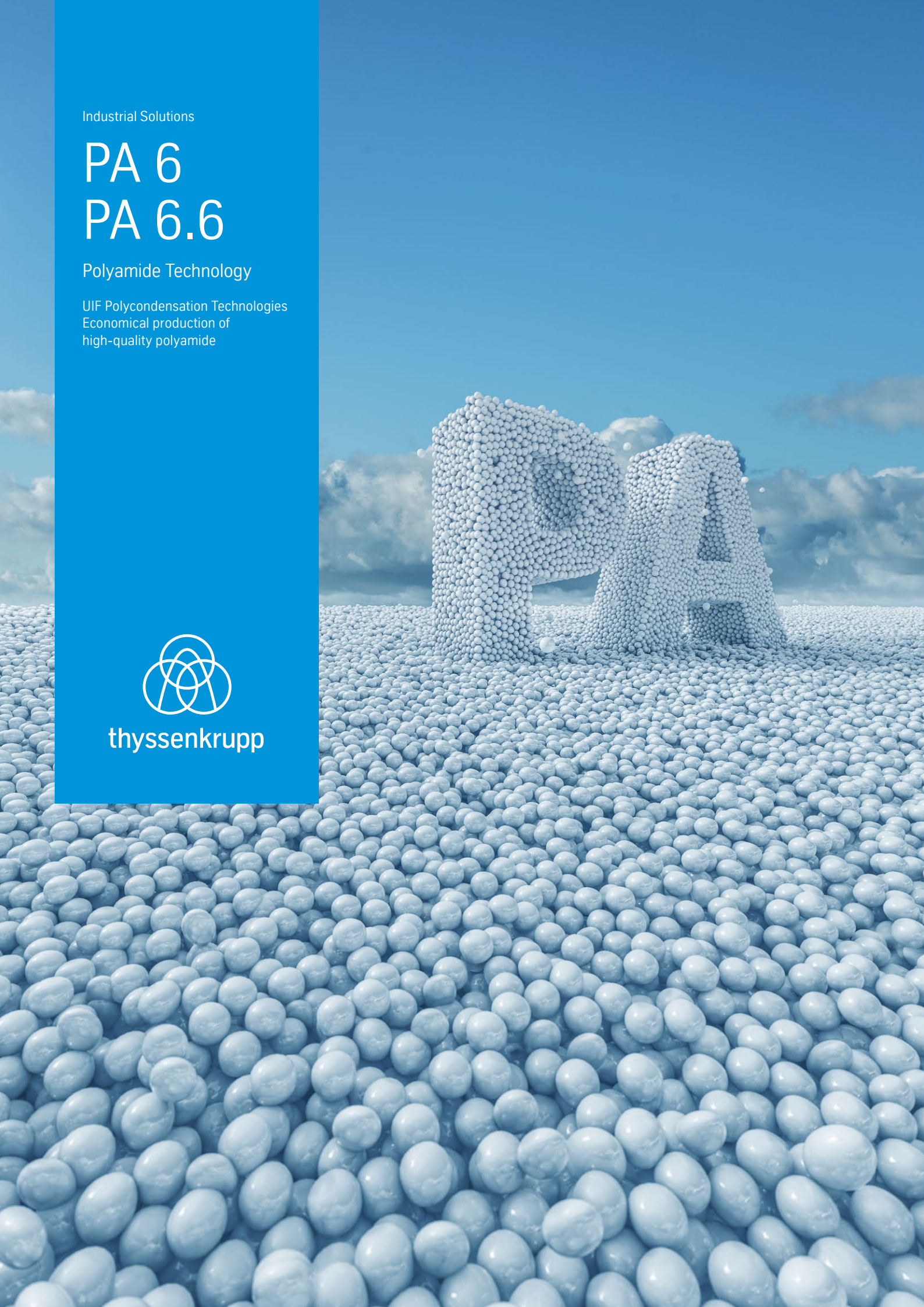
Industrial Solutions

PA 6
PA 6.6

Polyamide Technology

UIF Polycondensation Technologies
Economical production of
high-quality polyamide

