thyssenkrupp Uhde

The Evonik-Uhde HPPO technology

Best-in-class environmental performance, economy and product quality

thyssenkrupp

We create a livable planet

Our purpose: We create a livable planet

thyssenkrupp Uhde connects 100 years of strong heritage with the future. Thanks to our innovations and solutions, we help to provide the world with food, mobility, and much more. We strive to minimize emissions, reduce feedstock consumption – and with green chemicals, help to create sustainable value chains.

Thanks to the fertilizers produced in our plants over the decades, many people have been provided with enough food and sustenance to live a healthy life. We have continuously improved our processes and technology, thereby reducing pollution and emissions, while increasing the efficiency and safety of our plants.

In addition, our refining, organics and polymers technologies have been, and continue to be, instrumental in providing mobility, safety and comfort to people all over the world.

Our portfolio also includes bioplastics and recycling technologies. Our high-pressure know-how is applied in innovative areas such as food preservation and supercritical CO_2 extraction. And our coke plants are among the most advanced and environment-friendly in the world, with the gas treating units playing a crucial role on our path towards green chemicals.

Content

Overview

Evonik and thyssenkrupp Uhde have jointly developed a co-product-free process for the production of propylene oxide (PO) via hydrogen peroxide. Apart from the economic benefits, it offers numerous other advantages compared with current state-of-the-art processes.

In 2001, Evonik and thyssenkrupp Uhde announced an exclusive partnership to develop the new process. Evonik investigated the process and developed a catalyst optimized for the particular purpose, while thyssenkrupp Uhde contributed its expertise in process engineering and the design and construction of chemical and other industrial plants. At Evonik's site in Hanau-Wolfgang (Germany), experts from the two companies further optimized the process parameters in a mini plant which included all recycle streams and reflected the complete production process. Since 2008 the Evonik-Uhde HPPO technology has been in successful commercial operation in the first plant of its kind at SK picglobal in South Korea, the capacity of which was expanded to 130,000 t/year in 2012. Evonik and thyssenkrupp Uhde were also commissioned to build a 300,000 t/year HPPO plant for JiShen Chemical Industry Co. Ltd. in Jilin City in Jilin Province, P.R.C., which was started up in 2014. In 2022, the cooperation partners gained another reference when Qixiang Tengda Chemical Company's 300,000 t/year HPPO mega-scale plant in Zibo, China successfully went onstream. And a fourth mega project is also nearing completion: The 200,000 t/year plant for Hungarian customer MOL Group has entered the commissioning phase.

Since 2008, the world's first commercial-scale plant for the production of propylene oxide based on the innovative HPPO process has been in successful operation at SK picglobal's plant.

Since 2014, the first world-scale plant based on Evonik-Uhde HPPO technology has been producing propylene oxide in P.R. China with a capacity of 300,000 t/year.

In 2022, a mega-scale 300,000 t/year complex based on the Evonik-Uhde HPPO technology commenced production for QXTD in Zibo, P.R. China.

In 2023, one of Europe's largest HPPO plants, with a capacity of 200,000 t/year, was completed for MOL Group in Hungary, Central Europe.

The Evonik-Uhde process produces PO from propylene and hydrogen peroxide (H_2O_2) using a special titanium silicalite (TS-1) catalyst. The advantages of the new process are clear. It is more cost effective to operate than the PO production processes currently used, and the significantly lower capital investment costs allow investors greater flexibility in their investment decisions.

In addition, the new process is environment-friendly, highly efficient and the only co-product is water. Moreover, feedstock consumption is low due to high specific yields (> 96% propylene).

The advantages of the Evonik-Uhde HPPO technology

- → Co-product free
- → Efficient feedstock consumption
- → High-performance catalyst with long lifetime
- → Low investment costs

The HPPO technology is licensed by Evonik and thyssenkrupp Uhde. Evonik can either license the H_2O_2 technology or supply the H_2O_2 to the PO plant "over the fence" as the preferred supplier. As the contracting and engineering partner for both technologies, thyssenkrupp Uhde can build both the H_2O_2 and the PO plants.

