Organic chemicals and polymers

A company
of ThyssenKrupp
Technologies

Uhde

ThyssenKrupp

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Organic chemicals and polymers
Plastics have become an indispensable material in everyday life and are used in a wide variety of technical applications. Over 200 million tonnes of plastics are produced throughout the world every year, most of which are commodity polymers such as polyethylene, polypropylene, polyvinyl chloride and polyester.

When it comes to the production of these plastics Uhde provides its customers with large-scale, cost-effective, environment-friendly plants based on first-class processes.

1. Company profile

Uhde's head office
in Dortmund, Germany

With its highly specialised workforce of more than 4,900 employees and its international network of subsidiaries and branch offices, Uhde, a Dortmund-based engineering contractor, has, to date, successfully completed over 2,000 projects throughout the world.

Uhde's international reputation has been built on the successful application of its motto **Engineering with ideas** to yield cost-effective high-tech solutions for its customers. The ever-increasing demands placed upon process and application technology in the fields of chemical processing, energy and environmental protection are met through a combination of specialist know-how, comprehensive service packages, top-quality engineering and impeccable punctuality.

Overview

In the world of international plant construction, companies have to be able to provide industrial plant owners with first-class processes which guarantee the maximum level of productivity, availability, economic viability and environmental compatibility.

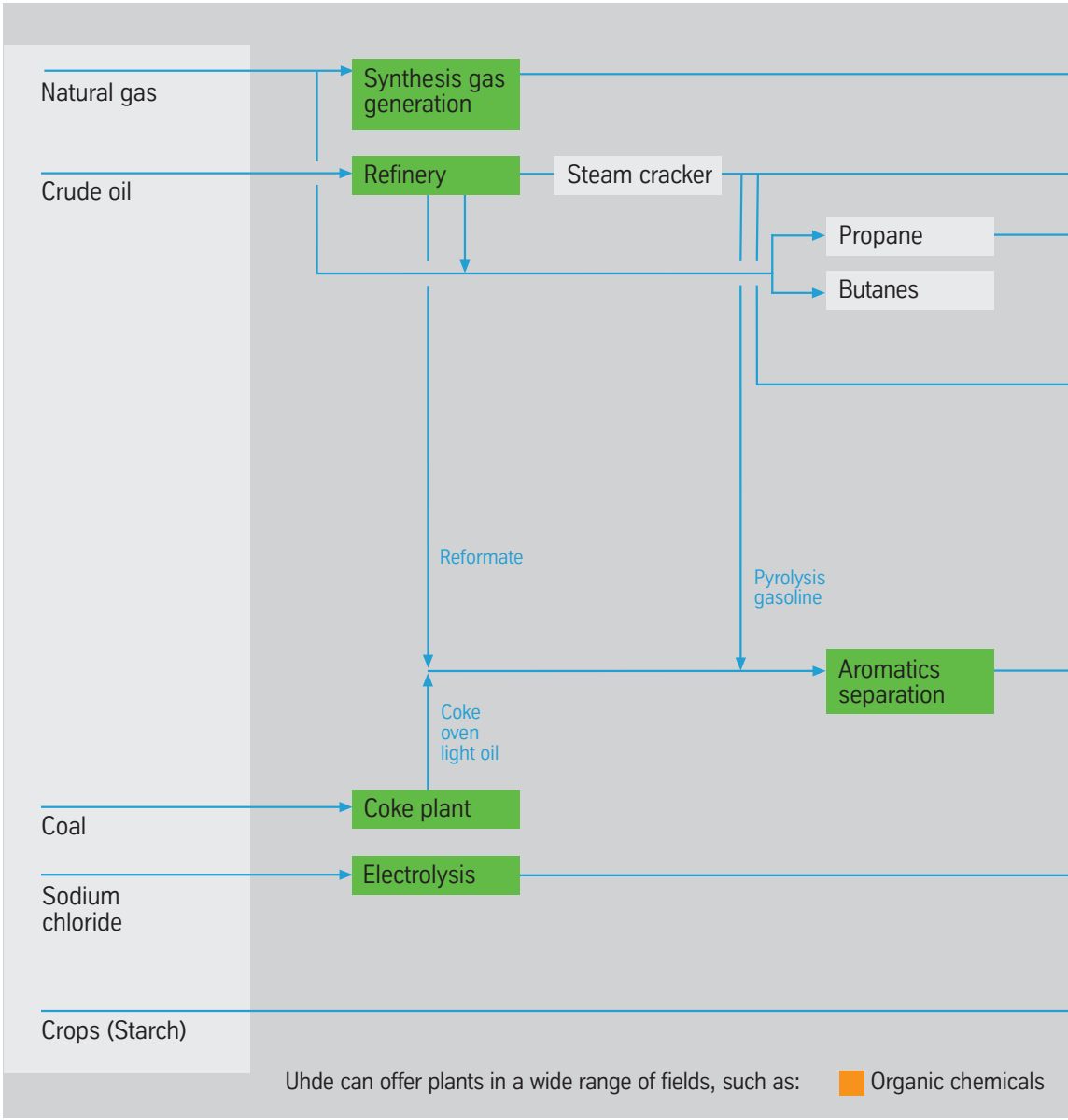
For decades now, Uhde has been a leading force in the construction of plants for organic chemicals and polymers. Supported by licensors of international acclaim, such as LyondellBasell, Evonik, Shell and Vinnolit, we are able to provide our customers with premium processes in a variety of fields.

By working closely with these licensors, we are among the market leaders in various fields of activity, such as EDC/VCM and polyethylene, with respect to the overall annual capacity of the plants we have so far built.

The following pages provide an overview of the main fields in which we are active.