thyssenkrupp



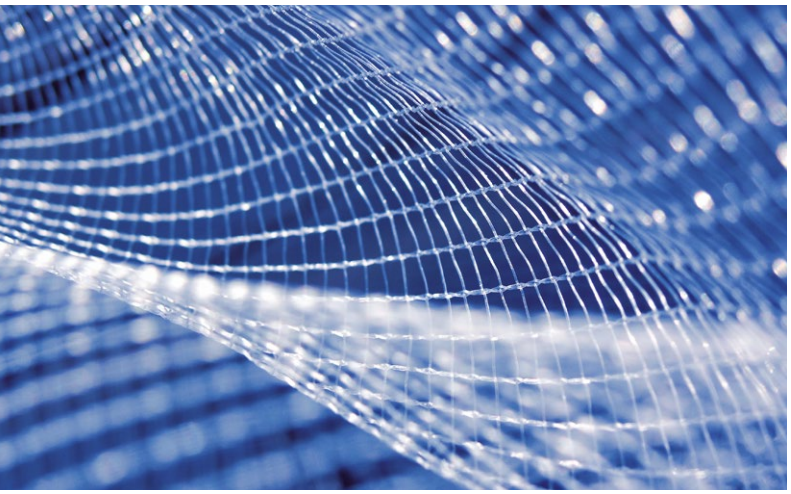
Polyamides 6 and 6.6

The most important polyamides

Polyamides have been established key polymers for construction and manufacturing materials for decades now. In particular the polyamides 6 and 6.6 have have become manifest in the field of commercial polymers with prospects of further growth in the future due to their outstanding properties. Besides being used for the production of textile filaments, technical yarn – especially tire cord – and carpet yarn, polyamide resins are also used for the production of engineering plastics as well as in film and extrusion applications.

The know-how of UIF Polycondensation Technologies with regards to polyamide covers a wide range of processes for all applications, not only focusing on PA 6 and PA 6.6, but also on co-polyamides and specialties.

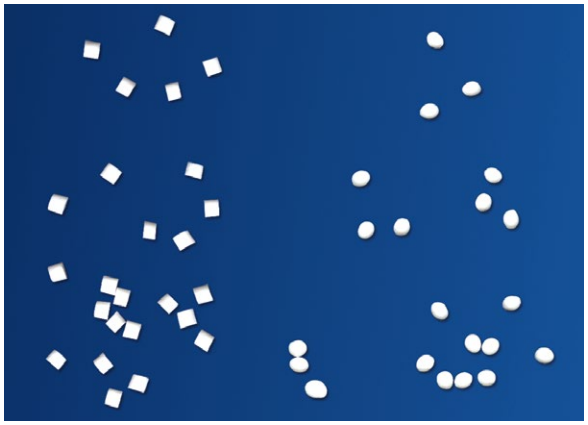
Constant process optimizations, new process developments and innovative polymer modifications have allowed us to become the state-of-the-art market leader in providing polyamide technology to our customers.



PA 6 two-stage polymerization
54,000 t/year (one line) with DRP®
DSM Chinalon, Jiangyin, China (top left)

PA 6 single-stage polymerization
144,000 t/year (4 lines) with VLP®, OMDP® and HPPA®
Changle Highsun Technologies, Fujian, China (top right)

PA 6.6. batch technology
42,000 t/year (6 autoclaves)
Huafon (China) (left)



Polyamide 6 Polymerization Processes

PA 6 technologies for your applications

Whether you require a plant for the production of textile or film-grade chips, or one for engineering plastics, our portfolio can offer the perfect solution based on proven proprietary technologies. We offer the following processes:

Two-stage process

The two-stage polymerization process offered by UIF Polycondensation Technologies is very well suited for all applications, especially high-viscosity applications, such as the production of engineering plastics and film, as well as for overproportional refeeding and for repolymerization plants.

It consists of a pre-polymerizer and a VK tube. The pre-polymerizer and the VK tube are designed for optimum heat transfer. This, together with other design features, leads to a high conversion of the caprolactam. The pre-polymerizer is pressurized while the VK tube is run under vacuum or atmospheric pressure.

The process can be adapted to produce a wide range of different grades to serve many applications. It is reliable, very flexible and economical, and the highly homogeneous product conforms to the highest quality standards.

We offer two-stage polymerization plants with line capacities of up to 400 t/day.

