Benefits of PB-1 for pressure piping systems

What does a higher SDR class mean in practice?

Werner Rothhöft  -  Application Development & Technical Service
Patrick van Beek  -  Marketing Manager PB-1

Webinar – March 7, 2019
Agenda

- LyondellBasell at a glance
- PB-1 pipe applications
- What is PB-1?
- Pipe dimensions and SDR Classes
- What does a higher SDR-Class mean in practice? - Pipe dimensions
- What does a higher SDR-Class mean in practice? - Water hammer
- What does a higher SDR-Class mean in practice? - Sound dampening
- Summary of PB-1 for pressure piping systems
- Real life PB-1 pipe application examples
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LyondellBasell at a glance

LyondellBasell is a strong, global company delivering outstanding performance

**LEADING**(1)**

World’s largest licensor of polyolefin technologies.

#1

Producer of **polypropylene compounds** globally

Producer of **oxyfuels** in North America and Europe

Producer of **polypropylene** in North America and Europe

Producer of **polyethylene** in Europe

**DIVERSE**

Many of our **materials** go into products that people use every day, such as food packaging, electronics, children’s toys and fuels.

**GLOBAL**

Every day, our **employees** work around the clock to safely **advance solutions** to our world’s biggest challenges.

**GROWING**

Increased U.S. ethylene capacity by **21%** since 2012

Expanded polypropylene compounds capacity in **China, India** and **Europe**

Building the first world-scale **Hyperzone HDPE plant** and world’s largest **PO/TBA plant**

Acquired A. Schulman, expanding our position in the **advanced polymers markets**

One of the world’s largest plastics, chemical and refining companies producing products and materials key to advancing solutions to modern challenges

* 2017 data as of December 31, 2017
Chemicals

We produce the chemical building blocks for:

- automotive fluids
- furniture, household goods
- coatings, adhesives, cleaners
- cosmetics, personal care products

Polymers

Our versatile plastic resins are used to create a variety of products including:

- automotive parts
- packaging
- piping
- textiles
- renewable energy technologies
- agricultural films / irrigation
- healthcare
- food supply products

Advanced Polymers

Our diverse portfolio is used to create customizable products including:

- automotive parts
- differentiated packaging
- electronics / appliances
- construction materials
- roofing
- flooring
- geomembranes
- specialty pipe

Fuels

Our refinery in the U.S., produces:

- gasoline, fuel components
- low-sulfur diesel
- jet fuel
- lubricants
- oxyfuels that help improve air quality

Technologies

We license our state-of-the-art manufacturing and process technologies:

- technologies that are used by chemical and plastics companies around the globe
LyondellBasell at a glance

LyondellBasell delivers innovative products and solutions in five key areas

Key water pipe applications and materials:

- Pressure pipes for water supply made from high density polyethylene: PE80, PE100
- Piping systems for hot and cold water installations made from PEX, PE-RT, PP-R, PP-RCT and Polybutene-1 (PB-1)
- Sewage water pipes made from our polyethylene and polypropylene resins
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  - Real life PB-1 pipe application examples
PB-1 pipe applications

PB-1 has been in continuous service for pressurized hot and cold water piping systems for >40 years

**Interior pipe**
- Plumbing for hot and cold drinking water
- Surface heating and cooling (e.g. UFH *)
- Radiator connections

**Exterior pipe**
- District heating and cooling
- Geothermal pipelines

**Ship building**
- Plumbing for hot and cold drinking water

* UFH = Under Floor Heating

Source: John Guest Ltd.
Source: Thermaflex Isolatie BV.
Source: Shutterstock.com
Source: Georg Fischer Piping Systems Ltd.
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What is PB-1?

PB-1 is a flexible thermoplastic material, yet high stress and temperature resistant.

Source: Shutterstock.com

Source: LYB
LyondellBasell at a glance

PB-1 pipe applications

What is PB-1?

Pipe dimensions and SDR Classes

What does a higher SDR-Class mean in practice? - Pipe dimensions

What does a higher SDR-Class mean in practice? - Water hammer

What does a higher SDR-Class mean in practice? - Sound dampening

Summary of PB-1 for pressure piping systems

Real life PB-1 pipe application examples
Pipe dimensions and SDR Classes

SDR = Standard Dimension Ratio

SDR = d/s

\[ \text{di} = d - 2 \cdot s \]

\[ \text{Ai} = \text{di}^2 \cdot \pi / 4 \]