2. Uhde's fields of activity
Organic chemicals, polymers and more...

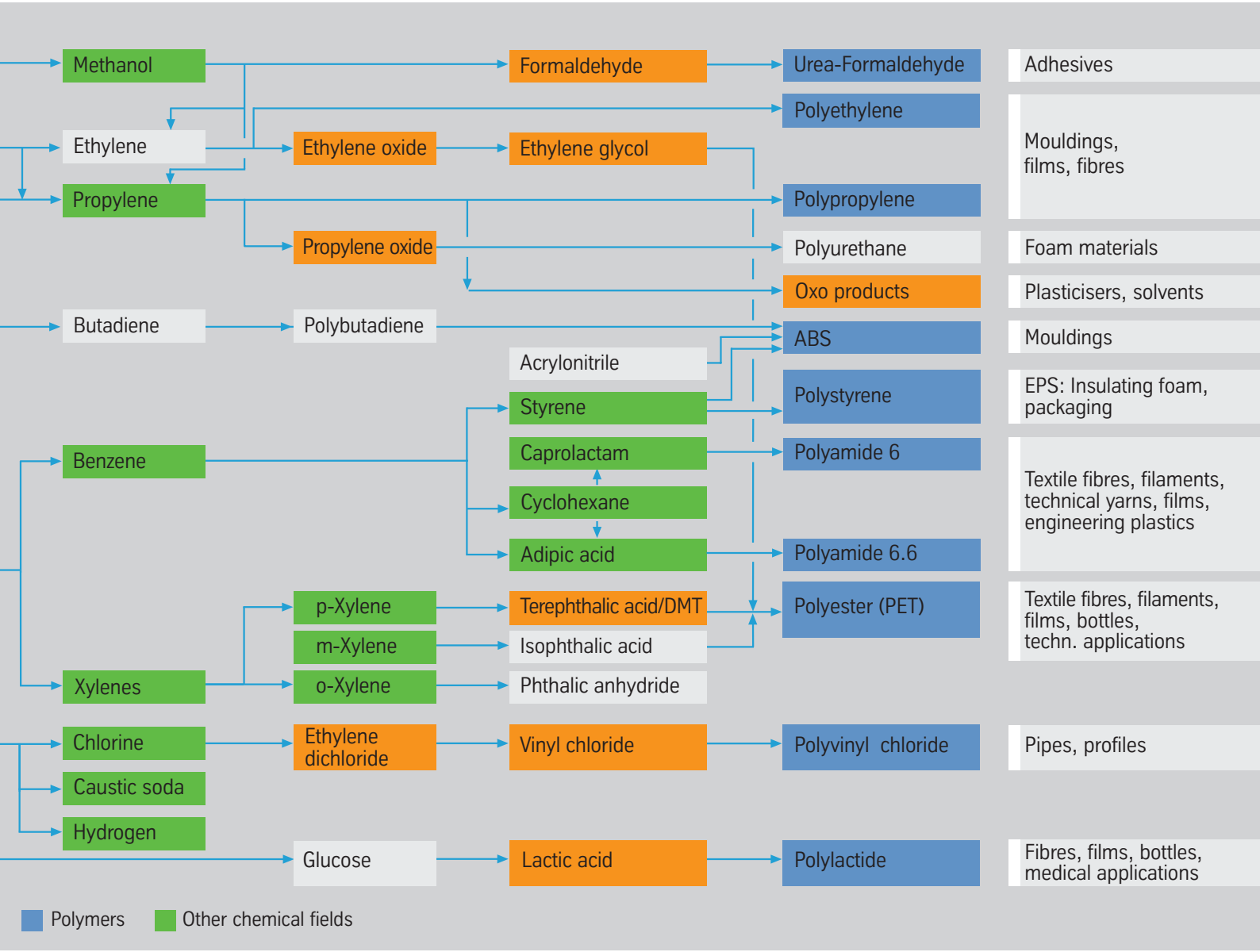
With its wide range of first-class proprietary technologies and those supplied by reputable licensors, Uhde is active in an extensive number of different chemical and petrochemical segments.



Organic chemicals

Ethylene dichloride (EDC)
Vinyl chloride (VCM)
Ethylene oxide (EO)
Ethylene glycol (MEG)
Propylene oxide (PO)
Vinyl acetate (VAM)
Oxo alcohols
Formaldehyde[UIF]

[UIF] These technologies are supplied by our subsidiary Uhde Inventa-Fischer



Polymers

Polypropylene
Homopolymers
Copolymers

Polyethylene
High-density polyethylene (HDPE)
Medium-density polyethylene (MDPE)
Low-density polyethylene (LDPE)
Linear polyethylene (LLDPE)

Polyvinyl chloride
PVC-S

Polyester[UIF]
PET, PBT, PEN, PTT and copolyester for textile, bottle and film grade

Polyamide[UIF]
PA 6, 6.6, 11, 12 and copolyamide for textile applications and engineering plastics

Polylactide (PLA)[UIF]

Others
Styrenic plastics (ABS, EPS, GPPS/HIPS)
Carboxymethylcellulose (CMC)
Urea-formaldehyde resins[UIF]
Engineering plastics

[UIF] These technologies are supplied by our subsidiary Uhde Inventa-Fischer

3.1 Ethylene dichloride EDC Vinyl chloride VCM

We provide technologies with economic and environmental benefits

Vinyl chloride, its precursor ethylene dichloride, and also polyvinyl chloride, the main end product, rank amongst the world's largest money-spinners. 35-50 million tonnes of each product are produced around the world each year. And, although people have been saying for decades that chlorine chemicals are on their way out, production continues to grow by 3-4 % per year. This is due on the one hand to the versatility of PVC, and on the other, to the considerable improvements which the processes have undergone in the last years with regard to environmental and safety issues.

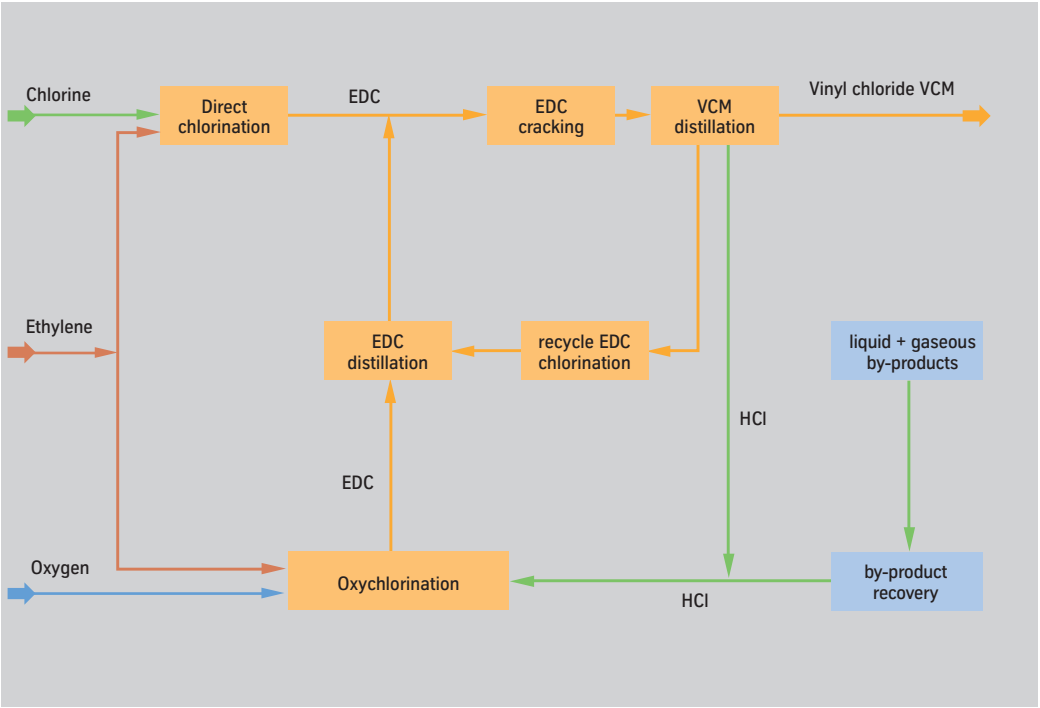
Uhde is the exclusive contractor for Vinnolit technology. Vinnolit has been producing EDC, VCM and PVC for over 60 years and is one of the 10 largest PVC producers in the world. Since 1963 we have used Vinnolit know-how to design new plants for our customers and optimise existing ones. The overall annual capacity of all these plants has reached more than 10 million tonnes of EDC and more than 5.5 million tonnes of VCM.

