



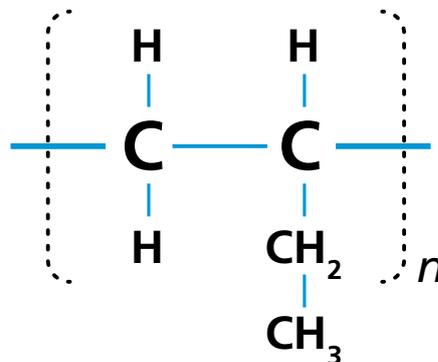
# LyondellBasell: Shaping Tomorrow

LyondellBasell is the world's third-largest independent chemical company. Our vertically integrated facilities, broad product portfolio, manufacturing flexibility, superior technology base and reputation for operational excellence enable us to deliver exceptional value to our customers across the petrochemical chain – from refining to advanced product applications.



PB-1 plant, Moerdijk, The Netherlands

LyondellBasell's polybutene-1 (PB-1) resins are high molecular weight polyolefins produced through the polymerization of the butene-1 monomer.



## Essential Ingredients

We manufacture products and develop technologies that improve the quality of life for people around the world. Our products are the basic building blocks used to manufacture countless everyday goods such as personal care products, fresh food packaging, lightweight plastics, high-strength construction materials, automotive components, biofuels, durable textiles, medical applications and many others. With the help of LyondellBasell materials, thousands of products are made safer, stronger, more affordable and more reliable.

## Experience and Long-term Commitment

The pioneering work of Karl Ziegler and Giulio Natta continues to shape and improve our lives. While working with LyondellBasell predecessor companies, these two fathers of modern polyolefins changed the world with their discoveries. They were recognized with the Nobel Prize in Chemistry in 1969. At LyondellBasell, their legacy of innovation lives on.

Polybutene-1 (PB-1), for example, was discovered in 1954 by the research team of Professor Natta. It is a thermoplastic polyolefin similar to polyethylene and

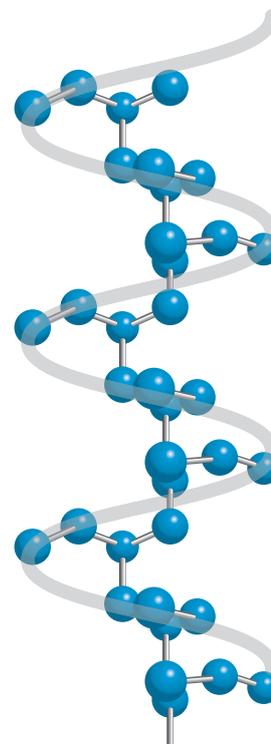
polypropylene produced through the polymerization of butene-1 using stereospecific catalysts to create a linear, highly isotactic and semi-crystalline polymer. The first industrial production and introduction into flexible pressure piping systems started in Europe in the mid 1960's. Since its introduction, LyondellBasell has introduced countless new and innovative PB-1 grades in many popular applications. Amazing then and amazing now – we are a technology-driven company powered by innovative thinkers.

# Polybutene-1: A High Performance Material

As a leading supplier of advanced polyolefins, LyondellBasell offers a wide range of versatile polyolefins selected by customers as building blocks in compounding and polymer property modification. Through research and development, LyondellBasell continuously discovers new opportunities to replace other polymers and traditional materials by introducing innovative properties and performance characteristics.

Pipe systems made from polybutene-1 have become a vital part of modern architecture and building technology. Polybutene-1 can be processed with conventional manufacturing equipment and exhibits superior thermal and mechanical properties that make it highly suitable in end-use applications that require high strength and flexibility over a broad temperature range. Excellent creep resistance combined with low stiffness makes polybutene-1 the technically preferred material for hot and cold water pipes.

Additionally, the properties of polybutene-1 can be tailored by copolymerisation with PE or PP to create random copolymers suitable for special applications in underfloor heating and inner layers of pressure tanks.



