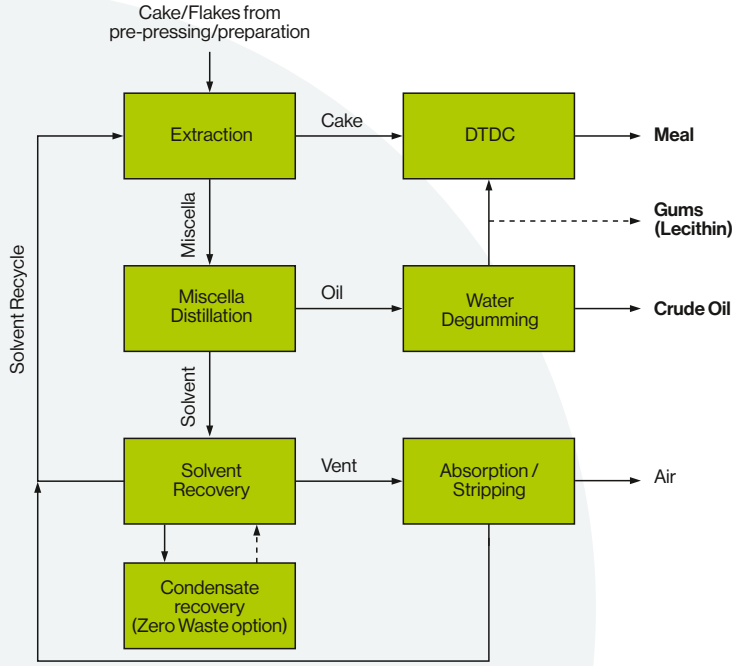
The oil content of different types of seeds ranges between 20-50% wt. After feedstock specific preparation steps (cleaning, drying, etc.) the oil is gained from the seeds by solvent extraction with hexane. For seeds with higher oil content (e.g. rapeseed, sunflower) the extraction is typically combined with a pre-pressing step to reduce the load on the extraction.

The Lurgi sliding cell extractor is the core of the extraction plant. It provides high flexibility regarding feedstock changes, very reliable operation and optimum extraction conditions with complete counter-current flow of solvent vs. cake and large contact areas.

The miscella (oil/solvent mixture) from extraction is separated into its components by distillation and water degumming. The solvent is reused in the extraction after removing the collected moisture. Gums can be purified to lecithin or recycled to the meal.

The desolventized, toasted, dried and cooled (DTDC) meal is used as protein rich animal feed.

The whole process is kept under slight vacuum so that emissions are controlled by absorption to fulfill environmental regulations.



References

>300

Contact

green-chemicals-fuels@airliquide.com

GREEN CHEMICALS & FUELS

Natural Oil Refining

Application

Removal of impurities from crude oils and fats

Feedstock

Crude oils and animal fats

Product

Pretreated and/or refined oils and fats (RBD oil)

Co-product

Fatty acid distillate (FAD)
Tocopherol

Capacity

100 tpd to 2,800 tpd

Economics

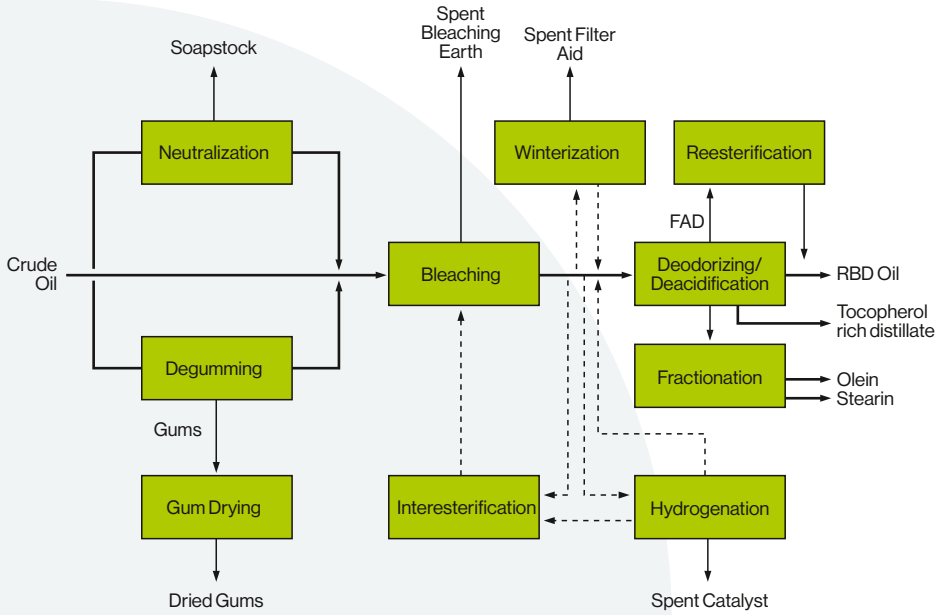
Economics are highly dependent on application of the refined oil (technical applications or edible oil), the required process steps (e.g. degumming, bleaching, winterization, deodorization, hydrogenation, fractionation and interesterification) and the type of process (batch, semi-batch or continuous)

Description

Crude oils and fats contain different contaminants like free fatty acids (FFA), phospholipids (gums), soaps, color, odor, etc. Their removal is called "refining" for food purposes to reach RBD oil quality (refined, bleached, deodorized) and "pretreatment" to reach quality for further processing, e.g. for biodiesel production or oil splitting.

Technologies are available for all applications: FFA can be removed chemically by neutralization or thermally by deacidification. Waxes are separated in winterization. Color and polycyclic aromatic hydrocarbons (PAHs) are removed in bleaching; odors and pesticides during deodorization (with vitamin E as potential by-product).