Single-stage process

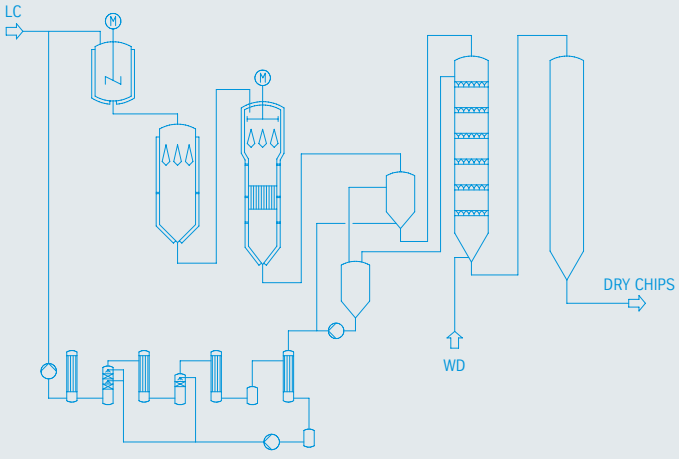
The single-stage process offered by UIF Polycondensation Technologies has proved successful for several applications, especially for textile grades. It produces a highly homogeneous polymer with a low level of cyclic dimers and can be optimized for the production of high-performance, textile-grade polyamide 6.

The process has proven to be very reliable, easy to operate and economical.

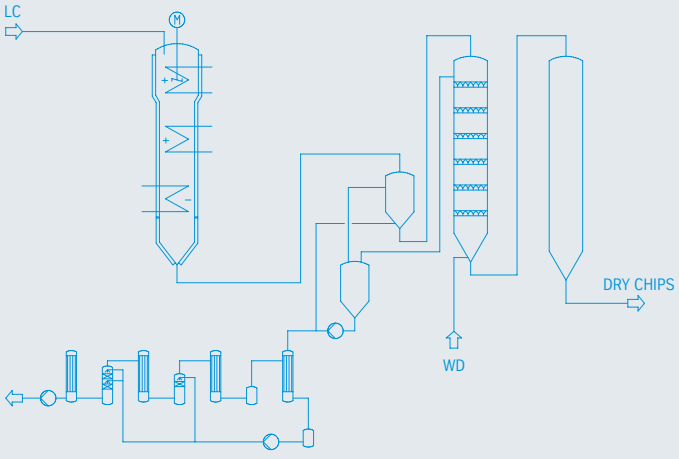
One line of the single-stage polymerization process can have a capacity of up to 200 t/day.

The largest (as at 2016) single-stage polymerizer in the world, with a nominal capacity of 200 t/day, was built by UIF Polycondensation Technologies for a client in China.

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



Uhde Inventa-Fischer's single-stage PA 6 process



Refeeding Technologies for Polyamide 6

Improved raw material yield

Recycling options within the continuous polymerization process

In the production of polyamide 6 the feedstock caprolactam accounts for more than 80% of all costs. As a significant amount of caprolactam and its oligomers is still present in the raw polyamide 6 produced due to the nature of the polymerization process, it is essential for an economic and ecological process to convert all feedstock. Accordingly, the remaining caprolactam and its oligomers are removed from the raw polymer by hot water extraction and recycled.

In the past, the standard process for recycling the extractables consisted mainly of distillation and depolymerization. This process has obvious disadvantages regarding product yield, energy consumption and the environmental impact.

UIF Polycondensation Technologies provides proprietary, modern technologies for complete extract recycling within the polymerization process, such as the Direct Refeeding Process DRP®, the Overproportional Refeeding Process OPRP® and the Repolymerization Process RPP®. These ensure that almost 100% of the caprolactam feed is converted to polyamide 6, providing our customers with a competitive advantage. Additionally, the quality of a refed polymerization line can be significantly improved by the latest OMPD® technology.

VLP® - In the Virgin Lactam Process, 100% virgin caprolactam is fed into the polymerization process to ensure the product meets the highest quality demands in textile applications. The extract water needs to be recycled by OPRP® or RPP®.