Due in part to a similar structure, PB-1 displays very good compatibility with polypropylene.

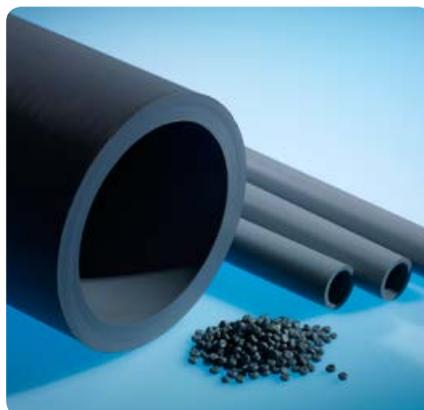
## Key characteristics of polybutene-1 in pipe systems

	PB-1
<b>Flexibility</b>	✓✓
<b>Creep resistance</b>	✓✓
<b>Thermal pressure resistance</b>	✓✓
<b>CLTE induced stress</b>	✓✓
<b>Pipe weight</b>	✓✓
<b>Acoustics / Noise absorption</b>	✓✓
<b>Impact toughness</b>	✓
<b>Chemical resistance</b>	✓

\*CLTE: Cyclic Linear Thermal Expansion

## Polybutene-1 pipe system suppliers cover the following application areas

- Hot and cold water supply systems
- District heating lines
- Radiator connections
- Underfloor heating
- Chilled ceilings and surfaces
- Shipbuilding
- Pressurized plastic tanks
- Sprinkler systems
- Geothermal systems



Pipe made from PB-1



Joints made of PB-1

# Polybutene-1: Advantages in Weight and Flexibility

The latest generation *Akoalit* polybutene-1 homopolymers (PB-H) show improved water quality properties providing the potential to meet stringent future organoleptic requirements. An increased melt flow ratio (MFR) allows up to 50% faster processing due to reduced sensitivity to process-induced orientation. *Akoafloor*, our PB-1 based copolymer (PB-R), has been designed to meet the growing demand for flexible pipes in surface heating and cooling systems. These random copolymers provide higher flexibility thus facilitating easier installation. Additionally, PB-R copolymers offer marked improvement in elongation at break and impact toughness allowing for quicker installation at lower temperatures with a lower risk of damage.