<table>
<thead>
<tr>
<th>SDR</th>
<th>13.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>s</td>
</tr>
<tr>
<td>[mm]</td>
<td>[mm]</td>
</tr>
<tr>
<td>25</td>
<td>1.9</td>
</tr>
<tr>
<td>32</td>
<td>2.4</td>
</tr>
<tr>
<td>40</td>
<td>3.0</td>
</tr>
<tr>
<td>50</td>
<td>3.7</td>
</tr>
<tr>
<td>63</td>
<td>4.7</td>
</tr>
<tr>
<td>75</td>
<td>5.6</td>
</tr>
<tr>
<td>90</td>
<td>6.7</td>
</tr>
<tr>
<td>110</td>
<td>8.1</td>
</tr>
<tr>
<td>125</td>
<td>9.2</td>
</tr>
<tr>
<td>140</td>
<td>10.3</td>
</tr>
<tr>
<td>160</td>
<td>11.8</td>
</tr>
<tr>
<td>180</td>
<td>13.3</td>
</tr>
<tr>
<td>200</td>
<td>14.7</td>
</tr>
<tr>
<td>225</td>
<td>16.6</td>
</tr>
<tr>
<td>250</td>
<td>18.4</td>
</tr>
</tbody>
</table>
## Pipe dimensions and SDR Classes

<table>
<thead>
<tr>
<th>SDR</th>
<th>13.6</th>
<th>11</th>
<th>9</th>
<th>7.4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>d [mm]</td>
<td>s [mm]</td>
<td>d_i [mm]</td>
<td>A_i [mm^2]</td>
<td>s [mm]</td>
<td>d_i [mm]</td>
</tr>
<tr>
<td>25</td>
<td>1.9</td>
<td>21.2</td>
<td>353</td>
<td>2.3</td>
<td>20.4</td>
</tr>
<tr>
<td>32</td>
<td>2.4</td>
<td>27.2</td>
<td>581</td>
<td>3.0</td>
<td>26.0</td>
</tr>
<tr>
<td>40</td>
<td>3.0</td>
<td>34</td>
<td>908</td>
<td>3.7</td>
<td>32.6</td>
</tr>
<tr>
<td>50</td>
<td>3.7</td>
<td>42.6</td>
<td>1,425</td>
<td>4.6</td>
<td>40.8</td>
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<tr>
<td>63</td>
<td>4.7</td>
<td>53.6</td>
<td>2,256</td>
<td>5.8</td>
<td>51.4</td>
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<tr>
<td>75</td>
<td>5.6</td>
<td>63.8</td>
<td>3,197</td>
<td>6.9</td>
<td>61.2</td>
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<td>90</td>
<td>6.7</td>
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<td>4,608</td>
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<td>73.6</td>
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<td>110</td>
<td>8.1</td>
<td>93.8</td>
<td>6,910</td>
<td>10.0</td>
<td>90.0</td>
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<tr>
<td>125</td>
<td>9.2</td>
<td>106.6</td>
<td>8,925</td>
<td>11.4</td>
<td>102.2</td>
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<td>140</td>
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<td>11,197</td>
<td>12.7</td>
<td>114.6</td>
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<tr>
<td>160</td>
<td>11.8</td>
<td>136.4</td>
<td>14,612</td>
<td>14.6</td>
<td>130.8</td>
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<tr>
<td>180</td>
<td>13.3</td>
<td>153.4</td>
<td>18,482</td>
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<td>200</td>
<td>14.7</td>
<td>170.6</td>
<td>22,859</td>
<td>18.2</td>
<td>163.6</td>
</tr>
<tr>
<td>225</td>
<td>16.6</td>
<td>191.8</td>
<td>28,893</td>
<td>20.5</td>
<td>184.0</td>
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<tr>
<td>250</td>
<td>18.4</td>
<td>213.2</td>
<td>35,700</td>
<td>22.7</td>
<td>204.6</td>
</tr>
</tbody>
</table>
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- LyondellBasell at a glance
- PB-1 pipe applications
- What is PB-1?
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- **What does a higher SDR-Class mean in practice?** - Pipe dimensions
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- What does a higher SDR-Class mean in practice? - Sound dampening
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What does higher SDR-Class mean in practice? - Pipe dimensions

The Dutch guideline BRL 5609 and the Russian standard GOST 56730 for district heating system have the same requirements

<table>
<thead>
<tr>
<th>Service pipe</th>
<th>Operating Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 bar</td>
</tr>
<tr>
<td>PB-1</td>
<td>SDR 13.6</td>
</tr>
<tr>
<td>PEX</td>
<td>SDR 11</td>
</tr>
<tr>
<td>PE-RT II</td>
<td>SDR 9</td>
</tr>
</tbody>
</table>
What does higher SDR-Class mean in practice? - Pipe dimensions