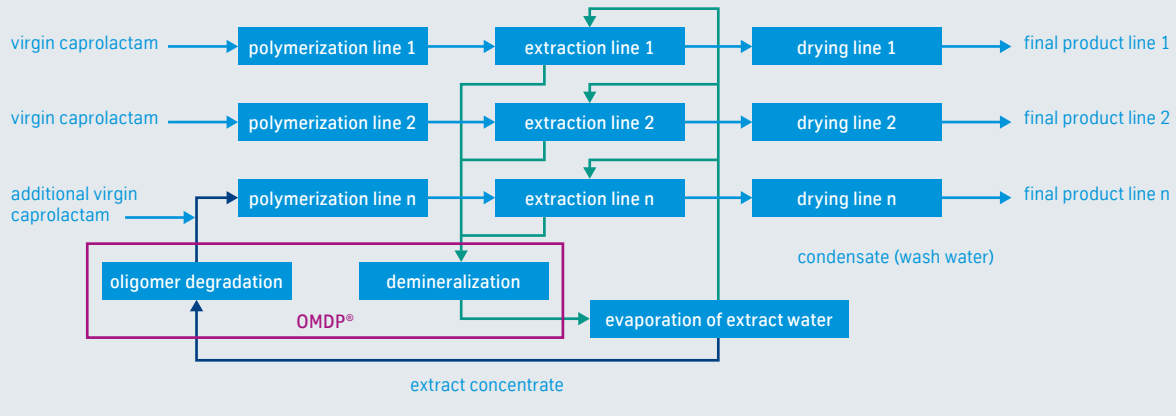
OMDP® - The Oligomer Degradation Process is a special treatment of extract concentrate to reduce cyclic oligomers before refeeding. Optionally, a mineral removal unit can be installed in the extract water stream (applicable for high-performance textile-grade PA6 and all other applications).

DRP® - In the Direct Refeeding Process the concentrated extract water from a polymerization line is mixed with virgin caprolactam and re-fed directly into the same polymerization line. It is especially suited for single-line productions.

OPRP® - The Overproportional Refeeding Process is applied when case extracts from two or more production lines are directly re-fed into a single polymerization line (up to 75% of the total caprolactam consumption). It is especially suited for multi-line plants.

RPP® - The Repolymerization Process is performed by polymerizing the concentrated extractables from several production lines in one recovery line while adding a minimal amount of caprolactam.

Multi-line plant with OMDP® recovery



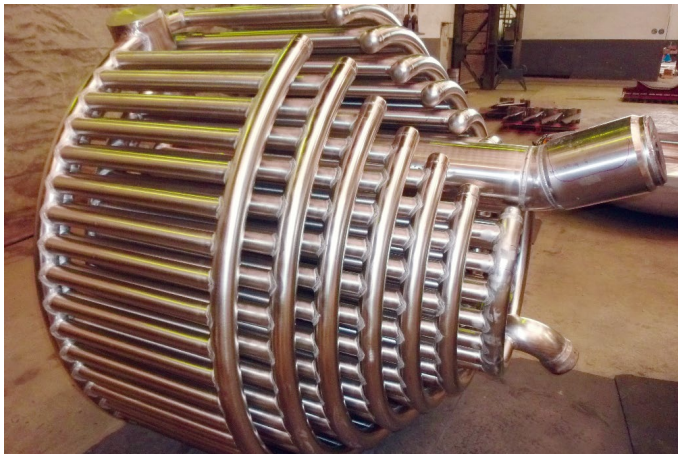
Polyamide 6.6

A flexible batch process

The high-performance autoclave batch process offered by UIF Polycondensation Technologies is the ideal solution for your polyamide 6.6 production needs as well as for co-polyamides or specialties.