Refining also includes process steps for fat modification like hydrogenation (saturation of double bonds), interesterification (to adjust the melting point) or fractionation (separation according to chain length) and side processes like soapstock splitting or gum drying.



References

>400

Contact

green-chemicals-fuels@airliquide.com

GREEN CHEMICALS & FUELS

Lurgi Biodiesel

Application

Production of biodiesel
(Fatty acid methyl ester, FAME)

Feedstock

Vegetable or animal oils and fats; major feedstock for fuel applications are rapeseed, soya, tallow or palm oil

Product

Biodiesel meeting all international quality standards, incl. EN 14214
and AS™ D6751

Co-product

Crude glycerin (purity > 80%)

Capacity

Standard capacities 100 - 1100 tpd

Economics

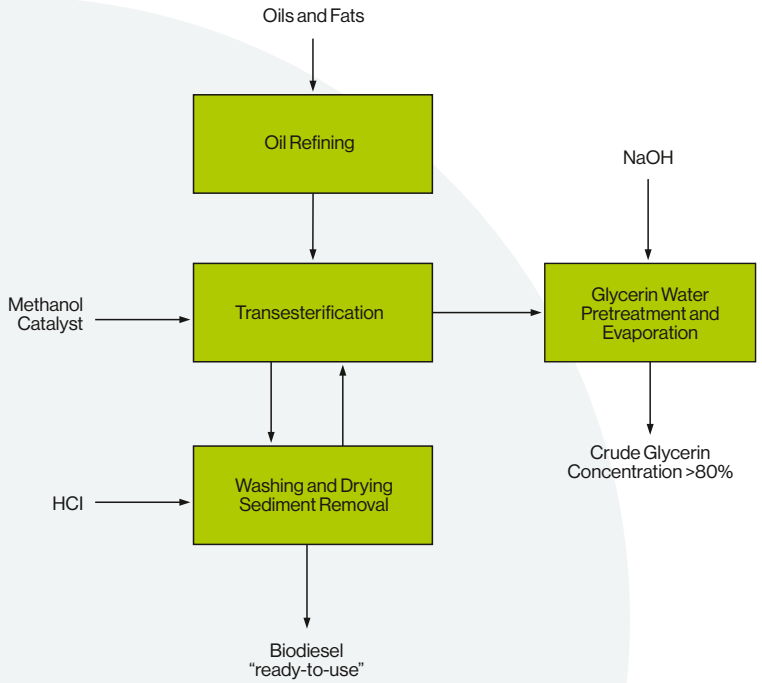
Capex: 7 to 12 mm USD

Description

Biodiesel is produced from triglycerides by transesterification with methanol under presence of an alkali catalyst (sodium methylate) at 60 degrees and atmospheric pressure.

Key features of Lurgi`s biodiesel technology are maximum yield (1 kg feedstock = 1 kg biodiesel), closed wash water loop (no waste water from core process units) and sediment removal for palm and soya oil to remove sterol glucosides far below limits given by international quality standards.

Only NaOH and HCl are used in the process. Resulting sodium chloride ends up in the glycerin, can easily be removed and does not cause fouling or side reactions during further processing (see glycerin distillation).



References

>50 (since 2000)

Contact

green-chemicals-fuels@airliquide.com

GREEN CHEMICALS & FUELS

Fatty Acid Methyl Ester Distillation/Fractionation

Application

Quality improvement of biodiesel and/or production of fatty acid methyl ester (FAME) fractions and metathised FAME for chemical industry

Feedstock

FAME from transesterification (see Lurgi Biodiesel process)

Product

FAME fractions and/or distilled biodiesel

Co-product

None

Capacity

100 tpd to 1,000 tpd

Economics

Opex: 30-50 USD/tonne (feedstock) (depending on number of fractions and their related purities)

Description

Fatty Acid Methyl Ester (FAME) is separated according to molecular chain lengths to apply specific cuts in a fractionation column. A falling film evaporator and vacuum pressure reduce heat stress to FAME resulting in superior product quality suitable for surfactant or personal care applications.

Distilled FAME can also be sold as top-quality water-clear biodiesel with improved cold flow properties and 50-100 ppm residual water. Sterol glucosides and monoglycerides are removed close to detection limits.

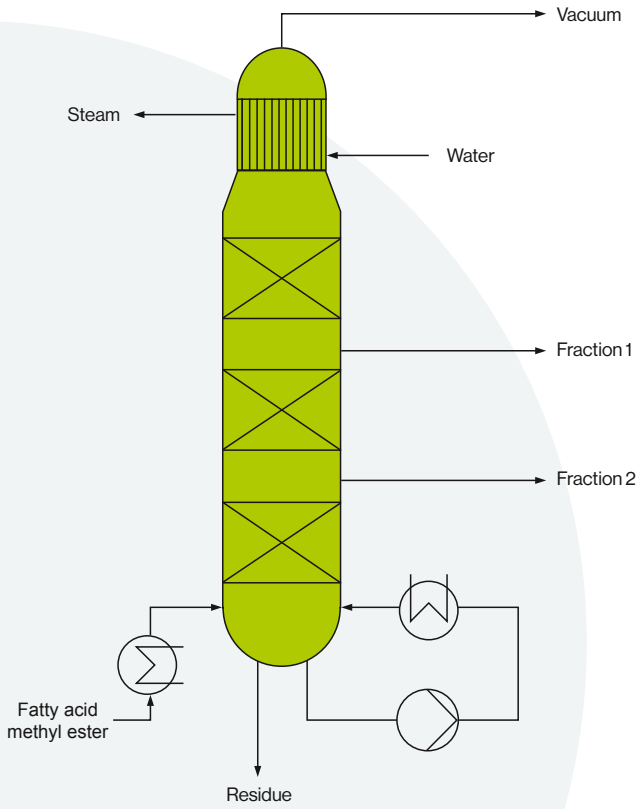
Heat recovery by steam generation makes this process very energy efficient.

