Where energies make tomorrow

Zimmer® Polymer Technologies

Polyesters, 1.3-Propanediol and Polyamides

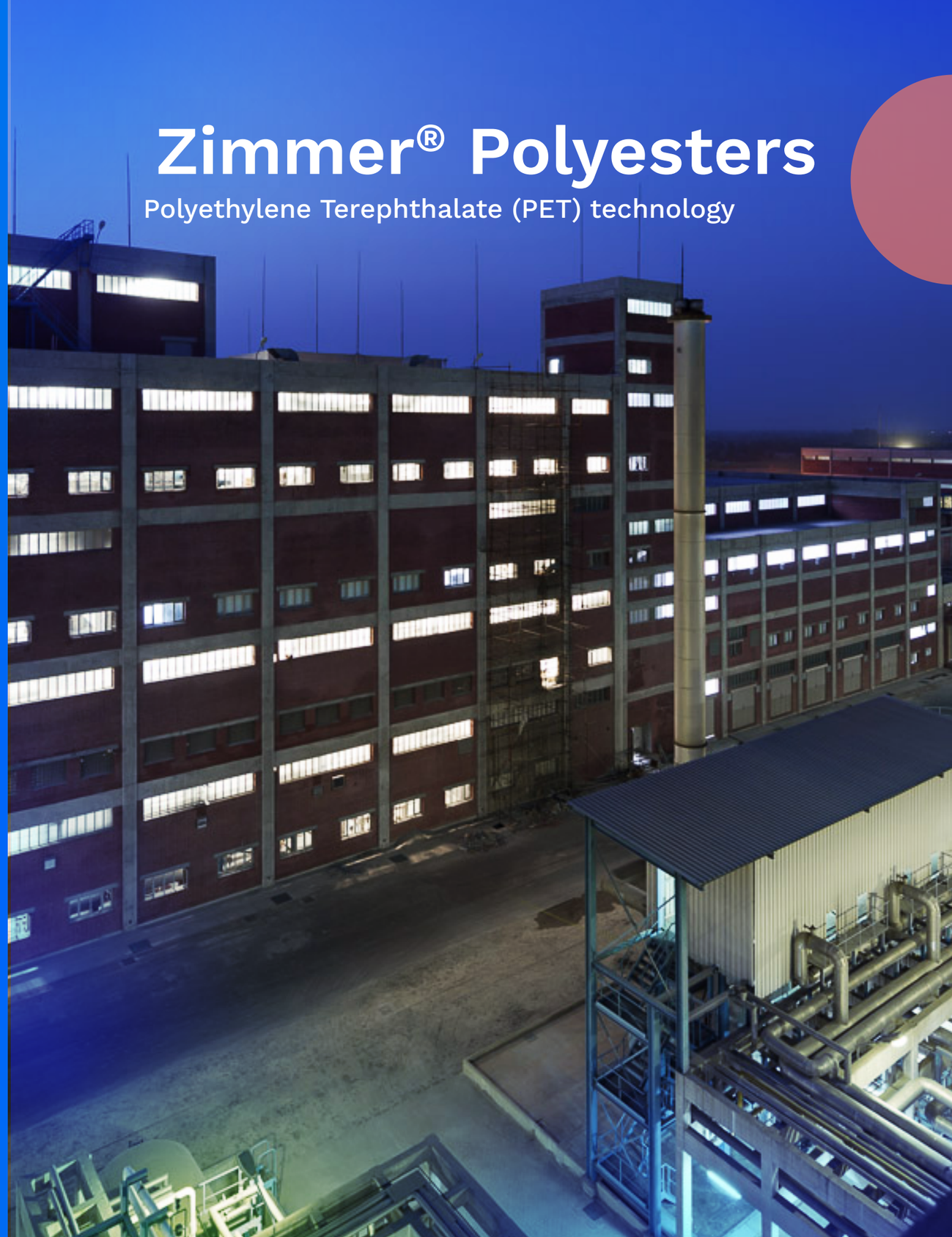
T.EN TECHNIP ENERGIES

Zimmer® Polyesters

Polyethylene Terephthalate (PET) technology

Technip Energies‘ Zimmer® Polymer Technologies provides technology, engineering, project management and procurement services for polyesters (PET, PBT, PTT, PBAT, PBS), 1.3-propanediol, polyamides (PA6, PA6.6) and Specialty Polymers (PCT, TPEE, PEN) production plants. These technologies include biodegradable and recyclable offerings. We are focused on our customers’ needs.

