Polybutene-1 (PB-1) Grades Used For Hot And Cold Water Pipe Applications

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- Historical review
- Product portfolio
- Properties and advantages
- Akoalit homopolymer innovations
- Introducing Akoafloor PB-R copolymers
- Typical customer applications
Polybutene-1: Historical Review
Historical Review: More than 50 years of PB-1

1954: First polymerisation by Prof. G. Natta, Italy
1964: First industrial production by Hüls, Germany
1968: Mobil Oil builds plant in Taft, USA
1977: Shell Chemicals takes over from Witco and invests in extension of the plant (27 kt)
1998: Shell exits business; Basell enters
2003: Basell starts up new 45 kt plant in Moerdijk, Netherlands
2008: Basell expands Moerdijk plant to >60 kt

Milestones in History of Polybutene-1
Reliability

Specified and constructed in 1969 by Salen, Austria

PB-1 system installed in 1974
(6.5 km of 20 x 2.5 mm to 225 x 20.5 mm)

Service conditions: 10 bar / 54° C / 33 litre/s

Zero breakdowns reported in over 30 years

Despite the aggressive nature of the water (high sulphur content) the PB-1 pipe system is still in operation today!
Polybutene-1 Product Portfolio
PB-1 Product Portfolio

- **Akoalit products** - LyondellBasell’s new family of resins selected for potable water applications
  - *Akoalit* PB 4268 white
  - *Akoalit* PB 4267 grey

- **Akoafloor products** - LyondellBasell’s new PB-R grade selected for UFH / SHC* applications
  - *Akoafloor* PB R 509 natural / brown

- **Standard PB-1 grade** selected for heating pipe applications
  - PB 4235-1 ivory

* UFH: Under Floor Heating
  SHC: Surface Heating and Cooling
Polybutene-1: Properties and Advantages
PB-1 is produced through polymerization of butene-1 using Ziegler-Natta catalysts to create a:
linear,
high molecular weight,
isotactic,
semi-crystalline olefinic homopolymer.

PB-1 is compatible with PP but not with PE.
PB-1 Basics: Crystallization From The Melt

Ageing (5 days) at room temperature and atmospheric pressure

Form II

Kinetically favored

Ageing (10 min) at room temperature and elevated pressure

2 kbar

Form I

Thermo-dynamically stable

Ageing (5 days) at room temperature and atmospheric pressure

1 bar
Kinetics of form II to form I transformation
Form II to form I transformation

Increase in molecule length (~ 14%)
Decrease in cross section (~ 10%)
Volume shrinkage (~ 2%)

Impact on:
- Rigidity, Strength,
- Crystaline modification,
- Melting point, Density,
- Shrinkage

Accelerated by:
- Hydrostatic pressure
- Mechanical stress
- Nucleation

Polybutene-1 (PB-1) Grades Used For Hot and Cold Water Pipe Applications
Polybutene-1 properties

PB-1 retains its properties better with increasing temperature.

![Graph showing retention of tensile property against temperature for PB-1 and PP]
**PB-1: Creep Resistance**

PB-1 displays excellent creep resistance and deforms less over time under applied stress.

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**Tensile creep at 23 °C, 8 MPa**

- PB-1
- HDPE A
- HPPE B
- PP

**Tensile creep at 80°C, 8 MPa**

- HDPE A
- PP
- PB-1

Source: Internal data
PB-1 Pressure Performance vs. Other H & C Materials (operating pressure of 10 bar)

Source: ISO 15874 / 15875 / 15876 / 15877, 22391
Classes according to ISO 10508
### PB-1: Flexibility / Hydrodynamic Efficiency

<table>
<thead>
<tr>
<th></th>
<th>PB-1</th>
<th>PE-X</th>
<th>PE-RT II</th>
<th>PE-RT I</th>
<th>PP-R</th>
<th>PVC-C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flexibility</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td></td>
<td>50%</td>
<td>45%</td>
<td>32%</td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>125% (PB-R)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pipe weight</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td></td>
<td>140%</td>
<td>166%</td>
<td>190%</td>
<td></td>
<td>195%</td>
</tr>
<tr>
<td><strong>Pressure loss @ V=2 l/s</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 mbar/m</td>
<td></td>
<td>33 mbar/m</td>
<td>50 mbar/m</td>
<td>80 mbar/m</td>
<td>24 mbar/m</td>
<td></td>
</tr>
</tbody>
</table>

(Calculated for application class 2, 10 bar design pressure, based on published data)
PB-1 exhibits excellent sound dampening properties due to its high elasticity and low density.

Pressure and sound waves are naturally absorbed, eliminating “water hammer” noise.
PB-1: Key Benefits For Customers

- Unique flexibility facilitates fast installation
  - shorter construction time
  - reduced labour costs and fewer fittings
- Excellent mechanical properties allow for lighter pipes
- The material can be welded and processed, enabling
  - one material solution for pipe and fittings without metal
  - relatively easy processing and weldable fitting constructions
- Fully recyclable
- Potable water approved
PB-1: *Akoalit* homopolymer Innovations
PB-1 Homopolymer Innovation: PB 4237 Grey -> PB 4267 Grey

- Modulus and tensile properties similar (PB-1 homopolymers)
- Faster processing (higher MFR)
- Improved organoleptic properties (updated additvation)
- Increased long-term performance (no brittle failures up to 95 °C)
PB-1 Homopolymer Innovation:
PB 4237 Grey -> PB 4267 Grey

• Similar mechanical properties*
  - Flexural modulus: 450 MPa
  - Stress at yield: 20 MPa
  - Stress at break: 35 Mpa
  - Elongation at break: 300 %

