Novolen® PP Technology

Global Refining and Petrochemical Congress
17th -18th July, 2019
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History of Novolen, Scope & Organization
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>1962</td>
<td>BASF starts Novolen Technology development in Germany</td>
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<tr>
<td>1967</td>
<td>First Commercial Novolen PP Production Plant (10 KTA)</td>
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<tr>
<td>1978</td>
<td>Commercialization of Random- and Impact Copolymers</td>
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<tr>
<td>1983</td>
<td>Commercialization of Terpolymers</td>
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<tr>
<td>1990</td>
<td>Super High Impact Copolymers with &gt; 50 % of Rubber</td>
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<tr>
<td>1994</td>
<td>Metallocene-PP</td>
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<tr>
<td>1998</td>
<td>Single Line Plant &gt; 225 KTA including Impact Copos (Wesseling, Germany)</td>
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<tr>
<td>2000</td>
<td>BASF and Shell merge polyolefins businesses, and are forced to divest 1 licensed PP technology. Novolen technology acquired by ABB Lummus + Equistar.</td>
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<td>2002-2006</td>
<td>Lummus starts to actively license Novolen technology, awards in Middle East, China, India. &gt; 5,000,000 mta licensed capacity. Single Line Capacity &gt; 300 KTA, Single Reactor Capacity &gt; 200 KTA.</td>
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<td>2007</td>
<td>CB&amp;I acquires the Lummus Technology business (including Novolen)</td>
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<tr>
<td>Year</td>
<td>Event</td>
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<tr>
<td>2009</td>
<td>New Novolen R&amp;D Center at BASF Ludwigshafen.</td>
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<td>2012</td>
<td>Scaling up continues: Available Single Line capacity exceeds 600 KTA</td>
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<tr>
<td>2013</td>
<td>Novolen and Clariant start joint Development and Commercialization for PP Catalysts</td>
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</tbody>
</table>
| 2015 | NHP® catalyst successfully commercialized  
Total Novolen PP licensed capacity exceeds 10,000,000 mta |
| 2017 | New Novolen Pilot Plant at CB&I Research & Development Centre (Pasadena, TX) |
| 2018 | New NHP® Catalyst Production Plant (JV with Clariant)  
McDermott and CB&I combine, continue Lummus Technology business |
| 2019 | Total Novolen PP licensed capacity approaches 14,000,000 mta globally  
No.1 Licensing position in India with total of 3,100,000 mta HP / RCP /ICP |
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Novolen Worldwide Locations & Licensees

- Lummus Novolen Headquarter, Mannheim, Germany
- Pilot Plant, Pasadena, TX USA
- Catalyst Production Plants, Louisville, KY USA / Jinshan, China
- Novolen Licensees with active Plants / Projects
Novolen Technology - Scope

- Technology Licensing
- Catalyst Supply
- Research & Development
- Project- and Engineering Solutions
- Lifetime Technical Service & Product Support
Novolen Process
Novolen Technology - Process

PP General Process Principles

✓ Catalyst system, gas phase composition, and additivation + MW control in extruder define PP product produced.

✓ Polymerization reaction is exothermic: cooling required, and effective continuous movement of polymer particles.

Novolen process concept

✓ Novolen process uses a helical agitator to keep particles in motion and move product between reactor cooling zones (top + bottom).

✓ Most compact and efficient reactor system:
  ✓ Dense bed (non-fluidized), no de-entrainment zone.
  ✓ Full condensing mode cooling
Novolen Process

- Gas phase process: highest product capabilities
- Mechanically agitated dense powder bed
- Direct catalyst injection
- Efficient polymerization heat removal through evaporative cooling in full condensation mode
- Single-, Parallel-, Cascade configurations available (+ VRC® Versatile Reactor Concept)
- Identical reactors
- No idled equipment during homo/random production
- Simple gas-polymer separation
- Lowest TIC known in the industry
**Novolen Technology - Process**

**Single Reactor**  
Homo-, Random Copolymer

**Cascade Reactor Concept**  
Homo-, Random-, Impact Copolymer

**Parallel Reactor Concept**  
Homo-, Random Copolymer  
(incl. Bimodal)

**VRC® Versatile Reactor Concept**  
Homo-, Random-, (incl. Bimodal)  
Impact Copolymer

* two extruders at capacities > 580 kta
Reactor / Powder Flow

✓ Helical agitator physically lifts PP polymer powder up, gravity flow down in center → continuous and reliable polymer particle movement.