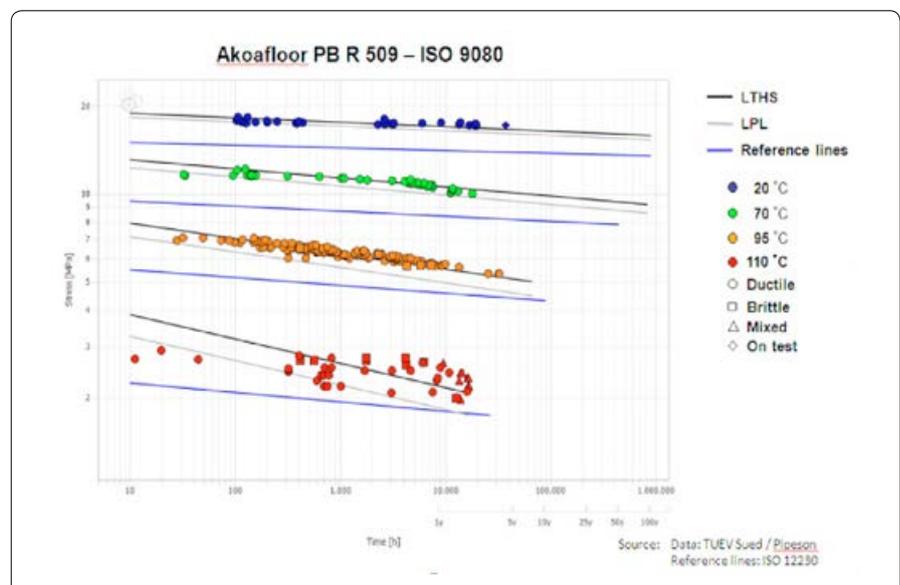
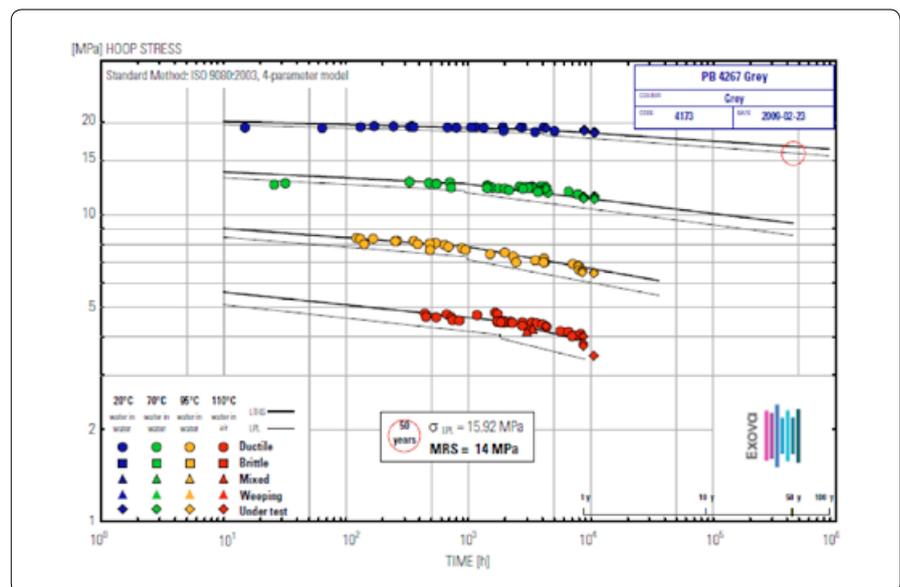
## Long-term mechanical performance

Polybutene-1 is an inherently flexible and highly resilient thermoplastic. ISO 9080 testing of *Akoalit* PB 4267 (a polybutene-1 homopolymer grade) confirms the long-term mechanical stability of polybutene-1, with no brittle failures detected up to 95°C. Similarly, a knee point could not be detected in ISO 9080 reference lines for *Akoafloor* PB R 509 (a polybutene copolymer grade).

## Light weight construction

PB-1 resins display excellent resistance to creep and burst allowing for thinner pipe walls to be designed, thereby reducing pipe weight significantly when compared to other plastic materials. The thinner pipe walls result in a larger inner diameter which leads to higher hydrodynamic efficiency (i.e. lower pressure loss).

Underfloor heating made from PB-1  
Courtesy of Viega / Gabo



## Sound Dampening

Among the superior properties of polybutene-1 is its excellent sound dampening. The combination of high elasticity, low specific density ( $\rho = 0.9 \text{ g/cm}^3$ ) and thinner pipe wall construction in polybutene pipes leads to high absorption of "water hammer" and other noises associated with heating and cooling in pipe systems. Tests showed a 90% reduction of pipe-borne noise in the Royal Albert Hall in London after the installation of polybutene-1 pipes.