Over the last 70 years, our engineers have worked to enhance our portfolio of well-proven technologies using in-house research and development facilities. This dedication to quality has helped us to build an outstanding track record of placing our technologies in more than 800 plants.



PET is one of the most recognized, used and versatile polymer. In the Zimmer® PET process, PET is produced from pure terephthalic acid (PTA) and ethylene glycol (EG). Designed using a three or four reactor process, the Zimmer® technology offers a low process temperature, fewer byproducts and an excellent polymer quality.

PROVEN TECHNOLOGY

Zimmer®'s track record of working with PET polycondensation plants stretches back more than 60 years. We build plants ranging from small batch facilities for specialty products to single-line plants with capacities of up to 2,000 tons of PET per day for commodities.

EFFICIENT REACTORS: HIGH RELIABILITY AT A LOW COST

Our proven reactors ensure a long-life time of the plant with low maintenance. The reactors are built using a standard design adapted to client specifications.

THE PET PRODUCTION PROCESS

In our three-reactor process, PET is produced starting from EG and PTA. The raw materials are esterified in a two-stage reactor while the final reaction step is done in our proprietary Disc Ring Reactor (DRR). Our robust disc ring reactor design is based on decades of experience, in-depth research and development andtechnological expertise. This proprietary reactor system, available as single- or double-drive version, guarantees a smooth and reliable operation with a high viscosity lift and/or large capacities.

Advantages of the Disc Ring Reactor compared to other finisher designs:

- Higher viscosity lift
- Lower process temperature
- Lower thermal stress and product degradation
- Exceptional availability and reliability

PET FOR PACKAGING: YOU HAVE THE CHOICE

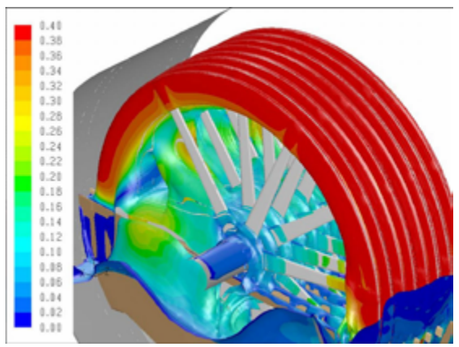
We offer two processes for producing PET for packaging or film. Our substantial global project experience enables us to help you select the best option for your application.

DIRECT HIGH INTRINSIC (DHI) VISCOSITY – A COST EFFECTIVE PROCESS

Years of continuous improvement and development of the PET process have culminated in the DHI process and eliminated the Solid State Polycondensation step. The dealdehydization (DAH) step is integrated with pelletization and crystallization to remove the acetaldehyde. By reducing the number of process steps, the DHI process increases yield, resulting in lower energy consumption (utility cost savings), less capital investment, which directly translates to CAPEX and OPEX savings.

FLEXIBLE PET RECYCLING

The production plants can be designed for recycling up to 50 percent PET flake feed. Potential contaminants are effectively reduced below the threshold of regulatory concern of the U.S. Food and Drug Administration (FDA) and European Food Safety Authority (EFSA).



Computational Fluid Dynamics simulation

STANDARD MELT POLYCONDENSATION WITH SOLID STATE POLYCONDENSATION (SSP)

In the SSP method, amorphous of medium viscosity chips are fed into the SSP plant. Under elevated temperature and residence time, and in a nitrogen atmosphere, the viscosity is increased.