• Faster processing*
  - MFR(190/2,16): 0,4 dg/min -> 0,6 dg/min
  - Can run up to 50% faster
  - Lower sensitivity towards induced orientation

• Improved organoleptics
  - Potential to meet more stringent future organoleptics requirements

* typical values, not to be construed as specification
PB-1 Homopolymer Innovation: PB 4237 -> PB 4267 – ISO 9080 Comparison

Polybutene-1 (PB-1) Grades Used For Hot and Cold Water Pipe Applications
PB-1: Introducing *Akoafloor* PB-R copolymers
# Akoafloor PB-R: Summary of Properties

## Mechanical properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Akoafloor*</th>
<th>PB 4235-1*</th>
<th>PE-RT**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flex. modulus</td>
<td>320 MPa</td>
<td>450 MPa</td>
<td>550 - 800 MPa</td>
</tr>
<tr>
<td>Stress at yield</td>
<td>18 MPa</td>
<td>19 MPa</td>
<td>15 - 20 MPa</td>
</tr>
<tr>
<td>Stress at break</td>
<td>38 MPa</td>
<td>30 MPa</td>
<td>35 - 40 MPa</td>
</tr>
<tr>
<td>Elongation at break</td>
<td>400%</td>
<td>250%</td>
<td>&gt; 350% - 800%</td>
</tr>
<tr>
<td>Izod 23 °C</td>
<td>65 kJ/m²</td>
<td>20 kJ/m²</td>
<td>23 kJ/m²</td>
</tr>
<tr>
<td>Izod 0 °C</td>
<td>25 kJ/m²</td>
<td>7 kJ/m²</td>
<td></td>
</tr>
<tr>
<td>Izod -20 °C</td>
<td>9 kJ/m²</td>
<td>4 kJ/m²</td>
<td>8 kJ/m² (-30 °C)</td>
</tr>
</tbody>
</table>

*typical values, not to be construed as specification

**various grades, data taken from published product data sheets
Akoafloor PB-R: Summary of Properties (cont’d)

<table>
<thead>
<tr>
<th>Rheology</th>
<th>Akoafloor</th>
<th>PB 4235-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFR(190/2,16)</td>
<td>0,7 dg/min</td>
<td>0,6 dg/min</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal properties</th>
<th>Akoafloor</th>
<th>PB 4235-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vicat A50</td>
<td>117 °C*</td>
<td>120 °C*</td>
</tr>
<tr>
<td>Ageing time</td>
<td>1 – 2 days**</td>
<td>5 days**</td>
</tr>
</tbody>
</table>

Source: *Polymerphysik
** Internal DSC data

Creep rupture
Lower level at elevated temperatures, but no knee point
Akoafloor PB-R: Design Stress Comparison

Hot water (60°C)
Hot water (70°C)
UFH (low temp)
UFH (high temp)
Radiator (high temp)
Cold water

Source: ISO 15874 / 15875 / 15876 / 15877/ 22391 / 12230
Application classes according to ISO 10508
Akoafloor Resins – Standard Recognition

Published standards including PB-R

- **ISO 12230** Polybutene-1 (PB-1) pipes — Effect of time and temperature on the expected strength
- **DIN 16968** Polybutene-1 pipes (PB-1) — PB 125 — General quality requirements and testing
- **DIN 16969** Polybutene-1 pipes (PB-1) — PB 125 — Dimensions

Standards under revision

- **ISO 15876** Plastics piping systems for hot and cold water installations - Polybutene (PB)
Akoafloor Resins - Conclusions

Main features

• Selected by customers for UFH (SHC)
• Performance advantages over competitive products
• Improved surface finish
• Higher productivity
• Faster ageing
• Increased flexibility
• Higher impact resistance
Polybutene-1: Typical Customer Applications
Typical Customer Applications - Piping Systems

Sanitary Installations
(hot and cold water plumbing)

District heating
For improved thermal insulation and protection, PB-1 medium pipes are embedded in plastic foam surrounded by PE corrugated pipe

Courtesy of LyondellBasell Customers
Acoustic Properties

Perfect Sound for the Royal Albert Hall

A PB-1 piping system was specified by +GF+ to replace the corroded galvanised steel plumbing system

Benefits:

• Pipe-borne noise emissions in the auditorium were reduced by 90%
• Heat loss was reduced by ca. 40 %
• Low CLTE and inherent flexibility provided the ability to match the unique shape of the building with reduced installation time
Typical Customer Applications - Piping Systems

LyondellBasell’s customers design and specify systems using PB-1 for:

- Underfloor heating
- Chilled ceilings
- Air conditioning

Courtesy of LyondellBasell Customers
Typical Customer Applications in Piping Systems

Renovation:
Prefabricated panels for wall heating

Used in historic buildings to meet special constraints (Wall heating in old town hall in Cologne)

Courtesy of LyondellBasell Customers
Customer Innovations

Sprinkler Systems

Retains pressure performance at elevated temperatures

Quick & easy to install: high flexibility and large variety of jointing techniques

To be insulated against direct contact with flame

Courtesy of LyondellBasell Customers
Looking Forward: The New Generations

- LyondellBasell is extending the boundaries of innovative process technology (copolymers, tailored molecular mass distribution, etc.)

- The properties of new-generation PB-1 materials are the starting point for future developments (mechanical performance, flexibility, processing, etc.)

- LyondellBasell works to continuously improve material performance to address the requirements of a variety of customer pipe applications
Thank you for your attention
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