Royal Albert Hall – London, England

## Water quality and safety

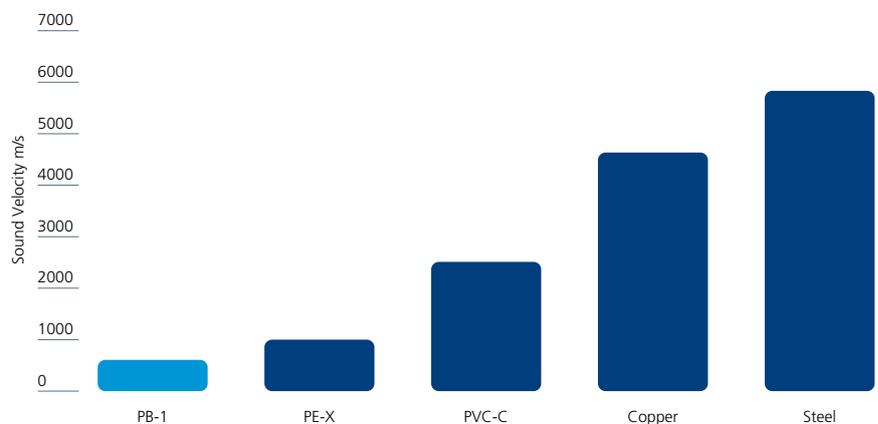
Polybutene-1 *Akoalit* grades, designed for potable water systems, comply with stringent requirements of regulatory and certification bodies. Water quality test certificates for drinking water contact, including tests on bacterial growth, have been obtained from the Technologiezentrum Wasser (TZW, Germany), the Water Regulations Advisory Scheme (WRAS, United Kingdom), NSF, United States and all other applicable national water quality approval bodies.

## Pipe Weight and Hydrodynamic Efficiency

	PB-1	PE-X PE-RT II	PE-RT I	PP-R	PVC-C
Flexibility	100%	50%	45%	32%	10%
Pipe weight	100%	140%	166%	166%	195%
Pressure loss @ V=2 l/s	18 mbar/m	33 mbar/m	50 mbar/m	80 mbar/m	24 mbar/m

(Calculated for application class 2, based on ISO 15874 / 15875 / 15876 / 15877, 22391)

## Sound Transmission in Solids



Note: calculation based on published data for E-modulus and density

## Akoalit and Akoafloor Summary of Properties

Property*	Akoalit (PB-1 homopolymer)	Akoafloor (PB-1 copolymer)
MFR 190 °C / 2.16 kg (g/10 min)	0.6	0.7
VICAT A50 softening point (°C)	120	117
Flexural Modulus (MPa)	450	330
Stress at Yield (MPa)	19	18
Stress at Break (MPa)	30	38
Elongation at Break (%)	250	330
Izod 23 °C (KJ/m <sup>2</sup> )	20	65
Izod 0 °C (KJ/m <sup>2</sup> )	7	25
Izod -20 °C (KJ/m <sup>2</sup> )	4	9

\*Typical values shown, not to be considered a specification

# PB-1: A Complete Solution

## Flexibility and wide range of possibilities

Polybutene-1 offers improved handling due to its flexibility, reduced pipe wall thickness and low memory effect. In addition to the potential cost savings of faster installation, polybutene-1 pipes provide opportunities for installation in tight, cramped spaces. A plastic pipe system consisting entirely of polybutene-1 is possible, due to the variety of jointing techniques to connect polybutene-1 pipes to fittings. Typical jointing techniques include push-fit, electrofusion, socket fusion and butt fusion. Welding technology with polybutene-1 offers additional opportunities to pre-fabricate pipe sections off-site further reducing logistical complexity in a project.

## Evolving product development

The innovative process technology used in manufacturing polybutene-1 – the copolymer structures, molecular mass distribution and additivation – continue to expand the boundaries for PB-1 products, resulting in greater advantages in mechanical performance, flexibility and processing.