During the SSP process, acetaldehyde is removed, and the nitrogen is purified and reused. The resulting resin is dried and can be easily loaded into big bags or containers. Zimmer® is well known for having decades of experience and a long track record with this dependable technology.

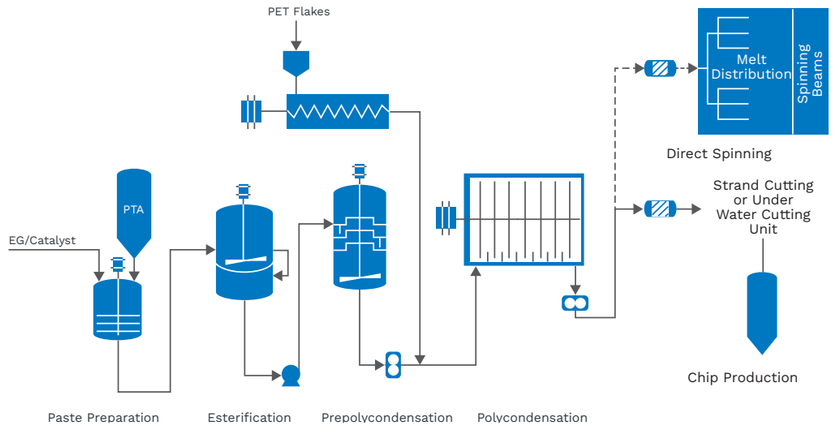
CRYSTAL SSP

Our latest crystal SSP process combines the traditional PET melt production with latent heat, underwater cutting, thus producing crystallized chips. In crystal SSP the crystallization step of SSP is eliminated from the traditional SSP, resulting in a lower-cost operation. The result is an economical operating SSP process. The Crystal SSP is suitable for debottlenecking traditional SSP processes.

DIRECT SPINNING FOR FILAMENT AND STAPLE FIBER

To achieve economies of scale, the PET melt is pumped directly to the spinning system for filament or staple fiber. Highlights of our direct spinning technology include:

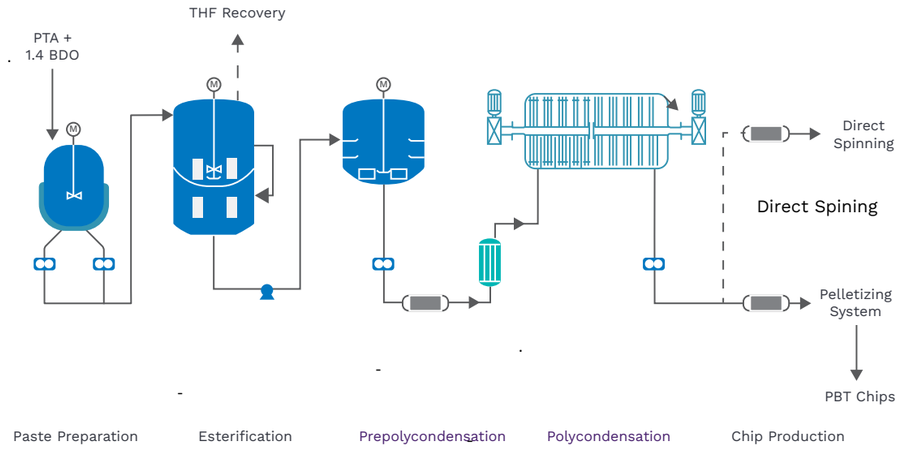
- Optimized melt pipe distribution system
- Bottom loading spin packs with quick connection
- Self-sealing spin packs
- Closed outside-to-inside quenching for staple fiber
- Special designed spin finish applicator.



Three-reactor PET polycondensation process for direct spinning or chip production

Polybutylene Terephthalate (PBT) technology

The most commonly used PBT technology found in about 70% of plants worldwide



Three-reactor PBT polycondensation process for medium and high intrinsic viscosity chip production or direct spinning

Polybutylene terephthalate (PBT) offers superior strength and durability compared to other polyesters. It also offers outstanding chemical resistance and physical properties making it especially suitable for applications in engineering plastics, automotive and high-value textiles.