Evonik is one of the world leaders in specialty chemicals. The company is active in more than 100 countries around the world and generated sales of €15 billion and an operating profit (adjusted EBITDA) of €2.38 billion in 2021. Evonik goes far beyond chemistry to create innovative, profitable, and sustainable solutions for customers. Around 33,000 employees work together for a common purpose: We want to improve life today and tomorrow. Evonik's Active Oxygens business line produces hydrogen peroxide and peracetic acid for a wide variety of specialized applications. These range from chemical synthesis to municipal and industrial wastewater treatment, food processing, semiconductor manufacturing, aerospace applications, active pharmaceutical ingredients, and more. As one of the world's leading producers of hydrogen peroxide and peracetic acid, the business line has production facilities at 19 locations across the globe. Its plants can be found in Europe, North America, South America, Africa, Asia, and Oceania, ensuring ready availability no matter where a customer is located.
At Evonik Active Oxygens, sustainability is at the core of futurizing our business. We make some the world's greenest chemicals: After their powerful oxidation action, hydrogen peroxide and peracetic acid break down into benign substances that leave no trace of harmful chemicals on the environment.

Learn more at: evonik.com/activeoxygens

General process description

The Evonik-Uhde HPPO technology for the production of propylene oxide using H_2O_2 is a highly exothermic process which takes place under relatively mild process conditions. It is shown in the flowchart below.

In the reaction unit, the catalytic epoxidation of propylene is carried out in the presence of a titanium silicalite catalyst using hydrogen peroxide (H_2O_2) in methanol as the solvent. Development of the HPPO process focused on the epoxidation reactor for the synthesis of PO using a fixed-bed reaction system operating at elevated pressure and moderate temperature. The special design combines an intense heat transfer with an almost ideal plug-flow characteristic, resulting in a high PO selectivity.

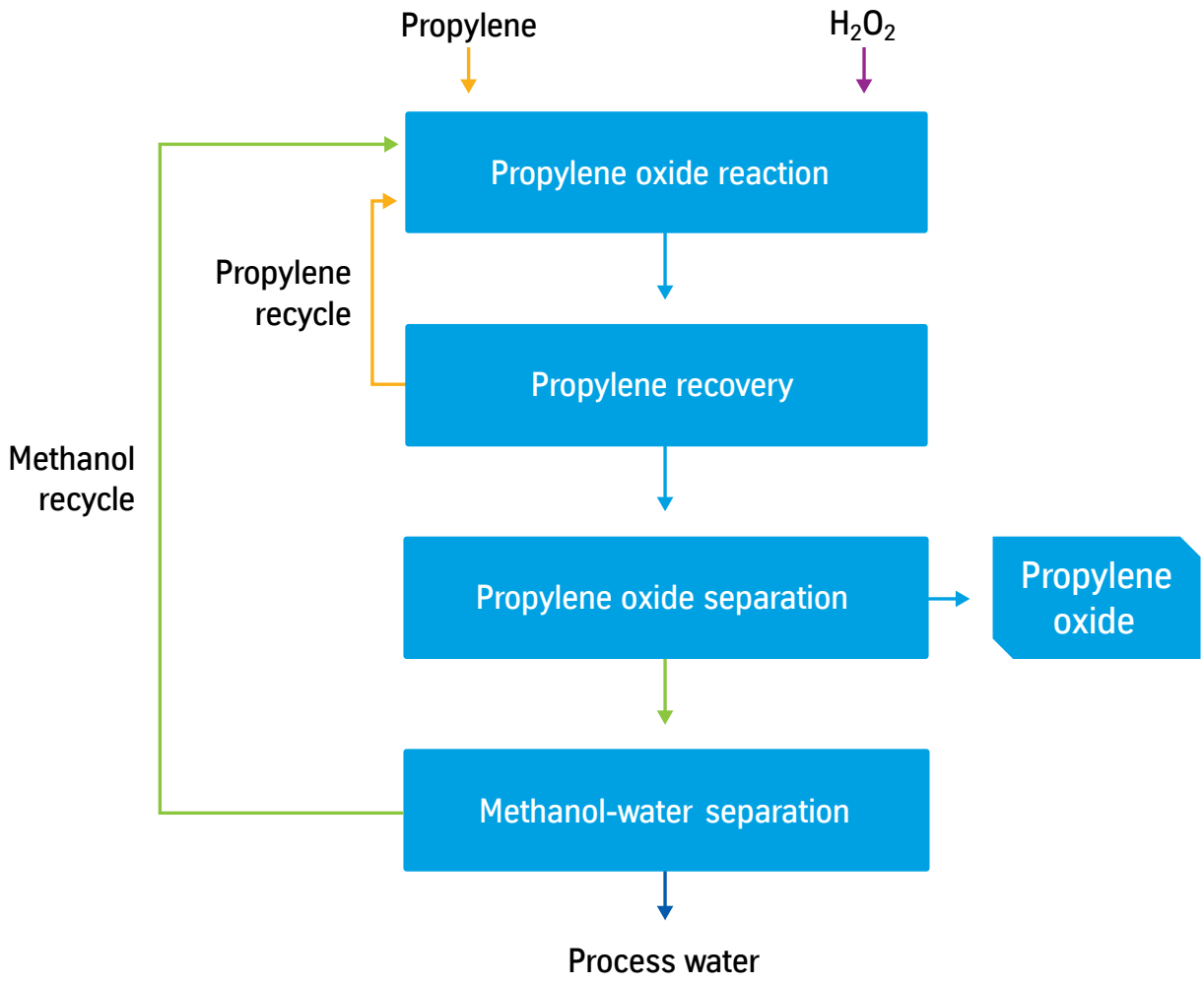
As the quality and characteristics of the hydrogen peroxide have a substantial influence on the process parameters, Evonik has developed a grade of hydrogen peroxide specifically designed for use as an oxidising agent in the epoxidation of propylene.