Uhde has engineered and constructed several large vinyl complexes with integrated chlor-alkali electrolysis plants. A new huge vinyl complex is being built by Uhde on the Persian Gulf. It includes the entire process chain from the chlor-alkali electrolysis and the EDC/VCM plants to the PVC plant. The annual capacities of the individual plants within the framework of this project will combine to form one of the world's largest PVC complexes.

Our extensive experience in the design, construction and commissioning of such plants and our intensive development of individual process steps and equipment are borne out by the above successes. Our joint research and development projects with Vinnolit ensure that we supply competitive, environment-friendly processes which produce high-quality products.

The latest joint development is the new boiling reactor technology for the direct chlorination of ethylene. This new technology provides an energy-efficient technology for the production of furnace feed and sales EDC from chlorine and ethylene without the need for a distillation step. In combination with a special catalyst, by-product formation is significantly minimised. The first production-scale plant (capacity 250,000 t/year of EDC) is operating successfully at Limburgse Vinyl Maatschappij NV (LVM), Tessenderlo, Belgium.

Balanced EDC/VCM process



Boiling reactor at LVM,
Tessenderlo, Belgium
250,000 t/year of EDC

Biggest VCM Plant in China
SINOPEC Qilu Petrochemical Corp.
Linzi, Zibo, Shandong Prov., China
400,000 t/year of VCM (balanced)

3D model of one of the world's
largest PVC complexes
ARVAND Petrochemical Co.,
Bandar Imam, Iran
Capacities of the complex:
570,000 t/year of chlorine
329,000 t/year of sales EDC
343,000 t/year of VCM
340,000 t/year of PVC

3.2 Ethylene oxide EO, Ethylene glycol MEG
World-class processes

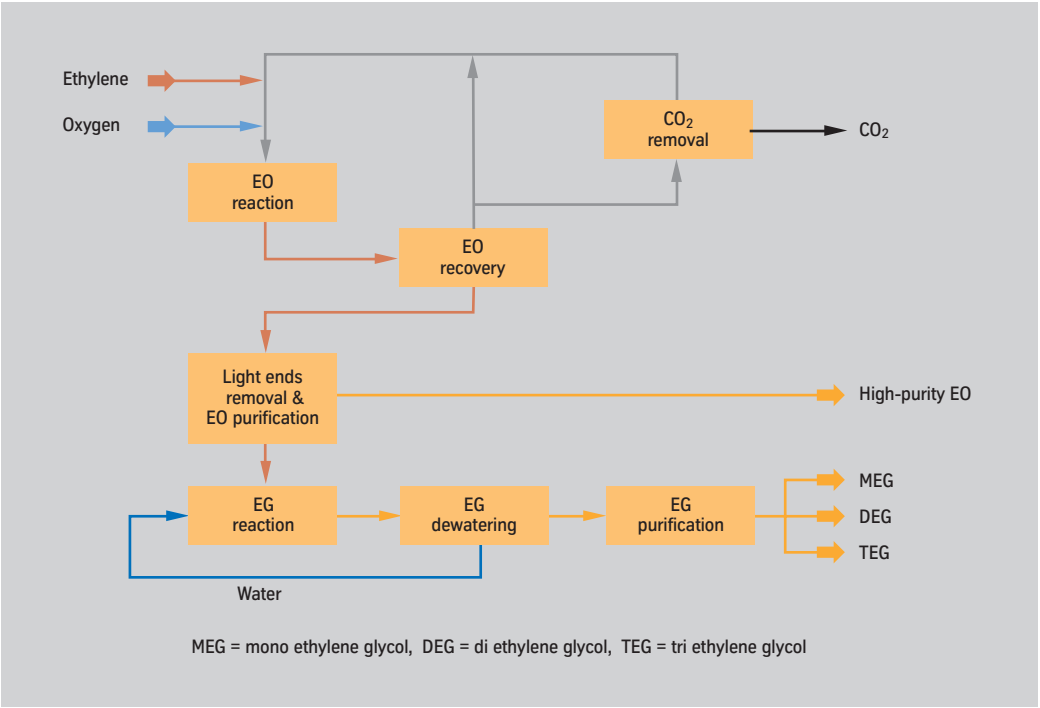
Ethylene oxide (EO) is one of the chemical industry's most versatile products. Its various derivates – ethylene glycols, glycol ether, ethoxylates and ethanolamines – are used in the production of plastics, and in the manufacture of solvents, brake fluids, cosmetics, propellants, antifreeze etc. An emerging application is the manufacture of 1,3-propanediol.

In the next few years the ethylene oxide market is estimated to grow by more than 5% per year. Mono ethylene glycol is the most important derivative of ethylene oxide. Its growth is driven by an increasing demand for polyester, both bottle-grade and fibre-grade.

Besides low feedstock prices and large capacities, the application of best available technology is of key importance. Shell is one of the leading EO/MEG manufacturers and licensors as well as the leading supplier of EO catalysts. The quality of the glycol produced by the Shell process ranks among the highest in the world and meets the most stringent specifications for polyester fibre-grade and bottle-grade PET. Furthermore, the Shell process is known for its high safety standards and its low environmental impacts.

For the engineering and construction of EO/MEG plants, Uhde uses Shell's outstanding EO/MEG technology and provides plant concepts which permit economical production. Uhde is one of Shell's authorised basic engineering contractors. Current project capacities range from 100,000 t/year to 600,000 t/year. At the moment a 360,000 t/year MEG is being constructed at Chengdu, Sichuan Province, China.

EO/EG production process



MEG = mono ethylene glycol, DEG = di ethylene glycol, TEG = tri ethylene glycol

Petrochina Sichuan Petrochemical
Company, Chengdu, China
360,000 t/year mono ethylene glycol

CNOOC / Shell Nanhai Petrochemical Complex, China
EO/EG plant: 320,000 t/year of mono ethylene glycol

Glicoles Mexicanos, Coatzacoalcos,
200,000 t/year of mono ethylene glycol

3.3 Propylene oxide and other organic chemicals
Optimum technical and economic solutions

Propylene oxide

On the basis of an exclusive partnership Evonik and Uhde have jointly developed an innovative co-product free and environment-friendly process for the production of propylene oxide (PO) from propylene and hydrogen peroxide (H_2O_2) with the aid of a special catalyst. The process has incorporated years of experience gained through the operation of a pilot plant with all relevant process steps. The pilot plant demonstrated under practical conditions the absence of co-products as well as the environmental compatibility and high product yield of the process, thus enabling it to be developed to market maturity. The Evonik/Uhde HPPO technology has successfully been in commercial operation since 2008 and has proven itself in a plant which is the first of its kind.

Operation is highly cost-effective due to efficient feedstock consumption, high-performance and low capital investment. The epoxidation reactor is specially designed for the exothermic reaction and combines efficient heat transfer with an almost ideal plug-flow characteristic. The lower capital investment compared to other state-of-the-art PO technologies allows the investor to be more flexible in his investment decisions. A further advantage: We can also provide our STAR process® for the production of propylene feed via oxydehydrogenation of propane.