The Dutch guideline BRL 5609 and the Russian standard GOST 56730 for plastic piping systems have the same requirements

<table>
<thead>
<tr>
<th></th>
<th>$T_{\text{design}}$</th>
<th>$T_{\text{max}}$</th>
<th>$T_{\text{mal}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>time</td>
<td>°C</td>
<td>time</td>
</tr>
<tr>
<td>years</td>
<td>time</td>
<td>years</td>
<td>hours</td>
</tr>
<tr>
<td>80</td>
<td>29</td>
<td>90</td>
<td>1</td>
</tr>
</tbody>
</table>

Beside the operating pressures, a temperature/time profile is also defined.
What does higher SDR-Class mean in practice? - Pipe dimensions

Example 1 - pipe diameter ø50mm

<table>
<thead>
<tr>
<th></th>
<th>SDR</th>
<th>outside diameter [mm]</th>
<th>wall thickness [mm]</th>
<th>pipe cross section [mm²]</th>
<th>weight per meter [kg/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE-RT II</td>
<td>7.4</td>
<td>50</td>
<td>6.9</td>
<td>1,029</td>
<td>0.934</td>
</tr>
<tr>
<td>PEX</td>
<td>9</td>
<td>50</td>
<td>5.6</td>
<td>1,182</td>
<td>0.780</td>
</tr>
<tr>
<td>PB-1</td>
<td>11</td>
<td>50</td>
<td>4.6</td>
<td>1,307</td>
<td>0.666</td>
</tr>
</tbody>
</table>

- **PE-RT II** has a higher SDR-Class of 7.4 compared to PE and PEX, resulting in a smaller pipe cross section but higher weight per meter.
- **PB-1** has the highest SDR-Class of 11, making it the lightest option per meter but with a smaller pipe cross section.
What does higher SDR-Class mean in practice? - Pipe dimensions

Example 1 - pipe diameter ø50mm

PB-1 offers the highest available inside cross section area

PB-1 provides substantial material savings vs. PE-RT and PEX

Inside cross section area

Material content per meter pipe

<table>
<thead>
<tr>
<th></th>
<th>PE-RT</th>
<th>PEX</th>
<th>PB-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside</td>
<td>100%</td>
<td>115%</td>
<td>127%</td>
</tr>
<tr>
<td>Cross</td>
<td>10%</td>
<td>15%</td>
<td>27%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>PE-RT</th>
<th>PEX</th>
<th>PB-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>100%</td>
<td>84%</td>
<td>71%</td>
</tr>
<tr>
<td>Per meter</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What does higher SDR-Class mean in practice? - Pipe dimensions

Example 1 - pipe diameter Ø50mm

At the same pressure, PB-1 pipes yield up to 35% higher output

PB-1 pipes yield same output at reduced energy consumption / pump capacity
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What does higher SDR-Class mean in practice? - Water hammer

What is water hammer?

Valve closed – water still

Valve open – water flowing

Valve closes – water hammer

Source: LYB

Repetitive water hammer impacts can be destructive to pipe systems
The maximum theoretical value of the pressure surge $p_s$ is:

$$v_0 \cdot a \cdot \rho = p_s$$

$v_0 = \text{velocity}$ of the medium [m/s]

$a = \text{propagation rate}$ of the pressure wave [m/s]

$\rho = \text{density of the medium}$ [kg/m$^3$]

$p_s = \text{pressure surge – water hammer}$ [N/m$^2$]
**What does higher SDR-Class mean in practice? - Water hammer**

**ISO 10508**
Plastic piping system for hot and cold water installations – Guidance for classification and design

<table>
<thead>
<tr>
<th>Application class</th>
<th>T&lt;sub&gt;design&lt;/sub&gt; °C</th>
<th>time years</th>
<th>T&lt;sub&gt;max&lt;/sub&gt; °C</th>
<th>time years</th>
<th>T&lt;sub&gt;mal&lt;/sub&gt; °C</th>
<th>time hours</th>
<th>Typical field of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>49</td>
<td>80</td>
<td>1</td>
<td>95</td>
<td>100</td>
<td>Hot water supply (60°C)</td>
</tr>
<tr>
<td>2</td>
<td>70</td>
<td>49</td>
<td>80</td>
<td>1</td>
<td>95</td>
<td>100</td>
<td>Hot water supply (70°C)</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>0.5</td>
<td>50</td>
<td>4.5</td>
<td>65</td>
<td>100</td>
<td>Low temperature underfloor heating</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>2.5</td>
<td>70</td>
<td>2.5</td>
<td>100</td>
<td>100</td>
<td>Underfloor heating and low temperature radiators</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>14</td>
<td>90</td>
<td>1</td>
<td>100</td>
<td>100</td>
<td>High temperature radiators</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*For the different application classes, different temperature / time profiles are defined*
What does higher SDR-Class mean in practice? - Water hammer