Polymer-grade or chemical-grade propylene can be used as feedstock. If chemical-grade propylene is used, propane is separated from propylene in an integrated propylene rectifier.

The propylene cycle of the PO plant is a closed loop and the surplus propylene recovered is returned to the reaction section.

The crude PO contains impurities, which are removed in the PO purification section by state-of-the-art rectification under moderate conditions.

Water and small amounts of by-products are removed in the methanol processing section and the purified solvent is recycled to the reactor.



Main applications of propylene oxide

Propylene oxide (PO) is a colorless, low-boiling liquid of high reactivity. Its polarity and strained three-membered epoxide ring allow it to be opened easily by reaction with a wide variety of substances.

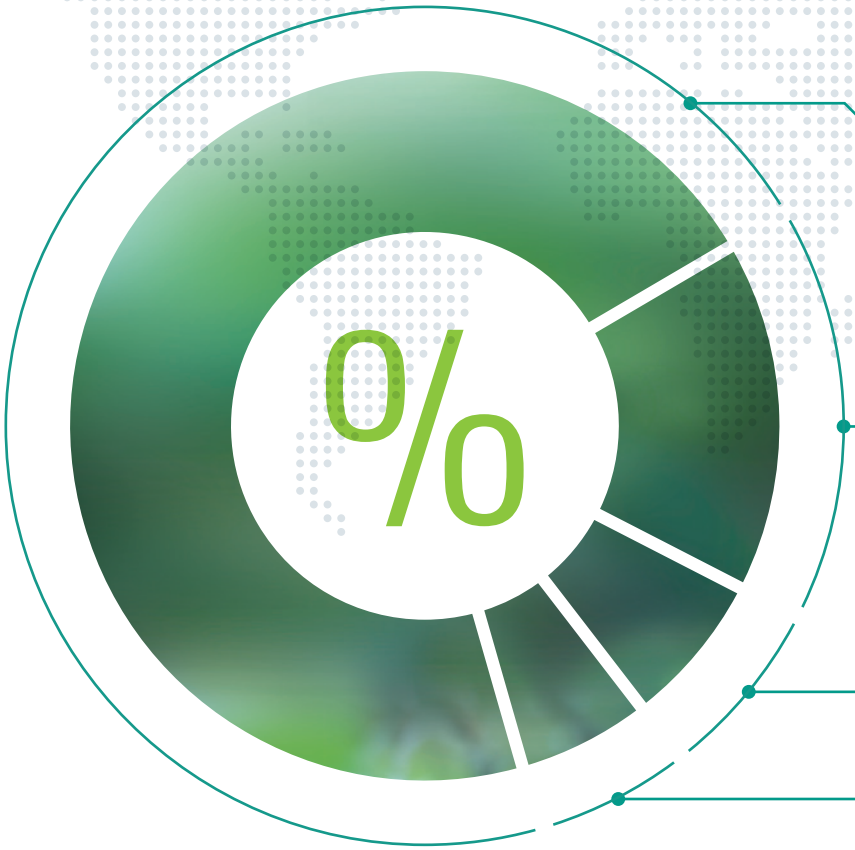
Having become increasingly important since the early 1950s, more than 10 million metric tons of PO are now produced annually worldwide, with consumption rates outstripping GDP growth rates.