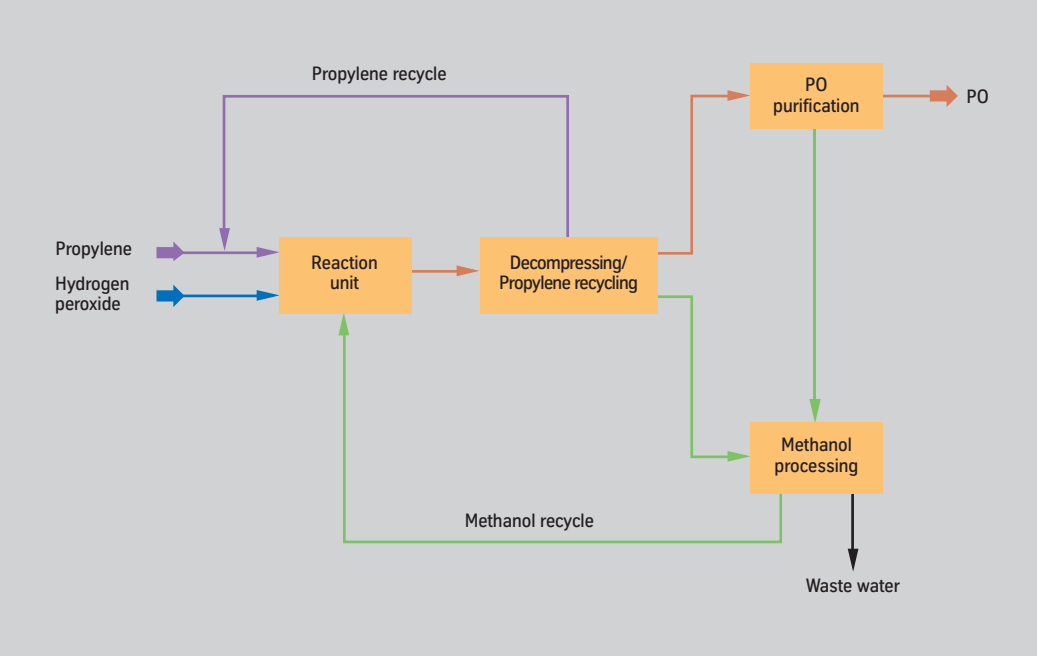
Other organic chemicals

For the production of formaldehyde from methanol Uhde licences two process variants based on silver and metal oxide catalysts, respectively, via its subsidiary Uhde Inventa-Fischer. Formaldehyde is mainly used for the production of synthetic resins, for instance for the production of urea-formaldehyde resins, which are used as adhesives for the production of plywood and particle board. Process technology for the production of these resins is also available from Uhde Inventa-Fischer.

As a process-oriented engineering company Uhde also offers, on a case-to-case basis, processes for the production of further organic chemicals such as oxo alcohols, vinyl acetate and purified terephthalic acid. We offer these processes in cooperation with various well-known producers and licensors.

In order to ensure that we offer customers the optimum technical and economic solution, we operate proprietary pilot plants, such as those for distillation, extraction and extractive distillation processes. In addition, we are also equipped with a number of test racks for testing new catalysts or process schemes.

New Evonik/Uhde propylene oxide technology



Propylene oxide pilot plant

World's first HPPO plant successfully in commercial operation since 2008

4.1 High-density polyethylene HDPE
A wealth of practical experience

Uhde's experience in the design of HDPE plants stretches as far back as the 1950s. The first plant was constructed in 1959, and by 2005 Uhde had already carried out the engineering for more than 30 plants around the world based on the Hostalen® process. The overall capacity of all the plants constructed amounts to more than 4 million tonnes per year. Additional plants with a capacity of 3 million tonnes per year are under construction.

The HD Hostalen® slurry process, originally developed by Hoechst AG, is now marketed by LyondellBasell, the largest manufacturer of polyethylene in Europe.

HDPE products are mainly used in film, pipes, blow moulding applications, injection moulding applications, tapes and fibres. And it is here that bimodal products used primarily in the manufacture of high-quality pipes and films are particularly worthy of mention.

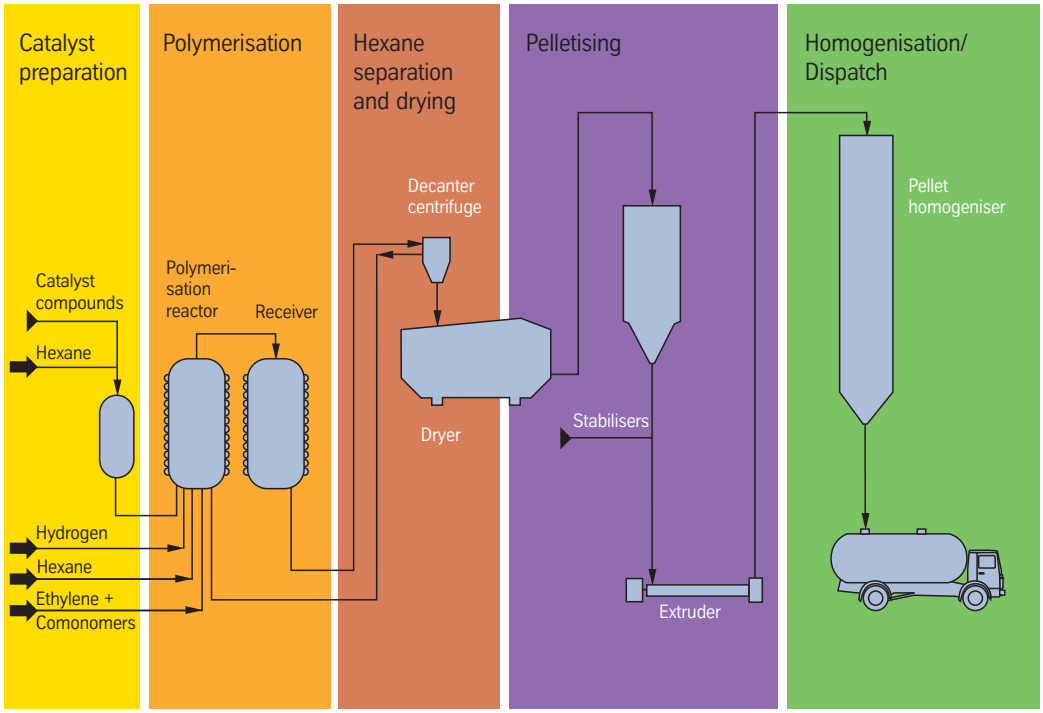
In the past, Uhde engineers have continually confirmed their expertise in this area by working with the licensor to incorporate the latest technological innovations in HDPE technology into their plants. Their scope of services covers every aspect of plant design, from basic engineering to detail engineering. And whilst the first plant designed by Uhde had a capacity of only 6,000 tonnes per year, today's plants now achieve capacities of 400,000 tonnes per year.