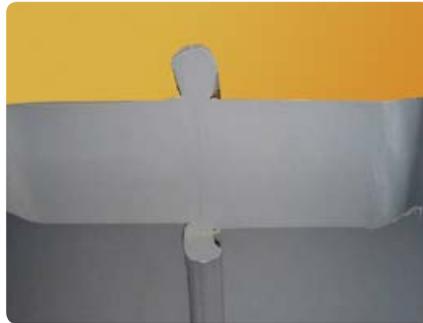
## Handling and Jointing



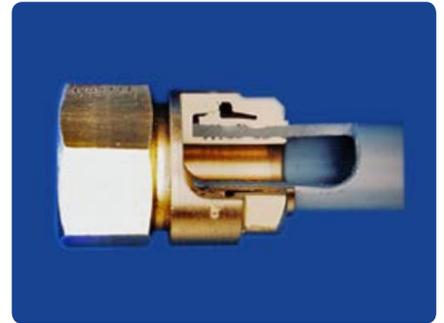
Push-fit



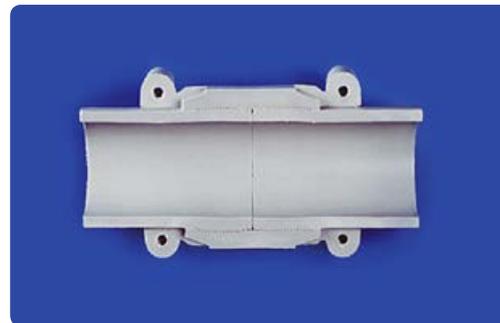
Socket fusion



Butt fusion

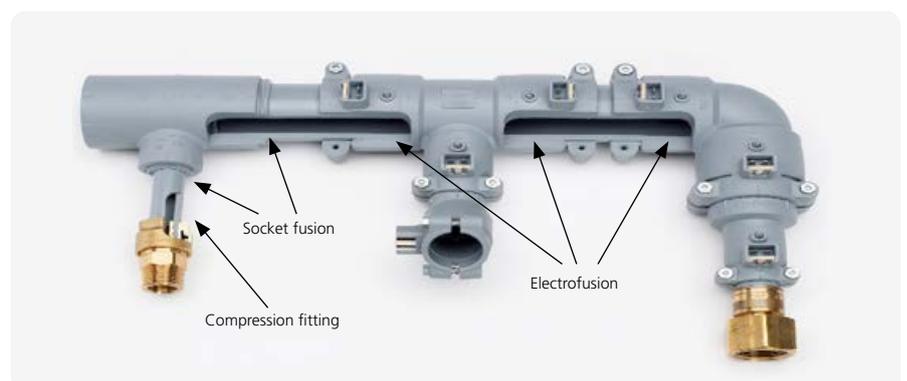


Clamping



Electrofusion

## Available jointing techniques for polybutene pipes



# PB-1 At A Glance

PB-1: The early days



Industrial / Commercial



Plumbing (hot and cold water)



District heating



Under floor heating



PB-1: The complete solution



# LyondellBasell

You can find out more about us by  
visiting our website at [lyondellbasell.com](http://lyondellbasell.com)  
or email [pipe@lyondell.com](mailto:pipe@lyondell.com)

## Rotterdam

Stationsplein 45  
3013 AK Rotterdam  
The Netherlands

Tel: +31 10 275 5500

## Houston

LyondellBasell Tower  
1221 McKinney Street, Ste. 300  
Houston, TX 77010  
P.O. Box 3646 (77253-3646)

Tel: +1 713 652 7200

## Hong Kong

12/F Caroline Centre  
Lee Gardens Two  
28 Yun Ping Road  
Causeway Bay, Hong Kong

Tel: +852 2577 3855

Users should review the applicable Material Safety Data Sheet before handling the product. Before using a product sold by one of the LyondellBasell family of companies, users should make their own independent determination that the product is suitable for the intended use and can be used safely and legally. SELLER MAKES NO WARRANTY, EXPRESS OR IMPLIED (INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE) OTHER THAN AS SEPARATELY AGREED BETWEEN THE PARTIES IN WRITING. This product(s) may not be used in the manufacture of any US FDA Class III Medical Device or Health Canada Class IV Medical Device and may not be used in the manufacture of any US FDA Class II Medical Device or Health Canada Class II or Class III Medical Device without the prior written approval by Seller of each specific product or application.

*Akoalit* and *Akoafloor* are trademarks owned or used by the LyondellBasell family of companies. They are registered in the U.S. Patent and trademark Office.

LyondellBasell does not sell PB-1 for use in pipe applications intended for use in North America, and requires its customers not to sell products made from PB-1 into pipe applications for North America.