PO is one of the most important bulk chemical intermediates, especially in the polyurethane and solvents industry.

Polyurethanes are used in a wide range of applications, including automobile components, furniture upholstery, thermal insulation, coating materials, sports shoes and sporting goods.

At present, more than two thirds of PO output is used for the production of polyether polyols, followed by about 16% for propylene glycols (PG) and about 13% for glycol ethers and other applications.

World consumption of propylene oxide in percent



71%
Polyether polyols
(polyurethanes, flexible & rigid foam)

16%
Propylene glycol
(polyester, pharmaceuticals, cosmetics)

7%
Glycol ethers

6%
Others
(surfactants, polyalkylene glycols for a variety of chemical intermediates & functional fluids)

Process highlights

Advantages of the Evonik-Uhde HPPO technology

- Co-product free process
- Best-in-class environment-friendly technology
- Go green with green hydrogen for H_2O_2 production
- Long track record on safe & reliable operation (since 2008) in reference plants
- Best-in-class propylene oxide product
- Best-in-class consumption figures
- High-performance catalyst with proven long lifetime
- Long track record on R&D (since 2000)
- Use of either polymer-grade or chemical-grade propylene
- Specially designed epoxidation reactor for highly exothermic reaction, combing an efficient heat transfer with an almost ideal plug-flow characteristic
- Maximum flexibility for production of a wide range of polyol grades due to lower water content and chlorine-free product

Environmental benefits

Best-in-class environment-friendly technology:

- Zero reported safety incidents since start of commercial operation
- Lowest carbon footprint compared to other HPPO technologies
- Optimized energy balance of entire plant
- All effluents can be treated using state-of-the-art technology for compliance with latest environmental standards

Economic benefits

Best-in-class economy:

- No market dependencies on co-products
- High operational flexibility and reliability
- Lowest capital investment of all HPPO technologies
- Lowest operating cost compared with all co-product-free technologies
- By-product recovery units enable greater revenue through the sale of valuable products (~ 15 kg PG/metric ton PO and ~ 23kg 1-MPOL + 2-MPOL/metric ton PO)
- Between 0.24 and 0.36 metric ton steam/metric ton PO can be credited

Propylene oxide product specification

Best-in-class product:

• PO purity by GC (dry basis):	min. 99.98	wt.ppm
• Water:	max. 80	wt.ppm
• Aldehydes, total:	max. 20	wt.ppm
• Methanol:	max. 20	wt.ppm
• Acidity:	max. 20	wt.ppm
• Color, Pt-Co:	max. 5	APHA Hazen Scale
• Chlorine:	b.d.l.	