The list of polyolefin plants designed by Uhde in the last few years is impressive and includes some of the world's largest HDPE plants:

- 2 HDPE plants, each 300,000 t/year, commissioning 2006
- 300,000 t/year MD/HDPE plant, commissioning 2006
- 300,000 t/year HDPE plant, commissioning 2007
- 220,000 t/year HDPE plant, commissioning 2008

Uhde has taken on a large part of the EPCC services (engineering, procurement, construction and commissioning) for these contracts up to and including the turnkey supply of the plants.

LyondellBasell's HD Hostalen® slurry process for the production of unimodal and bimodal HDPE



250,000 t/year HDPE plant
SABIC Polyolefine GmbH, Gelsenkirchen

300,000 t/year HDPE plant
Marun Petrochemical Co., Bandar Imam, Iran

300,000 t/year HDPE plant
Jam Petrochemical Co., Bandar Assaluyeh, Iran

4.2 Low-density polyethylene LDPE

Full engineering service enhanced by our own high-pressure equipment manufacturing facilities

Uhde has been actively involved in the construction of low-density polyethylene plants since these polymers were first produced on a commercial scale. The design work carried out by Uhde's engineers in this field provides proof of their many years of experience.

In the field of LDPE, Uhde works particularly closely with LyondellBasell, Europe's largest manufacturer of polyethylene with an annual capacity of more than 2.5 million tonnes. To date, Uhde has designed LDPE plants which are capable of an overall annual capacity of approx. 1.5 million tonnes.

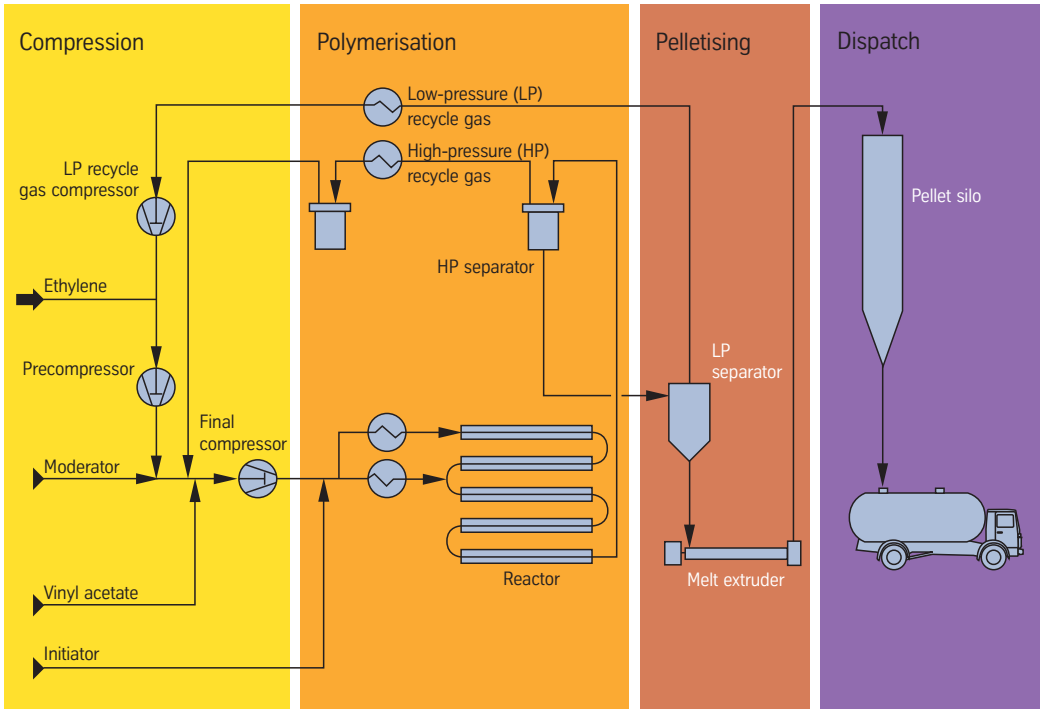
Uhde has been highly successful with its LDPE plants in China. In 2005 not only the world's largest has been commissioned, which has a capacity of 400,000 t/year of LDPE, but we also completed the basic engineering for a 250,000 tonne-per-year plant for Maoming.

Uhde's expertise in working pressures in excess of 3,000 bar is proof not just of an excellent process knowledge, but also of exceptional structural know-how. Moreover, the expertise of our design engineers is ideally enhanced by the expertise of our own high-pressure manufacturing facilities at our subsidiary Uhde High Pressure Technologies.

The engineering and construction services provided by Uhde include all process steps inherent in a plant, beginning with the extremely sensitive reactor system and extending to the extrusion, drying, storing and packing units.

The polyethylene obtained in the high-pressure process is predominantly used in the manufacture of films, but is also used for cable sheaths, blow and injection-moulded parts and pipes.

LyondellBasell's LupoTech T® process for the production of a broad range of LDPE homopolymers and vinyl acetate copolymers



High-pressure pipe reactor for LDPE

3D model of one of the world's largest LDPE plants
400,000 t/year of LDPE

LDPE plant in China

4.3 Polypropylene PP
Proven process gives you the leading edge

Polypropylene (PP), first produced commercially in the 1950s, is one of the fastest growing commodity thermoplastics. It is commonly used in the production of films, fibres and yarns, household goods, food packaging, bottles, crates, containers and car parts. Most of the propylene produced in the world is used for PP manufacture.

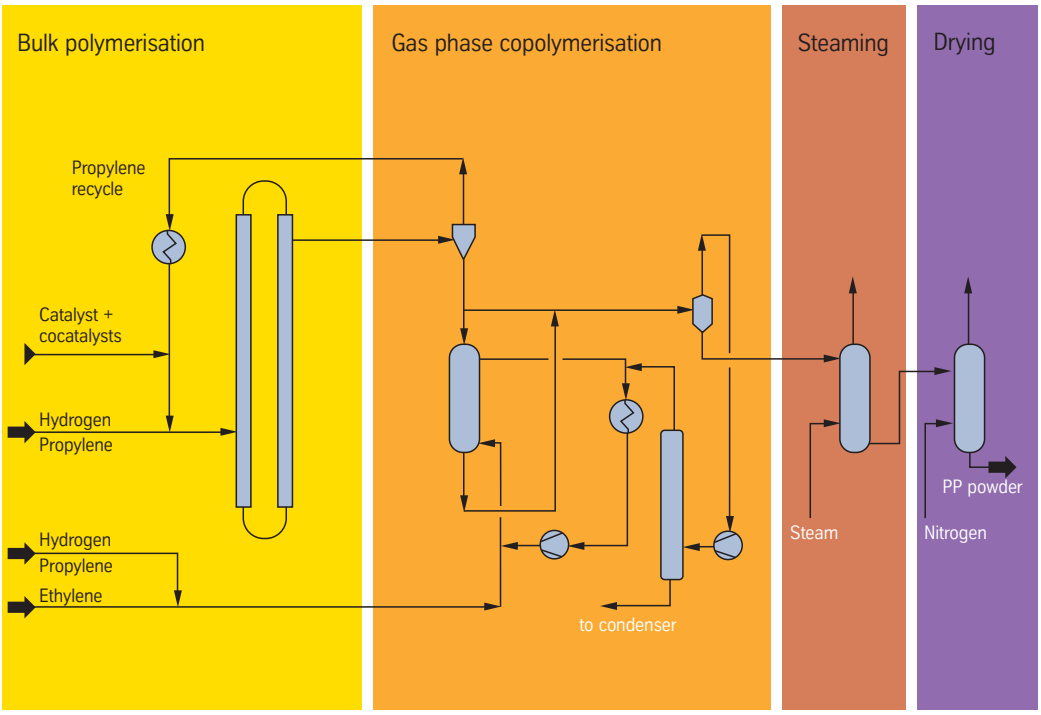
Today's polypropylene production technology is the result of 40 years of continual development. Uhde started building its first PP plants in the 60s, but the main technological progress was not achieved until the 80s when important new catalysts were introduced and reactor design was optimised. Since then, Uhde has constructed plants which produce more than 2.2 million tonnes per year of PP and has managed to increase plant capacity considerably from project to project.