References

>10 (since 2000)

Contact

green-chemicals-fuels@airliquide.com



GREEN CHEMICALS & FUELS

Methyl Ester Hydrolysis

Application
Conversion of methyl esters to fatty acids

Feedstock
Methyl ester fractions

Product
Fatty acid fractions

Co-product
Methanol

Capacity
60 tpd

Economics
Low value short-chain methyl esters can be converted to high value fatty acids

Description

Methyl ester is mixed with water and hydrolyzed to fatty acid and methanol at 250 °C and 70 bar. Heat recovery reduces the amount of energy used in the process.

The reaction mixture is cooled and separated into an organic phase and a water phase. Both streams are distilled and unreacted methyl ester and water are recycled.

The produced fatty acid is methanol-free and can be sold without further treatment. Methanol is recovered and can be used in the methyl ester production.

Contact

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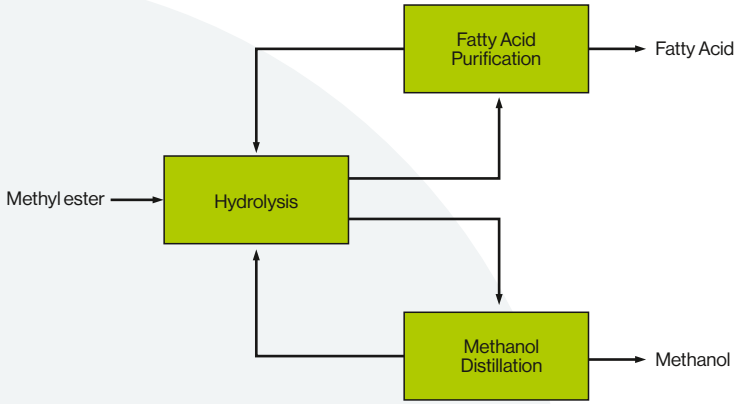


GREEN CHEMICALS & FUELS

Glycerin Distillation and Bleaching

Application
Purification of glycerin to pharma and technical grade

Feedstock
Crude glycerin from biodiesel or oil splitting (fatty acid) plants

Product
Pharma grade glycerin (purity > 99.7%)

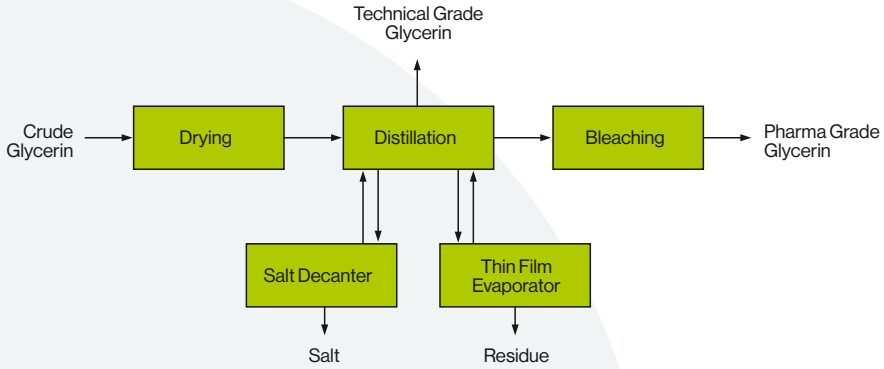
Co-product
Technical grade glycerin (purity 85-90%)

Capacity
10 tpd to 600 tpd

Economics
Opex: 35 USD/tonne

Description
Vacuum distillation is used to separate glycerin from organic components and salts at temperatures up to 175°C. The residue from the column bottom is sent to a thin film evaporator to increase glycerin yield. Salt can be separated from the residue by a decanter to reduce the amount of waste and to increase glycerin recovery even further.

Pharma grade glycerin as main product is polished by bleaching, i.e. adsorption at fixed beds of activated carbon. Light impurities end up in the by-product, technical grade glycerin.



References
> 45

Contact
green-chemicals-fuels@airliquide.com

GREEN CHEMICALS & FUELS

Fatty Acid

Application

Production of fatty acids

Feedstock

Seed oils, tropical oils, animal fats

Product

Fatty acid

Co-product

Glycerin water
(25-35% glycerin content)

Capacity

100 tpd to 1,000 tpd

Economics

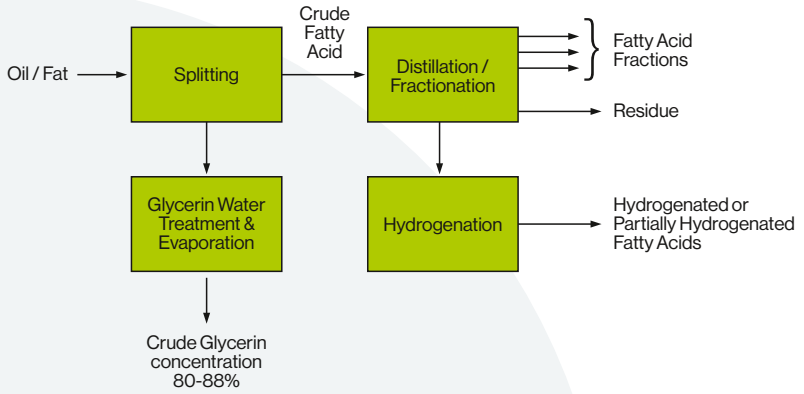
Opex: 10 USD/tonne (feedstock)
(depending on number of fractions and their related purities)

Description

Triglycerides are hydrolyzed catalyst-free to fatty acids and glycerin by addition of water at elevated temperatures (250°C) and elevated pressure (55 bar) with splitting degrees up to 99.5%. The fatty acids from the splitting column are dried by flashing before further processing by distillation/fractionation or hydrogenation. Water and glycerin are also flashed for heat recovery. Final concentration of crude glycerin is 80-88% (almost salt-free), which can be sold or further processed to pharma grade glycerin.