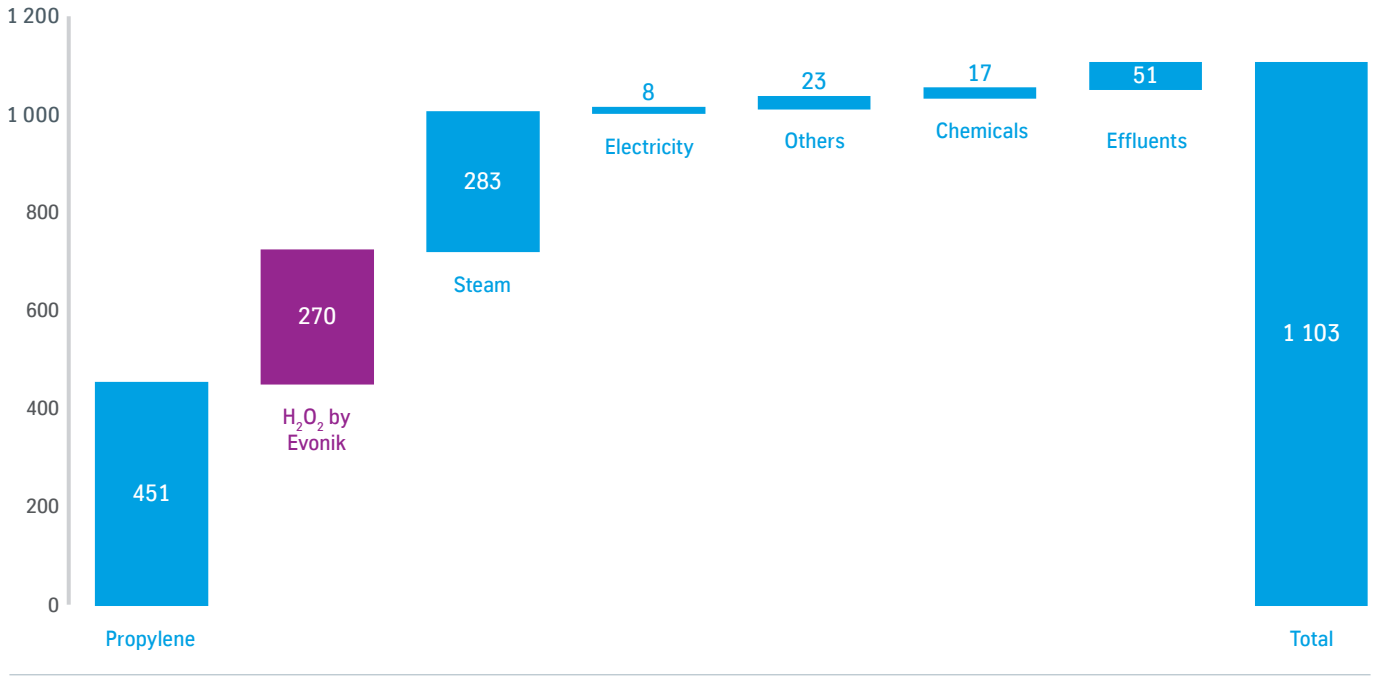
Consumption figures

Best-in-class feedstock and energy consumption:

• Propylene (at 100%):	0.75 kg/kg PO
• Hydrogen peroxide (at 100%):	0.64 kg/kg PO
• Steam (at 42 barg/400°C):	2.25 kg/kg PO
• Electricity:	240 kWh/t PO

World-beating carbon footprint

Carbon footprint for Evonik-Uhde HPPO plant
Best case



Thanks to the low feedstock consumption and consolidated energy integration concept of our HPPO technology, our PO production process achieves the lowest carbon footprint of all propylene oxide technologies.

The figures shown in the graph above are for feedstocks and utilities that are produced by renewable, low-carbon means, which have been gaining traction in the market in recent years.

The figures still leave room for improvement. The steam consumption is calculated based on the traditional natural gas production route. However, we are already evaluating state-of-the-art alternatives, such as electricity as a heating medium, which has the potential to reduce the CO_2 footprint to around 700 kg CO_2/metric ton of PO, as it reduces not only the steam footprint in the HPPO plant, but also in the H_2O_2 facility.

Ultimately, our core mindset is a zero-emissions philosophy. We continue to work hard to provide our customers with the most efficient and environment-friendly approach to treating HPPO plant emissions, thereby reducing the CO_2 footprint of downstream units.

Detailed process description of the Evonik-Uhde HPPO technology

Reaction

In the PO reaction, propylene (C_3H_6) and hydrogen peroxide (H_2O_2) are reacted in a methanol/water mixture over a special titanium silicalite catalyst (type TS-1) in a fixed bed reactor.