Uhde collaborated with Basell in this area for many years. In 2007 Lyondell and Basell joined forces combining two major industry players to create a new global leader. Since then, we have worked with LyondellBasell on a number of projects. LyondellBasell's Spheripol® process is the worldwide leading technology for PP production, and its Spherizone® process is THE new breakthrough process using a multizone circulating reactor for the production of all types of polypropylene and novel polyolefins. In 2005 Uhde signed a contract for the basic engineering of China's biggest single-line polypropylene plant at Tianjin Petrochemical Company which comes on-stream in 2009. The plant is based on LyondellBasell's Spherizone process. It has a capacity of 450,000 t/year.

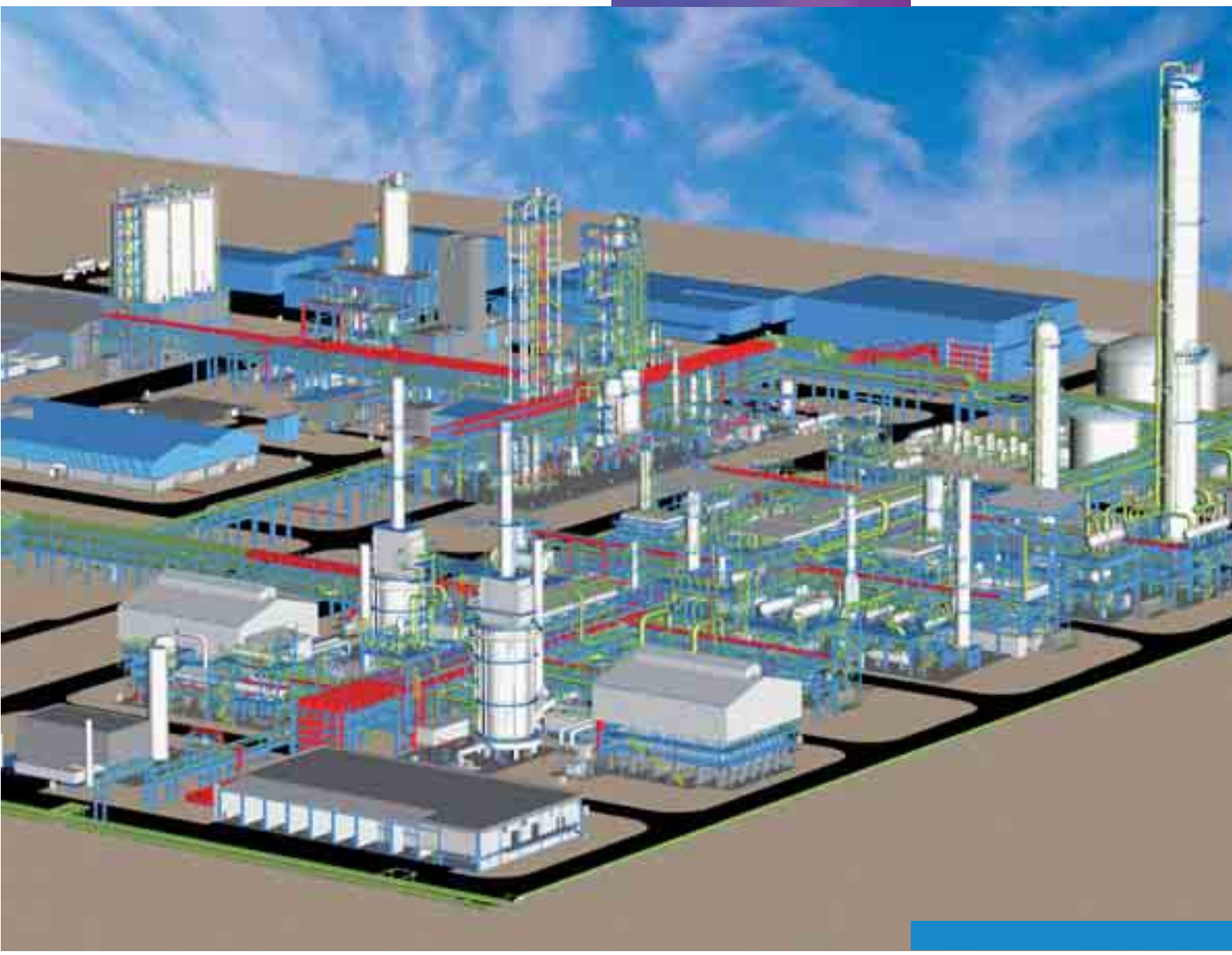
By combining LyondellBasell's PP technology with Uhde's STAR process® for the dehydrogenation of propane (PDH) to propylene, the production costs for polypropylene can be significantly decreased, because cheap propane feedstock from natural gas liquids (NGL) or associated gas can be used.

This process route is becoming more and more important because there is no equivalent capacity increase in propylene production from conventional sources (i.e. steam crackers and refineries) to meet the increasing demand for propylene. A propylene demand/supply gap has been forecasted for the future, leading the way toward wide application of propylene on-purpose technologies like PDH.

Uhde can supply tailor-made solutions for the propane - propylene - PP process chain. Common utility units (e.g. steam generation unit, refrigeration unit, cooling tower etc.) can thus be used, further increasing the feasibility of such projects.



LyondellBasell's Spheripol® process for the production of polypropylene homopolymers plus random and heterophasic copolymers



350,000 t/year PP, EPPC, Port Said, Egypt

PP Spheripol® loop reactors

4.4 Suspension polyvinyl chloride PVC-S

The entire process chain from Uhde Cl_2, EDC, VCM and PVC

The most widely used process in the manufacture of polyvinyl chloride (PVC) involves suspension polymerisation. The homopolymers produced are commonly used in pipes and cables manufactured using extrusion and moulding applications. Another extremely widespread use of PVC-S is the manufacture of sections for window frames. In addition, PVC-S is also used in the production of transparent films and in the manufacture of injection-moulded parts.

