

Overview

Polypropylene is currently one of the fastest growing polymers, with forecasted demand growth higher than GDP for the foreseeable future. Much of this growth is attributed to polypropylene's ability to displace conventional materials (wood, glass, metal) and other thermoplastics at lower cost.

Lummus Novolen Technology (Novolen), a division of Lummus Technology, a CB&I company, licenses the Novolen® gas phase polypropylene (PP) technology for the production of the full range of PP resins. This reliable, versatile, and environmentally clean process makes products meeting the requirements of even the most demanding applications.

Lummus Technology is the only company to offer technology integration between propyl-

ene and PP, with four processes aimed at producing or maximizing propylene from upstream refinery and petrochemical units.

The Novocene™ technology, developed by and proprietary to Novolen, a leading company in the field of metallocene technology, covers catalyst, polymerization technology, polymer products, and all related services. With the introduction of the latest generation of high performance Novocene catalyst, metallocene PP (mPP) technology has reached a cost competitive range compared to Ziegler-Natta catalysts. The Novocene technology has proven to be drop-in capable for the Novolen gas-phase process and is also available for other gas phase and bulk processes.

Advantages

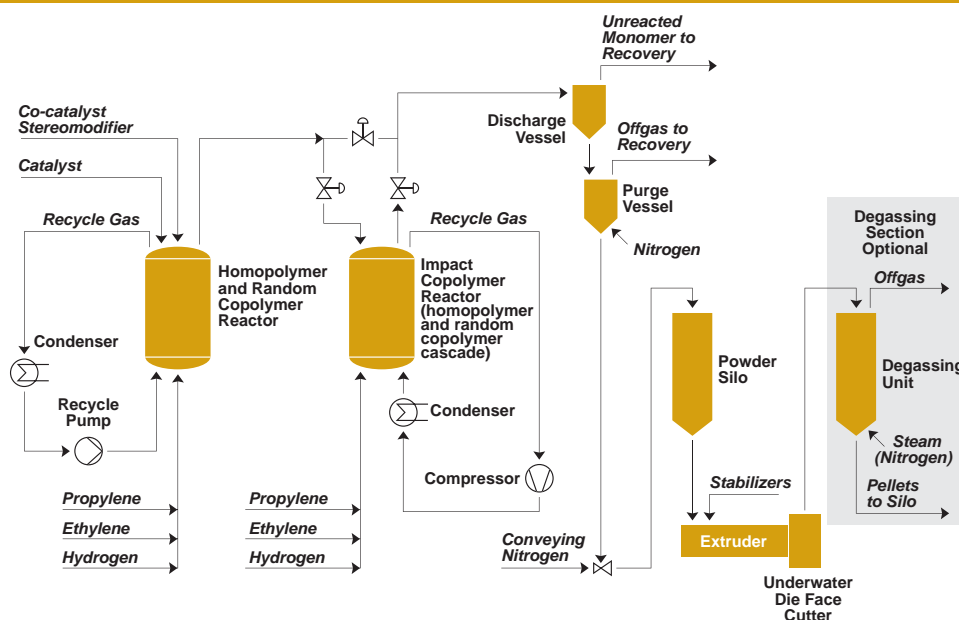
Process Features	Process Benefits
Produces full range of PP products in only two reactors with state-of-the-art catalysts	Covers all types of products (homopolymers, random and impact copolymers, terpolymers, and random-block copolymers) for all markets/applications • Special products include bimodal grades for biaxially oriented PP (BOPP), low melt flow grades for pipes, and ultra-high (up to 50%) rubber-content impact copolymers
Exceptional lot-to-lot and within-lot uniformity	Necessary for film and fiber applications, which need consistent and tight specifications
Mechanically agitated gas-phase process	Among the lowest operating and maintenance costs in the industry • Fastest start-up times in the industry: plant restart is possible within an hour after a power failure • Agitation independent from powder morphology, resulting in a unique product portfolio • No wall fouling and no shutdowns experienced due to lump formation
Low reactor volumes	Reduced monomer inventory results in inherently safe process • Minimizes capital investment (e.g., very low flare requirements and no blowdown system required)
Easy and highly reliable operation	Rapid grade changes generate minimal "off-specification" product • Highest reported on-stream times in the industry
A solvent-free process with a unique vacuum degassing system in the extruder	Very low taste and odor level for highly demanding applications (e.g., food packaging)
Exclusive pellet degassing with a further optional degassing section	Products with the lowest volatile content in the marketplace
"Drop in" Novocene metallocene technology available	Portfolio of superior mPP products especially for fiber, film, and injection molding applications • Most advanced metallocene catalysts with highest activity currently available in the market

Performance Characteristics The Novolen PP process utilizes one or two vertical, stirred bed, gas-phase reactors. Homopolymers and random copolymers can be manufactured either in a single reactor or in parallel operation of two reactors depending on the required capacity. Impact copolymers require two reactors connected in series: in the first reactor, propylene homopolymer or random copolymer is polymerized; in the second reactor, rubber is added by polymerizing an ethylene/propylene (rubber) mixture. Novolen's unique Versatile Reactor Concept (VRC) allows switching between the two operational modes and, by this unique process feature, it is possible to combine the broadest product capability with the minimum investment.

The polypropylene product portfolio covers a wide range of properties:

Melt flow rate (MFR)	0.1 - 3000 g/10 min.
Isotacticity	90 - 99.5%+
Tensile modulus	300 - 2,400 MPa
Tensile yield stress	10 - 40 MPa
Impact strength	No break at -30°C (reactor blends)
Transparency (1 mm disc)	Up to 93% for Ziegler/Natta PP Up to 96% for metallocene PP
Melting temperature	125 - 165°C

Process Flow Diagram



Process Description

Propylene, ethylene, and any other desired comonomers are fed into the reactor(s). Hydrogen is added to control the molecular weight. Polymerization conditions (temperature, pressure and reactant concentrations) are set by the polymer grade being made. The reaction itself is exothermic and reactor cooling is achieved by flash heat exchange, where liquefied reactor gas (mainly propylene) is mixed with fresh feed and injected into the reactor. Flash evaporation of the liquid in the polymer bed ensures maximum heat exchange.

The polymer powder is discharged from the reactor and separated from the unreacted monomer in a discharge vessel at atmospheric pressure. The monomer is compressed and recycled into the

reactors and partly returned to the upstream olefins unit for recovery in order to remove accumulated propane. The polymer is flushed with nitrogen in a purge vessel to strip it of residual propylene. The purge vessel offgas is passed to a membrane unit to recover the remaining monomers and the nitrogen for reuse. The powder is transported to powder silos and is then converted into pellets that incorporate a full range of well-dispersed additives.

For highly demanding applications requiring extremely low volatiles and odor levels, the Novolen process offers an optional degassing unit to treat the pellets after extrusion.