Fatty acids are separated from non-volatile components by vacuum distillation. Fractions of different fatty acid chain lengths with high purity can be obtained with our fractionation plants. The use of structured packing and vacuum in the fractionation columns reduces the thermal stress and ensures high product qualities. Each fatty acid fractionation plant will be tailor-made by our experts to ensure best fit to the needs of our customers.

Hydrogenation of fatty acids is the saturation of fatty acid double bonds by addition of H_2 (~99.9% by vol.) under elevated temperatures and pressure (up to 200°C @ 25 bar) in the presence of a Ni catalyst. This treatment adjusts melting points and enhances storage stability. Continuous (for full hydrogenation and large plants) and batch process variants (for full or partial hydrogenation) are available.



References

>25 (since 2000)

Contact

green-chemicals-fuels@airliquide.com

GREEN CHEMICALS & FUELS

Fatty Alcohol "LP3"

Application

Improved hydrogenation process for fatty alcohol

Feedstock

Fatty acid or methyl ester

Product

Fatty alcohol

Co-product

None

Capacity

90 tpd to 600 tpd

Economics

Opex: 100 USD/tonne
Contact us for more information.

Description

Fatty alcohols can be produced from fatty acids or methyl ester.

Latest improvement is the use of the hydrogenation step with LP3 features:

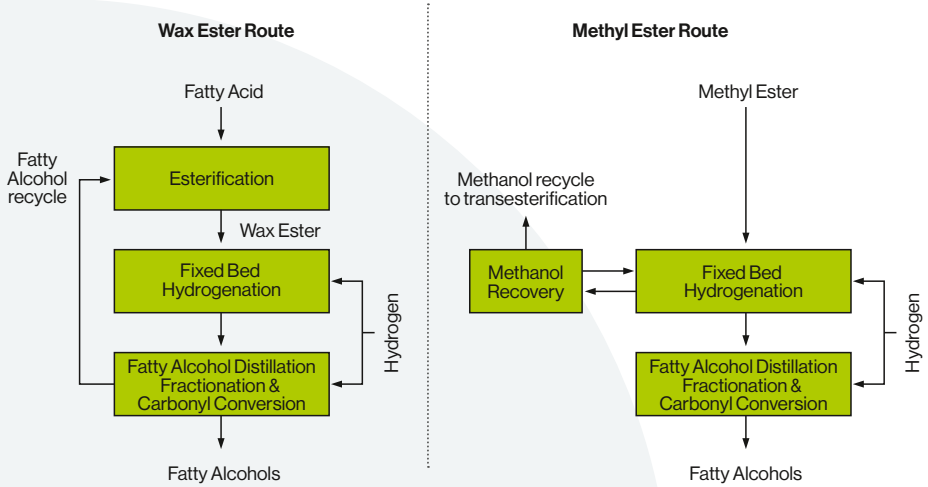
Liquid Phase: Proven liquid phase hydrogenation in fixed bed reactors also suitable for long chain fatty alcohols in contrast to vapor phase hydrogenation.

Low Pressure: Comparatively low pressure (reduced from 250 bar to 75 bar) reduces energy requirements (Opex savings approx. 5%) and Capex (savings approx. 15-20%).

Long Performance: Double reactor system for seamless catalyst changeovers with no disruption to operations and efficient catalyst utilization for more profitable lifecycles (see operation steps in diagram).

The temperature in the catalyst beds is controlled by hydrogen quenches to limit amount of side-products.

Traces of oxygenates are hydrogenated in a polishing section (carbonyl conversion).
The resulting fatty alcohol cuts can further be fractionated into final fatty alcohol products.



Unsaturated Fatty Alcohol:
As an option, long chain unsaturated fatty alcohols can be obtained retaining 95% of C=C double bonds, based on Methyl Ester route

References

8

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green-chemicals-fuels@airliquide.com

GREEN CHEMICALS & FUELS

Bio Propylene Glycol (BASF Licensed)

Application

Production of bio propylene glycol (1,2-propanediol, MPG) from glycerin as alternative to petrochemical route

Feedstock

Pharma grade glycerin

Product

Pharma grade propylene glycol

Co-product

Technical grade propylene glycol

Capacity

50 to 100 tpd

Economics

Contact us for more information

Description

In this process, licensed from BASF, glycerin is hydrogenated in liquid phase using a copper catalyst. The reaction takes place in two serial fixed bed reactors at a temperature between 175 to 195 °C and pressures between 75 and 200 bar.

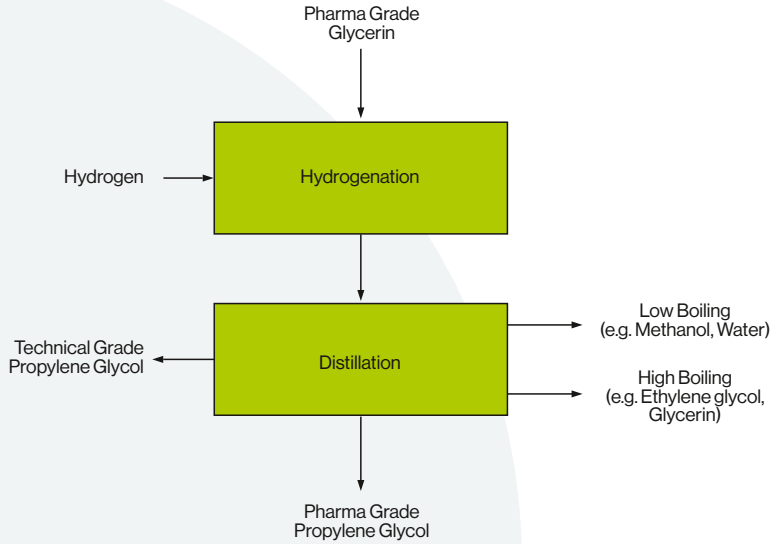
The crude product is purified in a two-column distillation unit to yield pharma grade propylene glycol.