C_3H_6 + H_2O_2 → C_3H_6O + H_2O

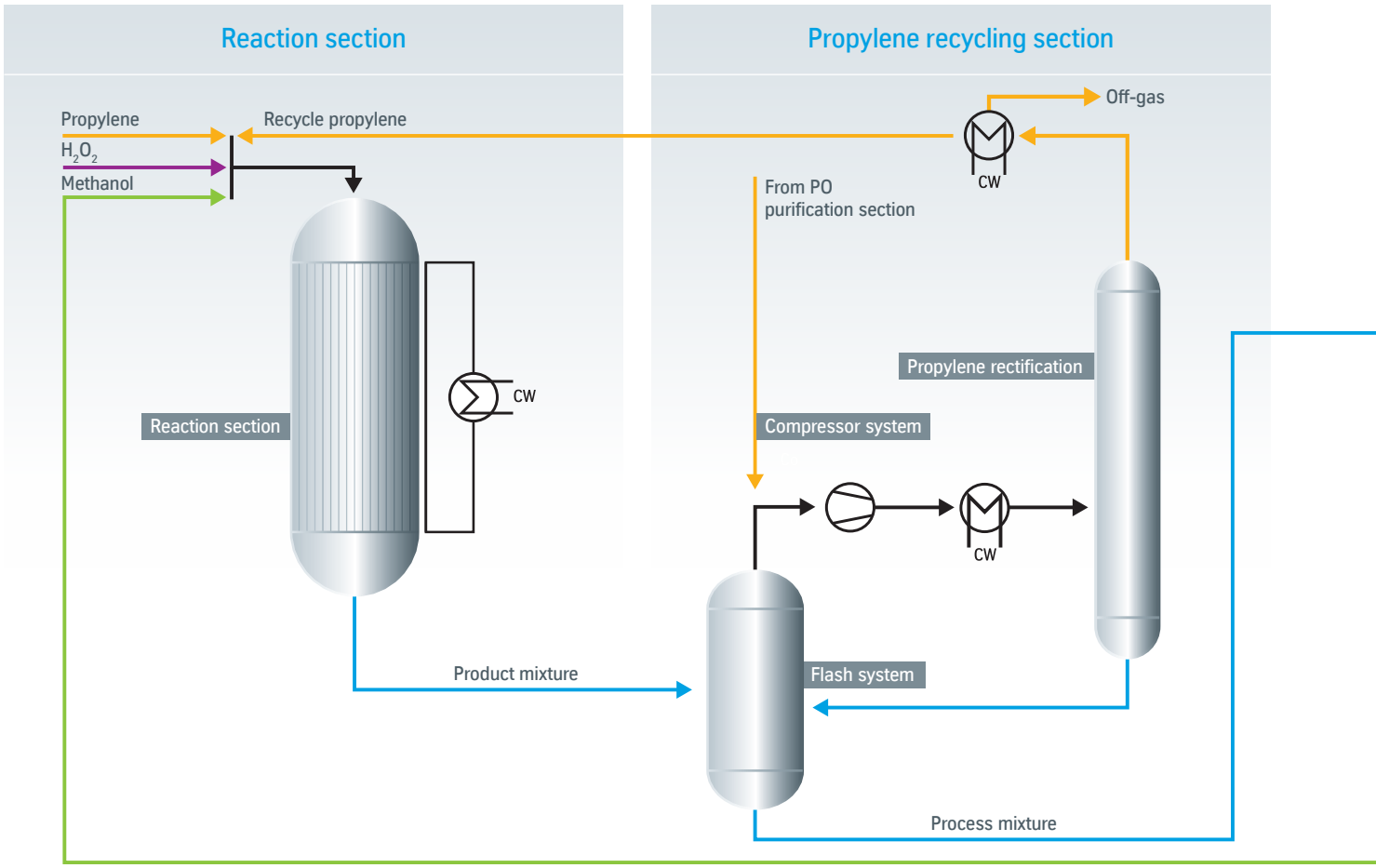
propylene **hydrogen peroxide** **propylene oxide** **water**

The process is characterized by mild process conditions with temperatures below 100°C, resulting in low by-product formation. The pressure in the reaction unit is approximately 30 bar.
Due to the optimized process parameters, a high propylene-based PO selectivity of more than 96% can be achieved.

The heat of the highly exothermic reaction is removed by an integrated cooling system. After reaction, the product mixture containing mainly methanol, water, propylene and PO is withdrawn from the reactor and sent to the propylene recycling unit.

Propylene recycling

In the flash system, the product mixture is heated and depressurized to a pressure slightly above atmospheric pressure, resulting in a propylene-rich gas phase, which is compressed, condensed and returned to the reaction section.
The off-gas, which contains mainly inert compounds and a small quantity of oxygen from the decomposition of the hydrogen peroxide, is withdrawn and delivered to the battery limits.