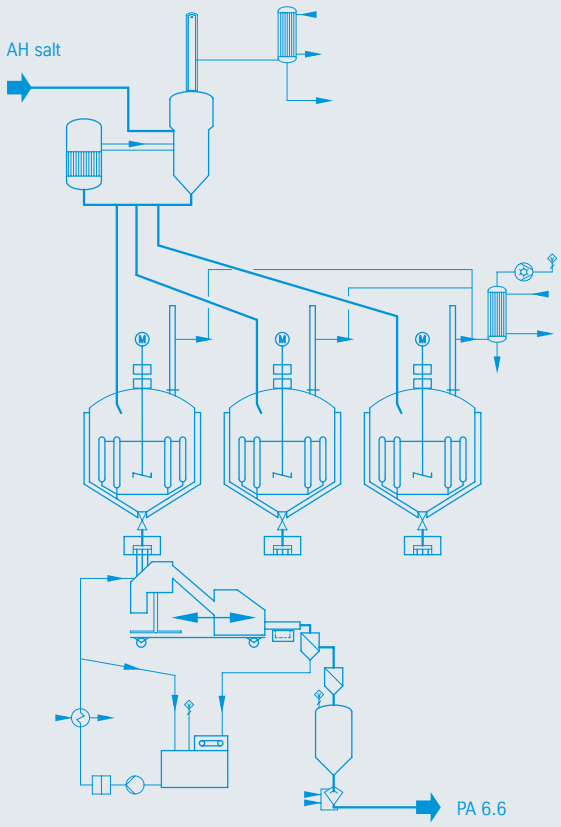
Highlights of the batch operation are:

- Quick product change
- Batch sizes of up to 3.2 t
- Batch time of less than 3 hours, i.e. 9 batches per day
- Continuous AH salt preparation
- Streamlined pre-concentration of AH salt (batch or continuous multi-stage)
- Optimized design, leading to minimal residues and contamination (self-cleaning)
- Custom-made heating elements and agitators for excellent heat transfer and superior product homogeneity
- Melt modifying
- Continuous solid-state polymerization (SSP) for higher viscosities available



High-performance heat exchanger of a polyamide 6.6 autoclave

PA 6.6 polymerization process with a capacity of 60 t/d



AH salt preparation	Continuous operation
AH salt concentration	Natural circulation process (continuous multistage or batch)
Polymerization	Autoclave process (1 - 3.2 t/batch)
Chip production	Underwater strand granulator
Conditioning	Drying with/without SSP
Specialties	Dry or liquid additive blending options
Recovery	Process water and nitrogen recycling

High-Performance Polyamide

Superior results in all applications

We support our customers not only in fulfilling their production needs in the most competitive way, but also in supplying additive recipes to meet the highest product quality requirements.

For example, the well-proven HPPA® additive recipe provides versatile advantages for all textile grades:

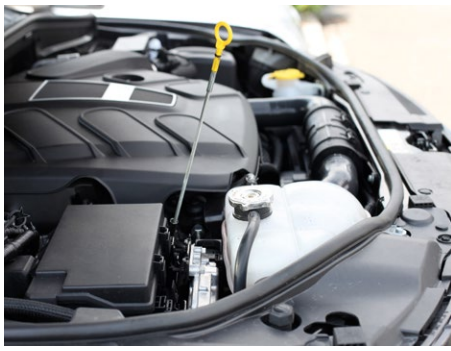
- Improved performance in spinning, high-speed spinning and downstream processing through increased take-up speed and higher full-bobbin rate
- Deeper dyeing through higher amount of amino end groups for better dye affinity
- Increased melt stability through reduced viscosity buildup in the spinning line
- Minimized caprolactam regeneration through less monomer smoke during melt processing
- Excellent heat-setting stability
- Superior resistance to heat, UV light and weathering
- Highest quality standards and spinning performance for dull as well as bright grades

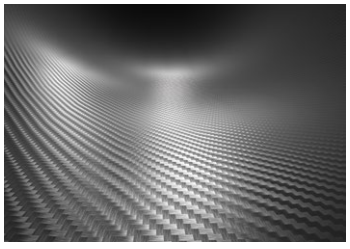
For film and engineering plastics, the following optional dry-blending recipes can be provided:

- Nucleating agent
- Lubricating agent
- Heat stabilizer
- Mold release agent
- Masterbatch
- Color pigments

UIF Polycondensation Technologies can provide recipes for engineering plastics to increase of the melt flow index (high-flow PA6). For other applications, additives to modify molecular weight distribution, relative viscosity and further physical properties are available.

Our tire cord recipes provide excellent heat-setting stability.