A PREMIUM PROVIDER

Zimmer®'s PBT technology accounts for approximately 70 percent of the plants built worldwide in the last decade. Our plants are highly reliable and cost effective, offering an exceptionally high yield of the required feedstock 1.4 butane diol (BDO) and purified terephthalic acid (PTA).

In addition, it provides tetrahydrofuran (THF), a valuable side product in a very high purity. The PBT chips' quality complies with highest product requirements and can easily be processed.

PROVEN TECHNOLOGY

Our track record of innovation in the engineering of PBT polycondensation plants stretches back more than 35 years. For example, we pioneered the use of PTA as a feedstock, driving down the costs of PBT production. We build plants from small-scale batch facilities for specialty products to continuous single line plants with capacities of up to 400 tons of PBT.

THE PBT PRODUCTION PROCESS AND EFFICIENT REACTOR DESIGN

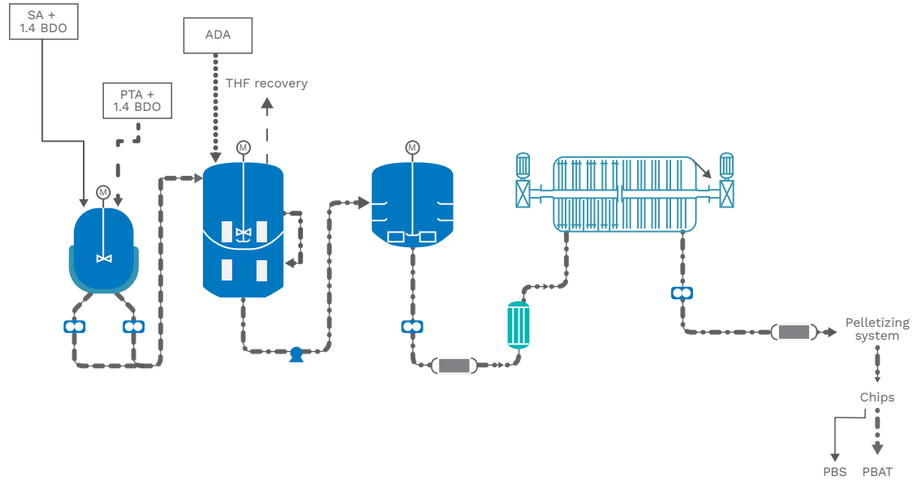
In our three-stage reactor process PBT is produced starting from 1.4 BDO and PTA. The raw materials are esterified. The final reaction step to reach the desired high viscosity is done in Zimmer®'s proprietary Double Drive Reactor (DDR). Our unique reactor design has enabled us to develop a more efficient process for high viscosity melt. The reactor allows for flexible, cost-efficient PBT production without the need for additional equipment.

Zimmer® PBAT and PBS technology

Zimmer® has expanded its portfolio with biodegradable polymers polybutylene adipate terephthalate (PBAT) and polybutylene succinate (PBS) that are produced in similar processes. In the continuous operation PBAT process, the raw materials PTA, 1.4 BDO and adipic acid (ADA) react in an esterification process. Through consecutive steps, polycondensation takes place with formation of PBAT.

PBS is a biopolymer from polycondensation of succinic acid (SA) and 1.4 BDO and can therefore be produced from bio-based sources. Due to their physical properties and the biodegradability according to EN 13432, both polymers are especially suitable for applications such as films or foils, e.g. in agriculture.