References

1 pilot plant
1 commercial demonstration plant
2 plants in engineering phase

Contact

green-chemicals-fuels@airliquide.com



GREEN CHEMICALS & FUELS

Sorbitol

Application

Sorbitol is produced by batchwise hydrogenation of aqueous glucose solution.

This technology is also suitable for different sugar alcohols, e.g. Mannitol, Xylitol.

Feedstock

Glucose from wet milling plants

Product

Technical, food or pharma grade sorbitol

Co-product

None

Capacity

100 to 200 tpd

Economics

Opex: 130-165 USD/tonne w/o feedstock and fixed cost.

Capex: 4 to 7 mm USD

Description

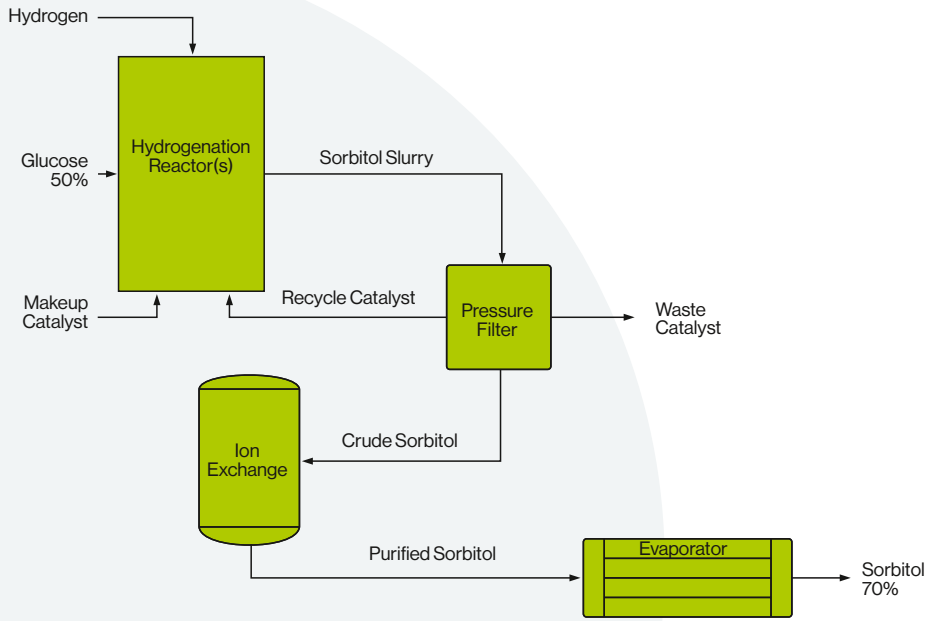
The glucose solution is hydrogenated in a batch reactor using nickel or ruthenium catalysts. Reaction takes place at 110°C and 40 bar pressure. After reaction, the product slurry is filtered to recover the catalyst. Makeup catalyst compensates catalyst loss and deactivation. The crude sorbitol solution is purified by ion exchange and evaporated to the final concentration. Optionally, sorbitol powder can be obtained by melt crystallization.

References

>10

Contact

green-chemicals-fuels@airliquide.com



CUSTOMER SERVICES

Air Liquide Engineering & Construction now offers its many years of engineering and operational experience to Customers through a growing range of Services.

Our goal is to be your one-stop service provider to make Customers gain full visibility over Total Cost of Ownership and optimize each process in the short and longer term.

CUSTOMER SERVICES

A growing range of services developed for the plants of the group

Our offer is organized in the following categories:

Engineering Services

Conversions, modifications, upgrades: from conceptual and feasibility studies to project execution for the improvement of operating plants; design for third parties and validation, performance improvement programs.

Remote Support Services

Customer training, safety studies and recommendations, technical assistance, monitoring and diagnostics from our technology centers and front-end offices.

On-Site Services

Deployment of our experts to site for issue resolution, performance checks, installation of components, supervision of planned or unplanned shut-down events.

Spare Parts Services

Customers' spares management, supply of parts through custom lists, safety stocks, interchangeability studies, compliance with regulations.

Customer Service Agreements (CSA)

To strengthen the partnership with our Customers, Air Liquide Engineering & Construction also offers its Services through tailored CSAs. These CSAs are customized and adjusted to a Customer's specific needs of support and can include services from the above categories as well as premium Services such as dedicated technical support, definition and optimization of maintenance plans, extension of guarantees. The CSA is the ideal tool to manage the Total Cost of Ownership.

Contact

customer-services@airliquide.com

CUSTOMER SERVICES

Engineering Services: pre- and post-sales solutions

Air Liquide Engineering & Construction offers a full range of pre- and post-sales solutions, from feasibility studies to upgrading of operating plants for performance improvement purposes.

A typical, comprehensive project includes detailed design work, procurement, supervision of installation and restart, performance validation tests to verify the effectiveness of the implemented solutions.

Engineering Services are central to Customer Service Agreements, where regular product or process improvement options are evaluated.