Uhde's experience in the design, engineering and construction of PVC plants goes as far back as the 1960s. In designing plants for PVC-S, Uhde works exclusively with Vinnolit, one of the 10 largest PVC manufacturers in the world. Overall, the worldwide capacity of plants based on the Vinnolit PVC-S process is about 1.8 million tonnes per year.

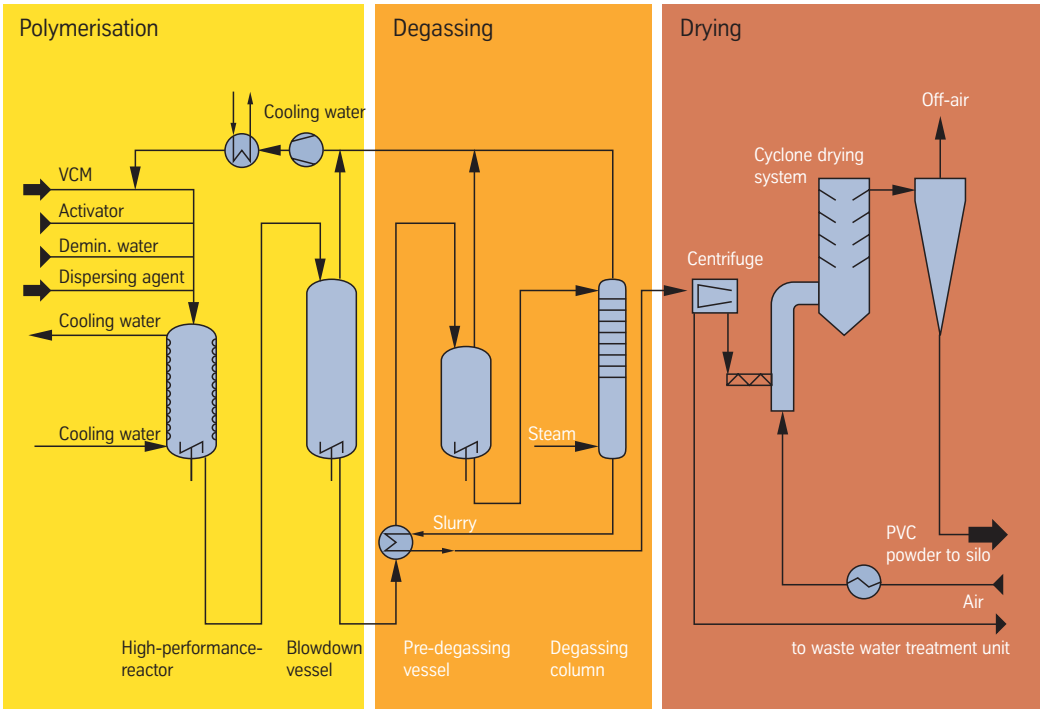
The Vinnolit PVC-S process uses a high-performance polymerisation reactor, which is available in sizes up to 175 m^3 and achieves an annual productivity of up to 600 t of PVC per m^3 of reactor volume. Vinnolit's technology does not require chilled water and can be operated without or in combination with a reflux condenser. For drying the wet PVC cake Vinnolit has developed a special cyclone dryer, which has been licensed via Uhde to many PVC producers worldwide.

The successful execution of numerous projects can be ascribed to the close partnership between Vinnolit, as the licensor, and Uhde. Based on this cooperation Uhde has gained a significant competitive edge: Uhde is the only engineering company able to provide customers, from a single source, with the entire process chain for a PVC complex, from chlorine manufacture to EDC/VCM and PVC production.

The world's largest integrated single-train PVC complex, which includes the complete process chain as described, is being built by Uhde on the Persian Gulf for ARVAND Petrochemical Co. The polymerisation section of this complex is equipped with 150 m^3 high-performance reactors.

As in all other cases, our cooperation with Vinnolit is not just aimed at marketing the technology, but also at continuously developing the process. Joint development projects complement the experience gained in production, research and licensing procedures. Together, they form a stable basis for continuous optimisation of the process.

Vinnolit's suspension PVC process includes a high-performance reactor and a cyclone dryer



Inside view of a PVC
high-performance reactor

3D model of one of the world's largest PVC complexes
ARVAND Petrochemical Co., Bandar Imam, Iran
Capacities of the complex:
570,000 t/year of chlorine
329,000 t/year of sales EDC
343,000 t/year of VCM
340,000 t/year of PVC

PVC high-performance reactor
115 m^3 volume

4.5 Polyester PET
Uhde Inventa-Fischer – a partner to rely on

Highly efficient production plants are of major importance in covering the increasing world demand for high-quality plastic products and synthetic fibers. As a plant construction contractor and special supplier, Uhde can offer numerous first-class proprietary processes for the production of polyesters (PET/PBT/PEN/PTT) and polyamides (PA 6/PA 6.6) via its subsidiary Uhde Inventa-Fischer, the leading technology supplier for these polymers. In total, Uhde Inventa-Fischer has built more than 400 polyester and polyamide 6 plants worldwide and ideally enhances Uhde's technology portfolio.

Polyesters are the feedstock basis for a wide variety of plastic products, such as fibres and film as well as bottles and other mouldings. Polyester plants based on a continuous polycondensation process once required up to five reactors, but Uhde Inventa-Fischer has succeeded in reducing this number to just two through technological innovations.

At the same time, the production capacity of polyester plants has been increased over the years. Today, Uhde Inventa-Fischer is able to provide most competitive, high-capacity plants.

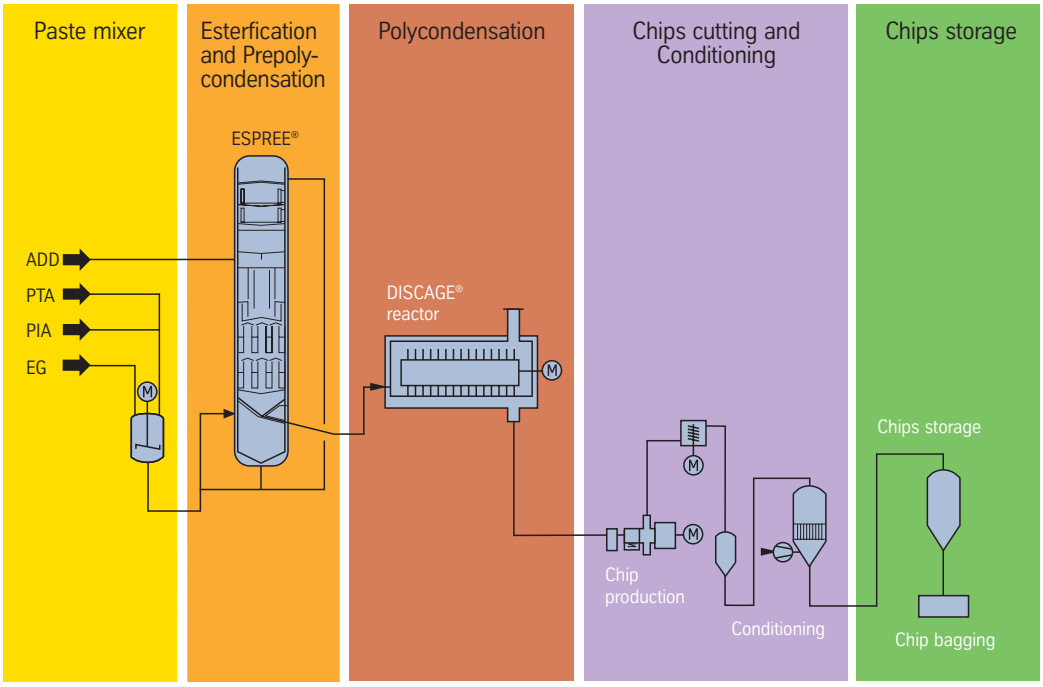
The two key technological features of the new highly economical two-reactor single-stream technology (2R technology) are the proprietary ESPREE® tower reactor which combines the esterification and prepolycondensation stages in a single vessel and the proprietary DISCAGE® reactor – a shaftless basket/disk-type reactor which operates extremely efficiently and ensures optimum postcondensation despite high viscosity. Uhde Inventa-Fischer can offer a number of different DISCAGE® reactor types. These cover a broad spectrum of polyester applications for various final viscosities.