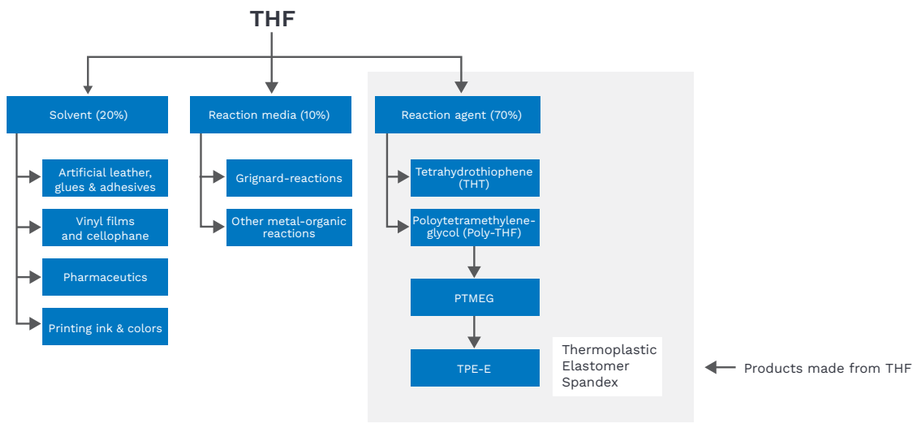
Zimmer® offers a special plant setup that enables flexible production of all three polymers depending on the requirements of the market.



Three-reactor PBAT/PBS/PBT polycondensation process for chip production

TETRAHYDROFURAN (THF) RECOVERY FOR BETTER RETURN ON INVESTMENT

THF, a valuable byproduct of the PBT/PBAT/PBS chemistry, has a wide range of applications from solvents over reaction agents to monomers. Zimmer®'s distillation system reliably produces high quality, pharmaceutical-grade THF at high yield, ensuring attractive returns. The recovery of THF is offered as part of Zimmer®'s PBT/PBAT/PBS technology or as a stand-alone solution for other polymer plants.



Applications of THF

Polytrimethylene Terephthalate (PTT) technology

A proven process for carpet, textiles and engineering plastics

Zimmer®'s PTT technology is a proprietary process developed in the late 1990's in our pilot facilities to satisfy market demand for textile properties. PTT has new characteristics, including producing a resin that is stain and static resistant and excellent performance. It is mainly used for carpet, textiles and engineering plastics. Our first commercial scale continuous PTT plant started up in 2004 in Canada.

EFFICIENT REACTOR DESIGN

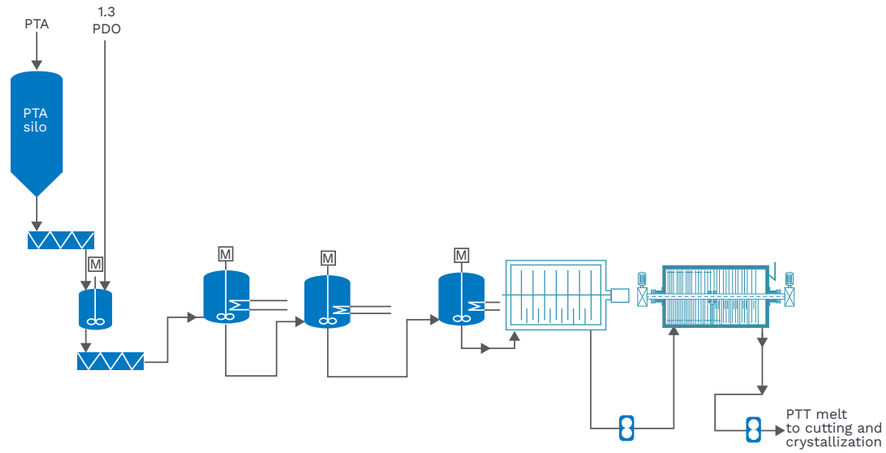
Our reactors for the PTT process are proven and ensure a plant longevity with low maintenance.

THE PTT PRODUCTION PROCESS

Our PTT process is based on 1.3 Propanediol (PDO) and terephthalic acid (PTA) as feedstock. The raw materials are esterified. The final reaction step to reach the desired high viscosity is done in Zimmer®'s Double Drive Reactor (DDR).

Our robust disc ring reactor design is the result of our extensive experience, in-depth research and development and technological expertise. This proprietary double-drive reactor system guarantees a smooth and reliable operation at high viscosity and large capacities.