Engineering Services:

- Revampings
- Design validation
- Debottlenecking
- Studies (Screening/Feasibility/Permitting)
- Process optimization studies
- Performance improvement programs (PIP)
- Modifications / Conversions / Upgrades
- Plant life cycle assessments and extensions
- Design for third party organizations
- Project development and cost estimates

Contact

customer-services@airliquide.com

Case Study: Unit lifetime extension

Mission Oxygen plant – Europe -2013:

Our Customer wanted to revamp their plant to bring it up date and extend its life.

Intervention:

We identified the need to replace:

- Front end purification
- Electrical room
- Main heat exchanger of the cold box

Revamping planned to take place during planned shutdown.

We supervised the re-start of the ASU.

Results:

- + 15 years' life plant
- Full compliance with more stringent safety regulations.
- Excellence of Execution
- Efficient intervention in a complex environment meeting customer requirements.

CUSTOMER SERVICES

Remote Support Services: monitoring and analyses for prompt assistance

Air Liquide Engineering & Construction specialists can perform plant data analysis, carried out in our product/process centers of excellence to provide reliable, effective solutions using on-line, connectivity-based services.

Remotely conducted predictive analyses support:

- Prevention of potential incidents or problems;
- Avoidance of costly unplanned downtime;
- Life extension programs through plant obsolescence management

To further assist operations, members of our Remote Support Services team are available to hold customized training courses for your personnel on safety, equipment, processes, operations and maintenance (O&M).

Remote Support Services:

- Plant diagnoses
- Vulnerability studies
- Accident risk analyses
- Energy efficiency assessments
- Remote monitoring and diagnostic reports
- Customer training (O&M, HSE) and upgrades
- Health, Safety and Environment (HSE) studies
- Operations and maintenance optimization studies

Contact

customer-services@airliquide.com

Case Study: Process optimization

Mission LNG Terminal, UK:

The needs of our client have changed. He wanted advice to re-optimize.

Intervention:

Experts mobilized in order to fully audit their processes:

- Detailed diagnostic with recommendations for plant optimizations in the short and long term
- Combination of Remote On-Site Support with back office analysis

Results:

- Significant reduction of OPEX:
  Optimization of common header system 30% energy reduction, Payback < 6 months
- Improved equipment lifetime
  Reduced stop and go operation of units

CUSTOMER SERVICES

On-Site Services: expertise in assessments, operations, repairs

Our experienced field service engineers, the same as deployed at Air Liquide Group facilities, are at Customer's disposal for site interventions, troubleshooting and fixes.

Prompt dispatch of experts is also provided to root cause incidents and restart reliable operations after unplanned shutdown events.

On-Site repair activities, executed by our qualified team, will ensure reliable plant operations for the long term to follow.

On-Site Services:

- Repairs
- Troubleshooting and fixes
- Support upon emergency call
- Performance / Efficiency checks
- Supervision for:
  - Plant operations
  - Supplier interventions
  - Planned maintenance events
  - Installation, commissioning, start-up
- Execution of plant relocation activities

Contact

customer-services@airliquide.com

Case Study: ASU relocation and uprating project to meet higher production demand

Mission ASU – Asia - 2010:

A customer asked us to plan and complete the ASU relocation, and propose a solution to increase significantly gaseous nitrogen production.

Intervention:

To address the uprating, we provided our Customer with two detailed proposals for increasing production: adding a new ASU or upgrading an existing unit.

Our Customer opted for the upgrade.

Results:

- Flexible approach to evolving needs
  Our well-structured proposals and sound technical support enabled our Customer to make a well-informed decision with confidence.
- Cost-effective major production increase
  Upgrading was the best solution, in CAPEX terms, while our efficient execution made for reliability and a doubling of N_2 production.

CUSTOMER SERVICES

Spare Parts Services: competent support from our supply chain

Thanks to strong relationships with selected suppliers, our E&C specialists will support you at best with custom spare part lists, specifying everything needed to respect fit, form and function of installed parts. We insure interchangeability and offer assistance related to change of suppliers, obsolescence and upgrading of parts and provide assistance in case of certification requirements to comply with the latest regulations and local jurisdictions.

We also carry our consultative studies on safety and capital stocks needed to maximize the availability of your plant.

Spare Parts Services:

- Standard supply
- Emergency supply
- Site inventory audits
- Spare parts installation
- Safety and capital stocks
- Inspection and expediting
- Interchangeability studies
- Storage recommendations
- Obsolescence management
- Compliance with updated regulations
- Lists for planned and unplanned maintenance

Contact

customer-services@airliquide.com

Case Study: Sourcing and procurement of an update for a 30-year-old bundle

Mission Chemical plant – South Africa – 2015:

Our client had to change three 30+ years old bundles in order to increase plant's reliability and comply with local regulations. They had no equipment documentation and the equipment was tailor made.

Intervention:

As the initial manufacturer didn't exist anymore, we searched for vendors able to manufacture the bundles based on the technical documents from our archives.

Several components had to be upgraded so as to comply with current local regulations.

Finally, the ready to install equipment was handed to the client's transporter together with the requested documents to apply for local certifications.

Results:

- Ready to install: the bundles were made to fit the plant's design
- Performance consistency: a 12 months' performance guarantee of the equipment

CUSTOMER SERVICES

Customer Service Agreements (CSA): Easy ongoing access to our broad range of services and expertise

Customer Service Agreements (CSA) are the most comprehensive way to benefit from our Customer Services.

By simplifying your access to the expertise of Air Liquide, a CSA makes for a close partnership between your team and ours. This includes regular on-site meetings.

A single CSA provides you with the ongoing support of as many of our Customer Service as you require, enabling you to optimize plant performance and maximize cost control over time.