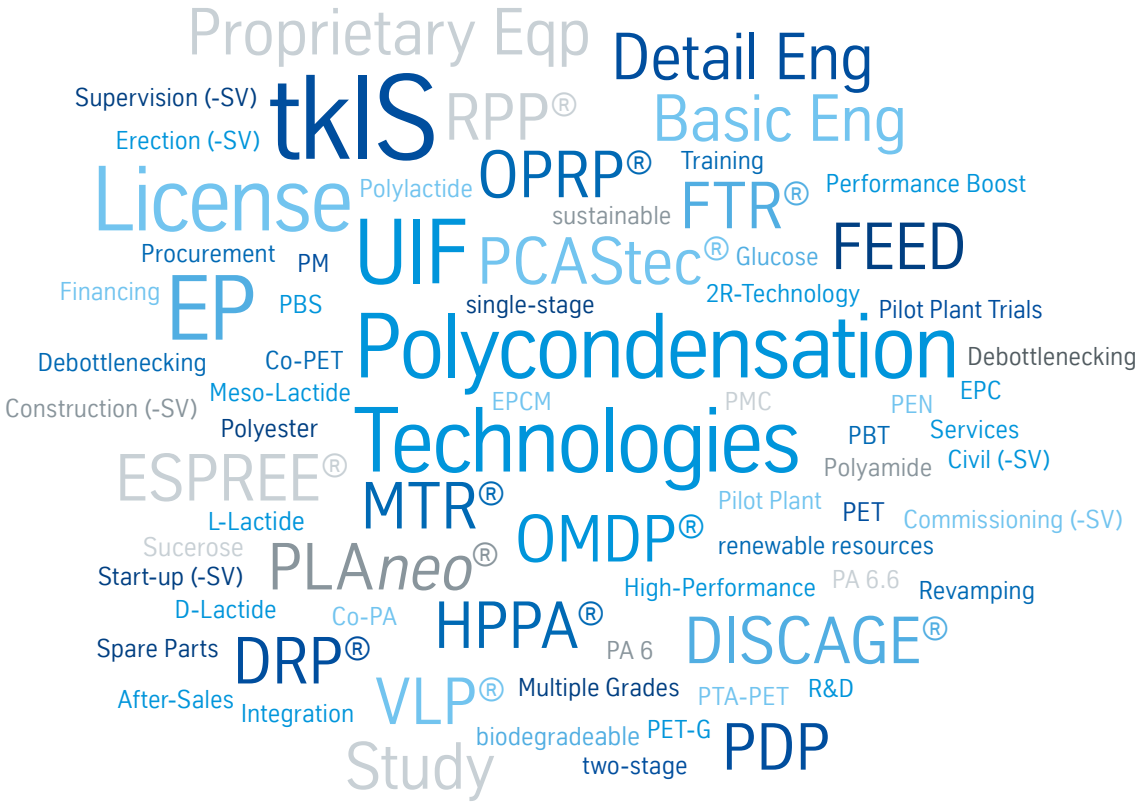
The Power Of True Efficiency

Optimal solutions for specific requirements

thyssenkrupp Industrial Solutions is one of the world's leading engineering companies for licensing, planning and constructing high-tech chemical plants. Around 19,000 specialists at over 70 locations around the globe ensure the highest degree of productivity as well as cost-effective, innovative and custom-made solutions to meet the technological and economic challenges of our customers. We offer a comprehensive array of services covering the entire life cycle of a plant.

UIF Polycondensation Technologies offer our proprietary, cutting-edge polycondensation technologies for producing various grades of polyesters, polyamides and sustainable biopolymers, such as polylactic acids, with customizable viscosity levels ranging from high to medium to low. These technologies are based on Uhde Inventa-Fischer's know-how, the engineering experience gained in the construction of more than 450 polymer plants worldwide since 1924 and through intensive research and development work in close cooperation with prominent scientific and industrial partners. UIF Polycondensation Technologies has successful established a large variety of self-developed, patented technologies and processes in the global market. Our customers can take advantage of these technologies to gain an edge over their competitors.

UIF Polycondensation Technologies, as part of thyssenkrupp Industrial Solution's polymer division, are located in Berlin, Germany and Domat/Ems, Switzerland. Around 150 polymerization specialists and engineers cover the entire field of professional project execution, from plant engineering with the delivery of proprietary and key equipment only up to procurement and construction services for turnkey EPC projects, working in close cooperation with local organizations of thyssenkrupp Industrial Solutions.



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