We build plants with a standard capacity of 300 tons per day and various sizes according to our customers' needs.



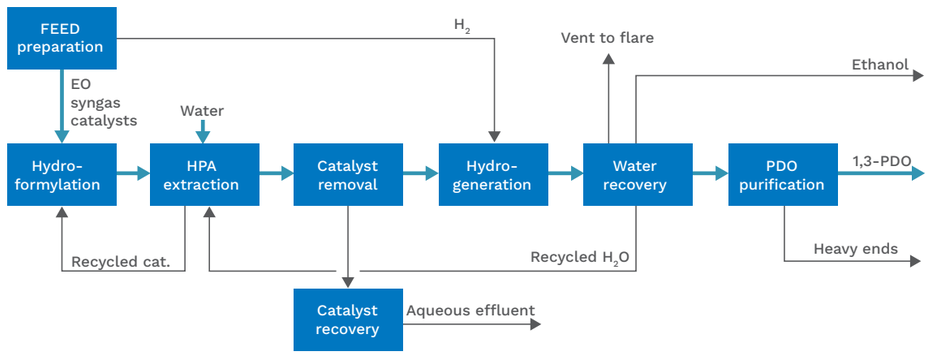
Five-reactor PTT polycondensation process for chip production

1.3 – Propanediol (PDO) technology

1.3-PDO is mainly used as raw material to produce polytrimethylene terephthalate (PTT) and can be formulated into a variety of industrial products including polyurethanes, copolyesters, paints, lubricants and coatings. It also has potential to be used in cosmetic and daily care applications.

The 1.3-PDO technology was developed by Shell Chemical and acquired by Technip Zimmer®. In a first step of the process a catalyzed hydroformylation takes place: ethylene oxide reacts with carbon monoxide and hydrogen to 3-hydroxypropionaldehyde (HPA). After extraction of the intermediate product with water the catalyst is removed and recycled. In the following HPA reacts catalytically with hydrogen in aqueous phase by forming the crude product 1.3-propanediol. In a next step water is removed and reused for the extraction step. Finally the light ends (ethanol) and heavy ends (derivatives of 1.3-propanediol) are withdrawn by distillation to obtain the pure product 1.3-propanediol.

Our 1.3-PDO technology provides a continuous process with low operating costs and large single line capacities. Stable and high product quality at highest utilization of raw materials is ensured. Additionally, EO and Syngas as feedstocks are easily available.



Route for the 1.3-PDO production

Zimmer® Polyamides (PA6, PA6.6) – Nylons

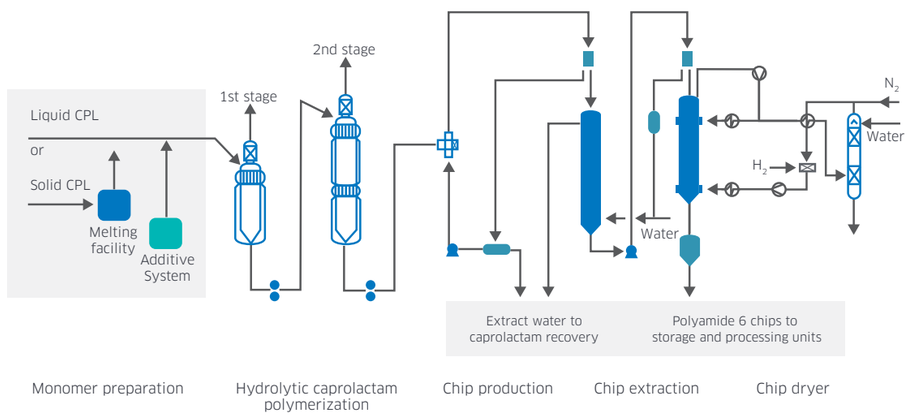
Polyamide 6 (PA6) technology

A reliable process for high quality polyamide 6 products

For top-quality polyamide, there's no better choice than Zimmer® technology. Our experience includes more than 160 tailor-made plants built since 1953. Through ongoing research and development activities, Zimmer® continues to build upon its technologies and engineering, resulting in process optimization and quality improvements.