PO purification

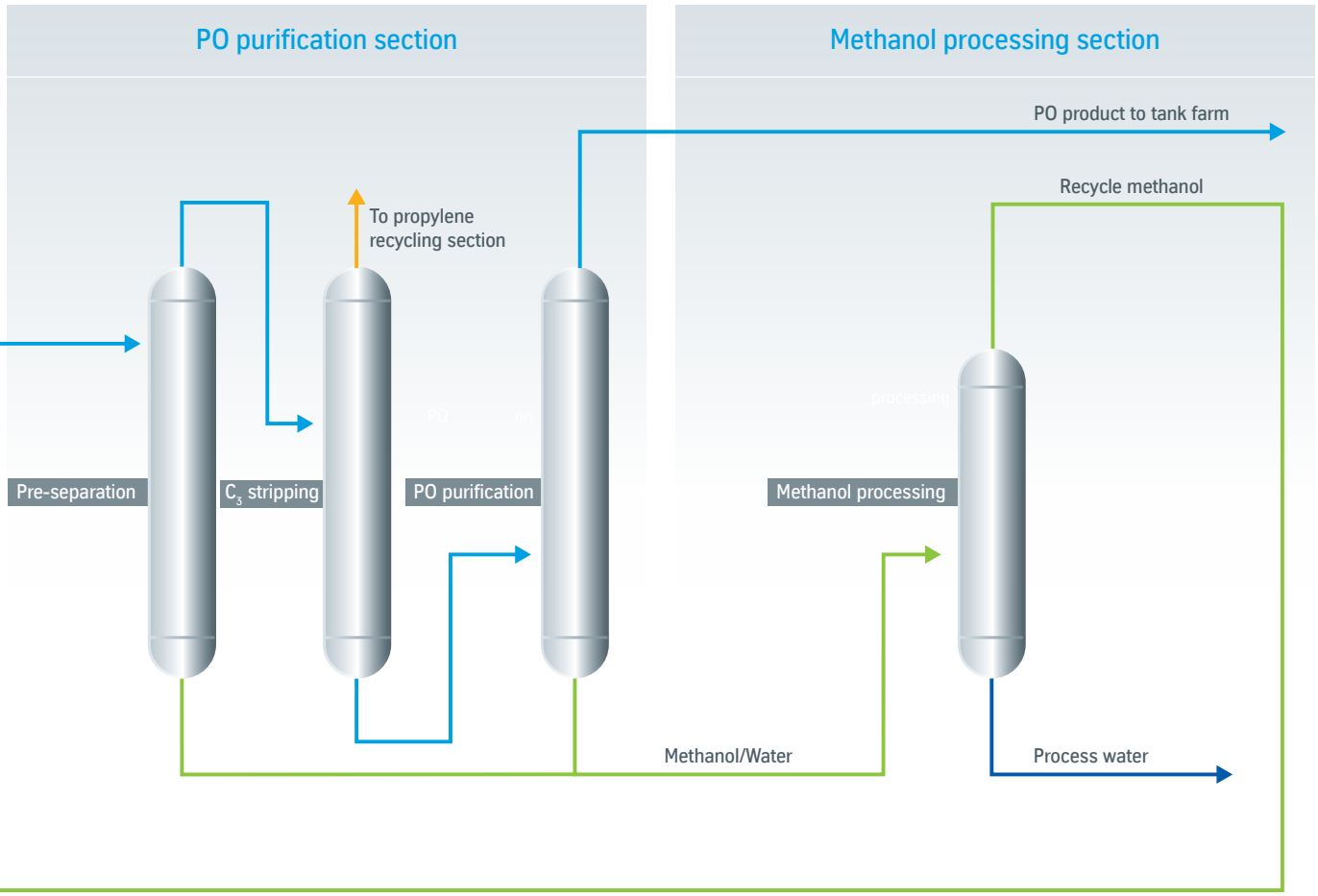
The depressurized liquid product mixture is then transferred to the pre-separation section, which ensures that all of the PO and dissolved propylene (which still contains some methanol) leave as overhead. A C_3 stripper then removes the remaining propylene from this PO/methanol mixture.
The PO distillate is purified in the PO column and the remaining methanol and water, as well as the small quantities of impurities, are removed in the bottom product. The PO distillate sent to the tank farms meets the highest quality standards.

Methanol processing

The methanol in the methanol/water mixture withdrawn from the bottom of the pre-separation column and from the bottom of the purification column is separated from the water in the methanol processing section. The overhead methanol stream is returned to the PO reaction section.
The bottom product from the methanol column contains water and small amounts of high-boiling by-products, which can be recovered for sale.

Purification of chemical-grade propylene

The PO plant can operate with both chemical and polymer-grade propylene. With the use of chemical-grade propylene in particular, considerable amounts of propane are continuously introduced into the process with the fresh propylene stream. Propane acts as an inert diluent in the reaction system. To keep the propane concentration at a constant level, the surplus propane is removed in the propylene purification column.
The column increases the propylene concentration in the overhead product while the bottom product accounts for the propane balance. The bottom product can be valorized in the form of steam credit while the propylene stream is returned to the PO reaction section.



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