✓ Powder movement is independent from the particle size and shape → low sensitivity to fines.

✓ Agitator preventing polymer sticking to the reactor wall enable high co-monomer content.

✓ Minimized polymer inter-particle friction leading to less static electricity build → no wall/dome fouling

✓ No blow-down system, powder remains inside the reactor. Reactor restart possible within 20-30 minutes.
The Novolen Process

- Degassing vessel
- Purge column
- Centrifugal dryer
- Stirred gas phase reactor
- Discharge cyclone
- Extruder
- Mixing silo

- Reaction
- Polymer-gas separation
- Extrusion + mixing
Novolen References
Novolen has licensed PP technology to 46 plants located over the world.

Total Licensed capacity = 13.9 million tons per year
No.1 Licensor in India (35% market share)
Novolen Products
Novolen Product Range

All Products made by Novolen Gas Phase Technology (max. two reactors)
<table>
<thead>
<tr>
<th>Grade</th>
<th>Number</th>
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<tbody>
<tr>
<td>Ziegler-Natta PP</td>
<td></td>
</tr>
<tr>
<td>Homopolymers</td>
<td>80</td>
</tr>
<tr>
<td>Random Copolymers</td>
<td>25</td>
</tr>
<tr>
<td>Impact Copolymers</td>
<td>33</td>
</tr>
<tr>
<td>Random Impact Copolymers</td>
<td>1</td>
</tr>
<tr>
<td>Terpolymers</td>
<td>6</td>
</tr>
<tr>
<td>Metalloocene PP</td>
<td></td>
</tr>
<tr>
<td>m-Homopolymer</td>
<td>12</td>
</tr>
<tr>
<td>m-Random Copolymers</td>
<td>2</td>
</tr>
</tbody>
</table>
Few applications:

**Electrical Appliances:**
1142 NC, 1143 NC

**Furniture:**
1040 N, 1100 N/NC
Caps & Closures: 1150 RC
Thin walled packaging: 1148 TC
Staple Fibres: 1101 N/S
Water Quenched & Cast Film
Confidential

Novolen Products

Sewage & Drainage Pipes

Pressure Pipes
High Transparency Packaging
Hygiene Applications, e.g. Baby Diapers

Heavy Duty Yarns
Heavy Duty Boxes

Raffia

Low Temp. Packaging
Novolen Catalyst
Clariant is Novolen’s exclusive co-operative partner for PP catalyst R&D and commercial supply: “Serving the global PP catalyst market.”

- Joint R&D in Ludwigshafen and Frankfurt, Germany.
- Pilot Plant in Pasadena, TX, USA
- World scale jointly funded catalyst production plant in Louisville, KY, USA
NHP®401 Series

- Single catalyst system, commercially implemented since 2015 across all continents
- NHP4010 and NHP4010S
- NHP4012 and NHP4012S (suspended in mineral oil)
- Covers the entire product range HP/RCP/ICP
- XS control with silane such as BUPS, C-Donor, D-Donor
- Advanced & special grades by Silane selection
- Catalyst REACH compliant, PP products do not require REACH registration.

NHP®402 Series

- Excellent operability and high activity and hydrogen response demonstrated in multiple commercial scale runs
- Phthalate free
- Single catalyst to cover the entire product range HP/RCP/ICP
- No/minimal Silane needed, keeping activity high across all products
- High XS safeguard
- Catalyst REACH compliant, PP products do not require REACH registration.
Novolen R&D
Development Fields

✓ Process development
  > 50 improvements implemented in 10 years

✓ Product development
  Up-date of products to cope with modern converting processes
  Grade innovations e.g. 12 new grades; 14 developmental grades

✓ Catalyst development
  Molecular and kinetic Modelling (Cheops & University of Halle)
  Screening of external- internal donors

✓ Pilot Plant in Pasadena, US

Fully equipped R&D laboratory
Catalyst and Polymer research work hand in hand!
Lummus Novolen Technology GmbH offers NOVOLEN technology and technical support services for the manufacturing of a full range of NOVOLEN polypropylene grades. The NOVOLEN technology includes NOVOLEN process reactors, which can be used with added flexibility by implementing the proprietary VRC reactor system, which allows for maximum product range/capacity flexibility. The Novolen technology also includes NHP catalysts for the production of high performance polypropylene grades and NOVOCENE metallocene catalyst for the production of special polypropylene grades.