Depending on capacity and product range, Technip Energies offers both one and two-stage PA6 technology. We offer standard capacities (100|130|200|260|390 tons per day), as well as customized solutions.

The typical product range comprises textile, engineering plastic and film applications. For film applications we provide dry-blending technology. Our latest development, in-line compounding enables us to offer high operation flexibility with various products out of one polymerization line.



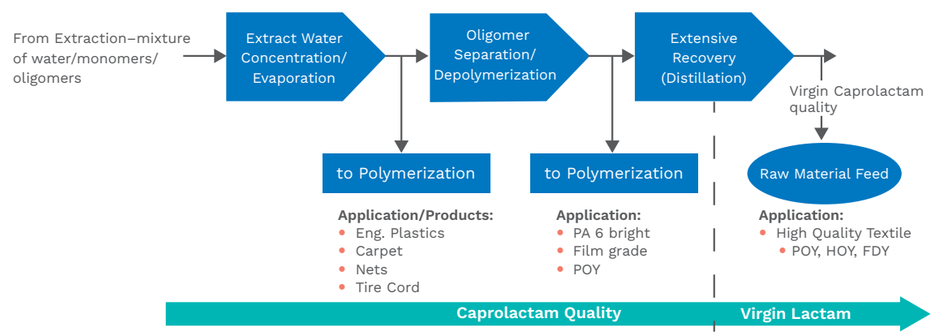
Two-stage polyamide process

A TWO-STAGE POLYMERIZATION PROCESS

The solid and/or liquid lactam feedstock is fed to the pre-polymerizer for the ring opening reaction of lactam. In the final polymerization the chains grow to the desired length until the specified viscosity is reached. Zimmer® PA6 technology is known for low consumption of utilities and minimal waste.

CAPROLACTAM RECOVERY SYSTEM (CRS)

Our CRS recovers the caprolactam from the extraction water. The recovered caprolactam can be reused as feedstock for PA6 production even for high quality textile applications. In addition, our patented Flexi Recovery® enables cost-efficient recovery of caprolactam to match the preferred product range for your plant.



Reusing of recovered caprolactam

PA6.6 and specialty polyamides

Zimmer® multi-autoclave process for PA6.6 and other specialty polyamides.

To produce the nylon polyamide PA6.6 an AH-salt solution is either created from the monomers adipic acid (ADA) and hexamethylenediamine (HMD) or by dissolving solid AH-Salt with water. This nylon salt solution is added to the concentration unit where water is evaporated to increase the salt concentration. It is then transferred to the autoclave where the polycondensation reaction takes place. Additives can be blended to the concentration unit and polycondensation unit. Multiple autoclaves in parallel ensure a continuous solid state polycondensation (SSP) after chip production.

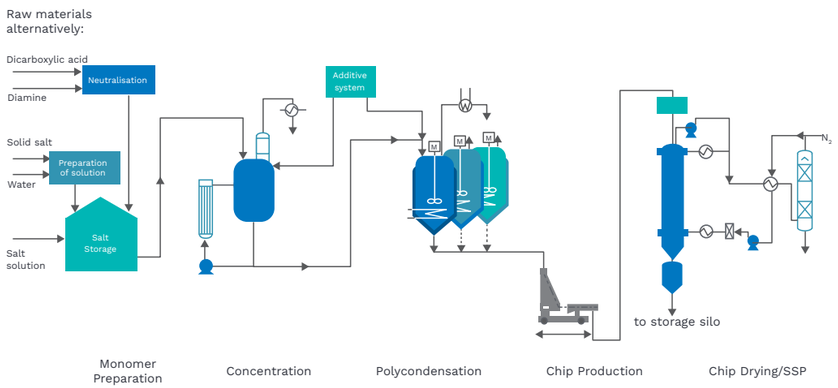
EFFICIENT REACTOR DESIGN

Our reactor design with a sophisticated agitator ensures high shear rates, good homogenization, self-cleaning and homogenous heat input. Its versatility allows for production of a wide range of specialty polyamides (PAx.y polyamides).