Example 2 - pipe diameter ø50mm

<table>
<thead>
<tr>
<th>Material</th>
<th>SDR</th>
<th>Wall thickness [mm]</th>
<th>Pipe cross section [mm²]</th>
<th>Weight per meter [kg/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP-H/PP-R</td>
<td>6</td>
<td>8.3</td>
<td>875</td>
<td>1.03</td>
</tr>
<tr>
<td>PEX/PE-RT/PPRCT</td>
<td>9</td>
<td>5.6</td>
<td>1,182</td>
<td>0.78 / 0.79 / 0.75</td>
</tr>
<tr>
<td>PB-1</td>
<td>13.5</td>
<td>3.7</td>
<td>1,425</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Standards:
ISO 15874 for PP, ISO 15875 for PE-X, ISO 15876 for PB-1, ISO 22391 for PE-RT

Again PB-1 is the material with the highest SDR Class, offering the highest cross section and has the lowest weight per meter pipe.
What does higher SDR-Class mean in practice? - Water hammer

Example 2 - pipe diameter Ø50mm

<table>
<thead>
<tr>
<th>Material</th>
<th>SDR</th>
<th>Wall thickness [mm]</th>
<th>Pipe cross section [mm²]</th>
<th>Velocity [%]</th>
<th>Propagation rate [%]</th>
<th>Water hammer [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP-H/PP-R</td>
<td>6</td>
<td>8.3</td>
<td>875</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>PEX/PE-RT/PPRCT</td>
<td>9</td>
<td>5.6</td>
<td>1,182</td>
<td>74</td>
<td>82</td>
<td>61</td>
</tr>
<tr>
<td>PB-1</td>
<td>13.5</td>
<td>3.7</td>
<td>1,425</td>
<td>61</td>
<td>40</td>
<td>24</td>
</tr>
</tbody>
</table>

The higher the SDR Class, the lower the water hammer at a given flow rate
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What does higher SDR-Class mean in practice? – Sound dampening

Sound Transmission in Solids

PB-1 offers excellent damping properties to absorb pressure surges and noise from water hammer
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Benefits of PB-1 for pressure piping systems

Summary
The use of PB-1 for pressure pipe systems offers:

■ substantial material saving opportunities, while at the same time increasing the capacity of the system

■ opportunities for reduced integral installation cost and cost in operation

■ a versatile material significantly reducing the negative effects of water hammer, positively affecting the lifetime of the pipe system

PB-1 is the most technically advanced material for pressure piping systems
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PB-1 pipe application Case 1 – District Heating

A challenging renovation schedule for Stadsverwarming Purmerend - The Netherlands

Replacing corroded steel pipes for 4,000 houses

Benefits:
• Flexibility and availability in long lengths
• Much reduced installation times due to the use of pre-fab sections
• Significantly reduced maintenance and operational costs and service downtime:
  - Heat loss -10%
  - Water loss -50%
  - Nominal water pressure -1 bar
  - Unplanned service downtime -84%

More information on www.pbpsa.com

Source: Thermaflex Isolatie BV.
PB-1 pipe application Case 2 – High Rise Building

Setting new boundaries with the BD Bacatá skyscraper in Bogotá - Colombia

A new high-rise building with risers from 50 up to 125mm are exposed to pressurized hot water 24/7

Benefits:
• The flexibility of PB-1 pipes enabled a much faster installation while reducing the number of joints and fittings
• Unmatched resistance to water hammer due to the outstanding absorption characteristics of PB-1

More information on www.pbpsa.com
PB-1 pipe application Case 3 – Major Building Project

Perfect acoustics for the Royal Albert Hall, London - United Kingdom

A PB-1 pipe system was specified to replace the corroded galvanized steel plumbing system

Benefits:
• The low thermal expansion and inherent flexibility of PB-1 allowed the unique shape of the building to be followed, reducing installation time
• Heat loss was reduced by 40%
• Pipe-borne noise emissions in the auditorium were reduced by 90%

More information on www.pbpsa.com
Polybutene Piping System Association (PBPSA)

PBPSA is an international association of market leading companies committed to the use of Polybutene-1 (PB-1) for the manufacture of piping systems.

More information on www.pbpsa.com
Q&A session

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