The CSA can be customized to fit your specific needs and circumstances, with options to renew or modify the subscribed services. The duration of the agreement is variable, keeping up with your requirements.

Customer Service Agreements:

- Easy and effective access to Air Liquide specialists and expertise:
  - Single renewable contract
  - Single contact person
  - First reply guaranteed timing
  - Practical answers with clear and easy operating instructions
  - Regular on-site meetings
- Maintenance programs
- Continuous technical support
- Extended performance guarantees
- Customer tailored terms on any selected Service

Contact

customer-services@airliquide.com

Mission ASU plants – Middle East - 2017:

Our customer wanted to increase its production, optimize the related energy consumption and sustain a good knowledge of its units.

Intervention:

We first assessed the current status of the units and their energy consumption:

- Off-site preparation and information gathering
- On-site visual inspection and report-out

Results:

A long term Service Agreement has been signed including 'on demand' specific diagnostics (feasibility studies, risk analysis, remote troubleshooting, ...), site services, spare parts services, guaranteeing the customer the best follow-up and ensuring him with support whenever requested.


Civil &
Structure
Electrical
Pressure
Vessel

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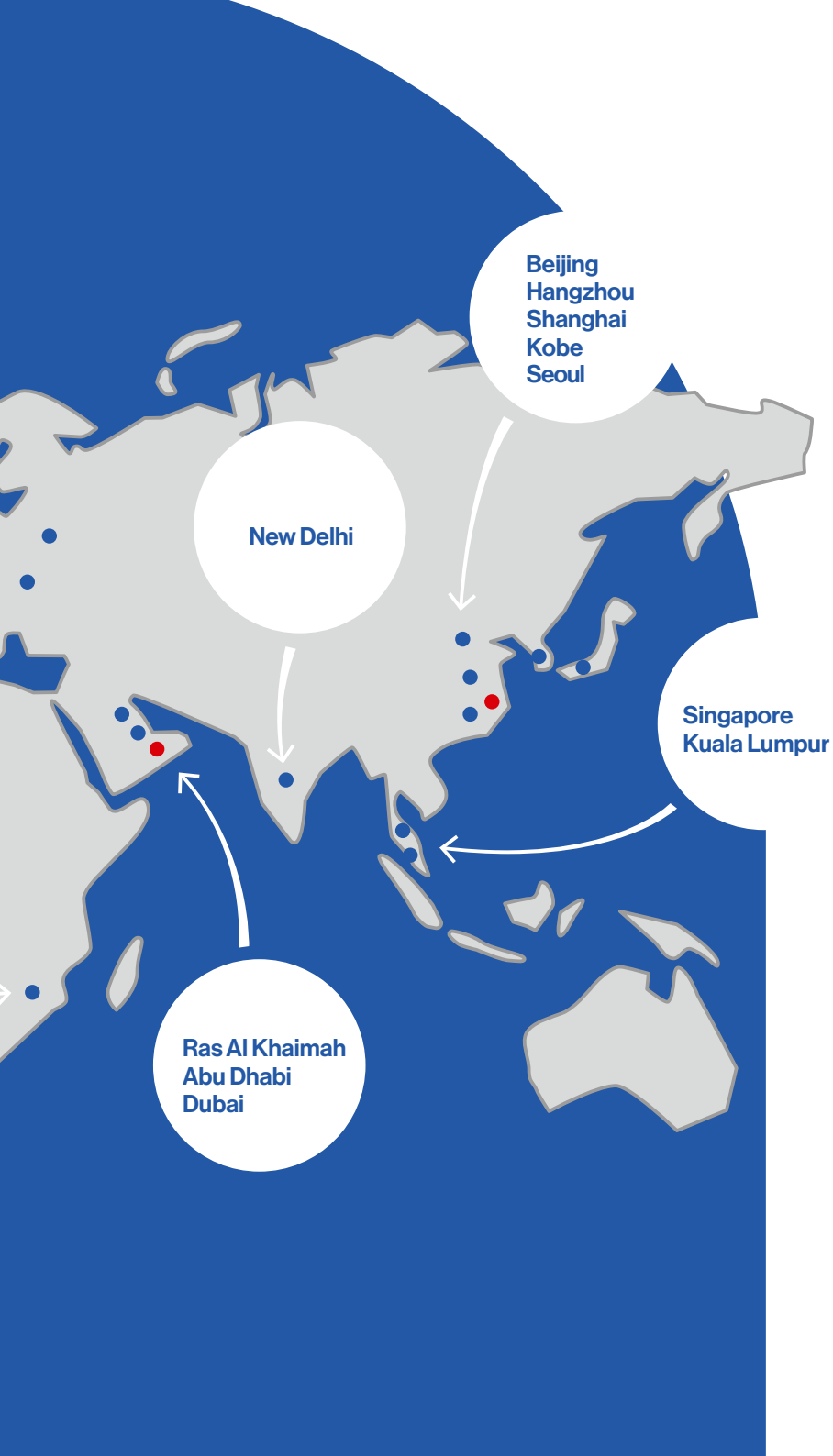
Our other locations' contact information can be found at
www.engineering-airliquide.com



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List of abbreviations and acronyms