OTHER SPECIALTY POLYAMIDES

Other PAx.y produced with our batch process are:

- PA5.6 – based on the feedstocks of PMD and adipic acid
- PA6.10 – based on the feedstocks HMD and sebacic acid
- PA6.12 – based on the feedstocks HMD and dodecanedioic acid



Three-reactor PA6.6 polycondensation process for chip production

Zimmer® Specialty Polymers

Research & Development

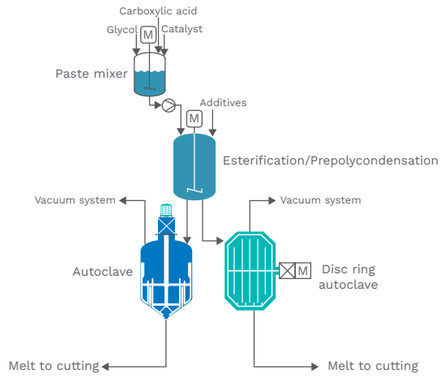
Adaptable technology to produce a variety of polymers such as PCT, TPEE, PEN or PET containing various additives and co-monomers

The specialty polyesters are based on a carboxylic acid and glycol as main feedstock. Both are mixed while catalyst/ additives are added in the paste preparation vessel. From there the paste is fed into the Esterification/Prepolymerization reactor. This step is controlled using a special temperature/ pressure regime and additives can be fed as required per recipe. The split-off vapors are released from the esterification stages and fed into the process column for rectification. The intermediate polymer product is then transferred to the Disc Ring Autoclave for final polymerization. This proprietary reactor enables a maximum evaporation surface due to high surface renewal, low process temperature, short polycondensation time and therefore low thermal stress.

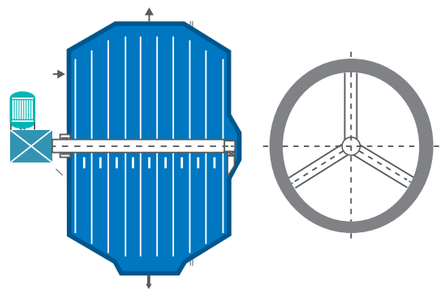
APPLICATION

- Adaptable technology to produce a variety of polymers such as PCT, TPEE, PEN or PET containing various additives and co-monomers
- Tailor made process for the specific requirements up to a capacity of 12.5 metric tons per batch

Technip Energies Zimmer®'s Disc Ring Reactor



Two-reactor polycondensation process either with or without disc rings in the autoclave



Technip Energies Zimmer®'s Disc Ring Autoclave

Technip Energies Zimmer’s development activities depend on the client’s need and can start with the business idea and goes typically to the global roll out.

To support the development Technip Energies Zimmer® can rely on its R&D center which comprises out of experienced engineers, unique lab/pilot plants and a modern analytical facility. Technip Energies Zimmer® can offer all phases of the development up to the marketing for specified applications with a wide range of cooperation services and concepts.

According to the open innovation approach, Technip Energies Zimmer® supports clients to commercialize their polymer products. Experiments in the lab generate the critical design data to scale up the process cost effectively to commercial conditions.

EQUIPMENT

- Semi-commercial, 1- & 2-stage batch pilot and SSP bench plants for polycondensation
- UV/VIS spectrometer, colorimeter, refractometer
- Viscosimeter, titrator, coulometer, polarograph
- GC, HPLC, DSC

3RD PARTY SERVICES

- R&D of proprietary processes, equipment and polymer recipe development
- Sample production/evaluation, process validation and commercialization
- Feedstock and polymer analytics according international standards (ISO, DIN, EN, ASTM)

Zimmer® Polymer Technologies

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