The high molecular polyester product from the DISCAGE® reactor is transferred directly to:
- direct spinning machines (textile-grade and technical-grade applications) or
- film and sheet casting machines (film applications, Melt-To-Film MTF®)

or it is discharged to the extrusion heads and converted into chips (pellets).

The latest big step in the polyester technology is Melt-To-Resin MTR® Technology which completely replaces the conventional solid stating (SSP) process. Meanwhile, the technology is in operation in high capacity plants. It is based upon the well-proven 2-Reactor technology. Direct production of high-viscosity polyester melt allows generation of bottle grade resin, sheet for containers, technical yarns and tyre cord in a one-step polycondensation process, thus saving more than 30% of conversion costs and adding to chips quality.

2-reactor Melt-To-Resin MTR® process for PET production



2-reactor Melt-To-Resin MTR®
plant in Oman for APET sheet production

2-reactor plant for textile grade PET
in Belarus which can use both PTA
and DMT as a raw material

2-reactor plant with SSP for
bottle grade PET (Russia)

4.6 Polyamide and special polymers
Uhde Inventa-Fischer – a partner to rely on

Polyamide polymers (PA)
Technically mature production plants for polyamide 6, known under the brand names Nylon and Perlon®, at the time revolutionised the textile industry. Now Uhde Inventa-Fischer's plants have a leading technological edge throughout the world. The company's innovations include two-stage and also single-stage polymerisation processes with 100% feedstock yield for the production of polyamide 6 granules for textile or technical applications. Uhde Inventa-Fischer is the only engineering company with the ability to exploit both polyamide 6 technologies.

Uhde Inventa-Fischer can now build polyamide 6 plants with daily capacities of up to 360 tonnes. In fact, the company has been responsible for constructing more than 50% of the world's total polyamide 6 production capacity built in the last five years.

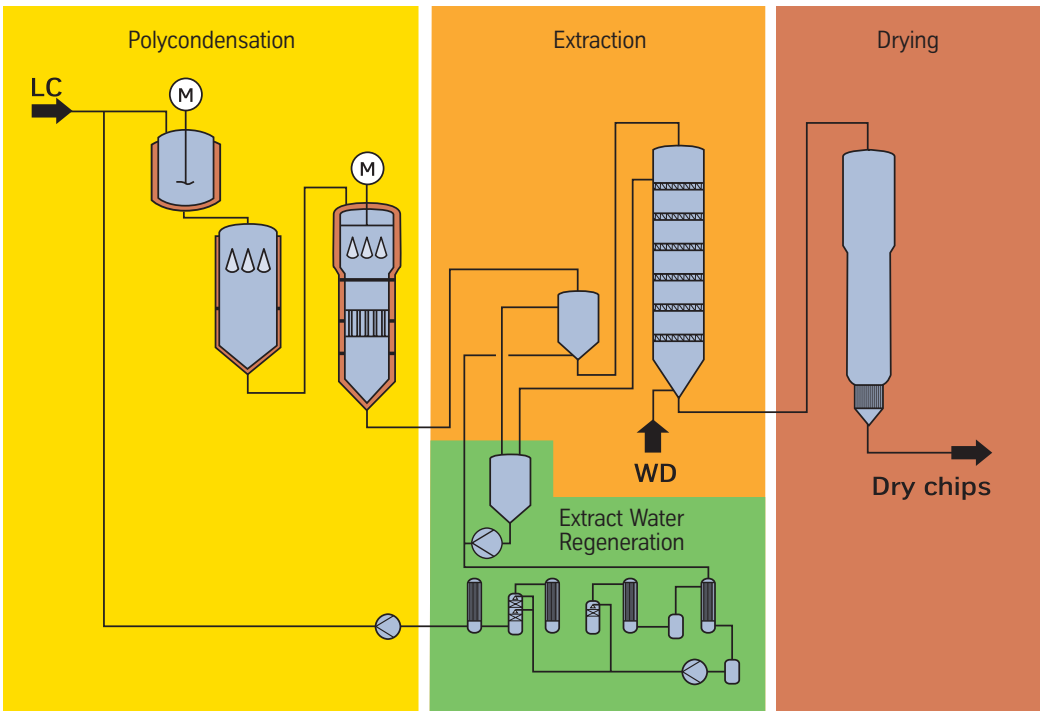
Batch processing of polyamide 6.6/11/12/6.10 and co-polyamides, such as engineering plastics, moulding compounds and other polymers, can be carried out in proven autoclave plants with either discontinuous or continuous drying and SSP units.

Biodegradable polymer polylactide (PLA)
Polylactic acid or Polylactide – PLA for short – is a biodegradable polymer based on renewable resources. The feedstock for Uhde Inventa-Fischer's PLA process is glucose or sucrose produced from any starch or sugar containing raw material such as corn, cereals, cassava, sugar cane or beet, etc. The feedstock may be sourced locally. It is expected that PLA will be sourced from non-food, cellulosic materials in the long term. The application range of PLA is similar to PET. It is applied as packaging material (film, sheet, bottles), textiles (filament, fibers, nonwovens), and engineering plastics.

The continuous PLA polymerization is the central part of the PLA process. It is based upon polymer grade L-lactic acid which comes from the fermentation of glucose to L-lactic acid. The polymerization of PLA resembles in some respect other melt-phase processes such as PA 6 and PET where Uhde Inventa-Fischer has long-term experience and offers well proven equipment.

Today Uhde Inventa-Fischer is in the position to license its technology for PLA production plants with annual capacities of industrial size. With its mini plant Uhde Inventa-Fischer can perform customer specific polymer grades development and sample production.

Uhde Inventa-Fischer's two-stage Polyamide 6 process



DSM, Emmen, Netherlands
Polyamide 6 film plant

Kuibyshev Azot's PA 6 complex in Russia,
producing 215 t/d of Polyamide 6 for all applications

Polylactic acid
Raw materials and products