2EHA	2-ethylhexylacrylate
2EHOH	2-ethylhexanol
AA	Acrylic acid
AA	Methanol specification per US federal regulation O-M-232e
AcAc	Acetic acid
AGR	Acid gas removal
APH	Air pre-heater
Ar	Argon
ASU	Air Separation Unit
ATR	Autothermal reformer/reforming
BA	Butylacrylate
BFD	Block flow diagram
BFW	Boiler feedwater
BOG	Boil-off gas
BTU	British thermal unit
BuOH	Butanol
C2+	Hydrocarbons with 2 or more carbons
C4	Mixture of 4-carbon hydrocarbons (butane, butylenes and butadienes)
Capex	Capital expenditures
CCR	Continuous catalytic reforming
CDU	Crude distillation unit
CH4	Methane
CLS	Claus
CO	Carbon monoxide
CO_2	Carbon dioxide
COS	Carbonyl sulfide
CSFT	Cold soak filtration test
Cu	Copper
CW	Cooling water
DEA	Diethanolamine
DME	Dimethyl ether
DMR	Dehydration and mercaptan removal unit
DRI	Direct reduction of iron ore
DTDC	Desolventizer, toaster, dryer and cooler
E&C	Engineering and construction
EA	Ethylacrylate
EAA	Ester-grade acrylic acid
EOR	Enhanced oil recovery
EtOH	Ethanol
FAD	Fatty acid distillate
FAME	Fatty acid methyl ester
FBDB	Fixed bed bry bottom gasifier
FEED	Front-end engineering design
FFA	Free fatty acid
FOB	Free on board
F-T	Fischer-Tropsch
G2G	Gas-to-Gasoline
GAN	Gaseous nitrogen
GAR	Gaseous argon
GNG	Gasesous natural gas
GOX	Gaseous oxygen
H_2	Hydrogen
H_2S	Hydrogen sulfide
HC	Hydrocarbon
HCl	Hydrochrloric acid
HCN	Hydrogen cyanide
HDS	Hydrodesulfurization
He	Helium
HF	Hydrofluric acid
Hg	Mercury
HHC	Heavy hydrocarbon
HP	High pressure
HT	High temperature
IGCC	Integrated gasification combined cycle
IMPCA	International methanol producers and consumers association
ISO	International Organization for Standardization
Kr	Krypton
LAR	Liquid argon
LIN	Liquid nitrogen
LNG	Liquefied natural gas
LOX	Liquid oxygen
LP	Low pressure
LP3	Low pressure fatty alcohols production
LPG	Liquefied petroleum gas
LTGT	Lurgi tailgas treatment
MA	Methylacrylate
MDEA	Methyl diethanolamine
MDI	Methylene diphenyl diisocyanate
MEA	Monoethanolamine
MEG	Monoetylene glycol
MeOH	Methanol
MP	Medium pressure
MPG	Multi-purpose gasifier Mono propylene glycol
MTG	Methanol-to-Gasoline
MTP	Methanol-to-Propylene
NaOH	Soda
Ne	Neon
NG	Natural gas
NGL	Natural gas liquids
NH3	Ammonia
Ni	Nickel
NMP	N-methylpyrrolidone
NO	Nitrous oxide
NOx	Nitrous oxides
NRU	Nitrogen removal unit
Opex	Operating expenditures
PAH	Polycyclic aromatic hydrocarbon
PC	Polycarbonate
PDH	Propane dehydrogenation
PDP	Preliminary design package
PIMS	Proprietary simulation software
PIP	Performance improvement program
POX	Partial oxidation
PSA	Pressure swing adsorbtion
PSD	Prevention of significant deterioration
PTSA	Para-toluene sulfuric acid
RBD	Refined, bleached and deodorized
RSH	Carbon-bonded sulfhydryl or thiol
SMR	Steam methane reforming or reformer
SNG	Synthetic natural gas
SO2	Sulfur dioxide
SOx	Sulfur oxydes
SRU	Sulfur removal unit
TDI	Toluene diisocyanate
USD	United States dollar
VDU	Vacuum distillation unit
VSA	Vacuum Swing Adsorbtion
WHRS	Waste heat recovery system
Xe	Xenon

This manual is also available in:

DIGITAL VERSION

Send request to any email address on pages 102/103
or any Air Liquide Engineering & Construction representative

More from Air Liquide:

EASY GAS CONVERTER

Gives users the ability to instantly calculate volume conversions from gaseous to liquid state for 14 gas molecules such as nitrogen, oxygen and hydrogen.

Available on Google Play and Appstore

GAS ENCYCLOPEDIA

https://encyclopedia.airliquide.com

Allows users to quickly access a host of information on the physical and chemical properties of 64 gas molecules (oxygen, nitrogen, hydrogen, etc.) in their solid, liquid and gaseous states.

Air Liquide
ENGINEERING & CONSTRUCTION

Technology Handbook

General: This Technology Handbook is intended for general information purposes only and is not intended as an offer, representation or warranty of any kind, or as a statement of any terms or conditions of sale.

The information herein is believed to be correct, but is not warranted for correctness or completeness, or for applicability to any particular customer or situation.

Economic hypothesis and definitions: Unless otherwise specified, Opex calculations include variable operating costs (utilities, feedstock...) and fixed costs (labour...). Natural gas cost is assumed to be $4/mmBTU HHV. In addition, unless otherwise specified, Capex is calculated either: a) including all EPC costs (process units, offsite and utilities) but excluding owner's costs for a plant built on the USGC; or, b) using 1.8xEP costs (process units, offsite and utilities). Price base is 2017. Opex and Capex are indicative and can vary according to the basis of design, such as: product(s) yield and quality, site conditions, feedstock quality, utilities, project scope and plant capacity. Units are metric. Gallons (gal) are US Gallons (3.785 liters). Barrel (bbl) refers to oil barrel (42 gal). Heating value shall be understood as Lower Heating Value (LHV). Exchange rate used is: 1 Euro = 1.1 US Dollar.

Editor: Air Liquide Engineering & Construction

Contact information for suggestions, improvements... email at EditorTH@airliquide.com

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Artwork: ComNext

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ENGINEERING & CONSTRUCTION

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