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

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

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*

LyondellBasell at a glance

LyondellBasell delivers innovative products and solutions in five key areas

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:

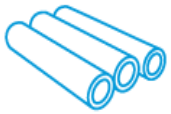
- technologies that are used by chemical and plastics companies around the globe

LyondellBasell at a glance

LyondellBasell delivers innovative products and solutions in five key areas

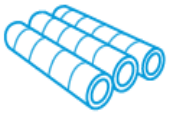
POLYMERS

- **piping**



Industrial pipe

Drinking water pipe



Soil & waste pipe

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

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

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


Source: John Guest Ltd.

Exterior pipe

- District heating and cooling
- Geothermal pipelines


Source: Thermaflex Isolatie BV.

Ship building

- Plumbing for hot and cold drinking water

Source: Shutterstock.com


Source: Georg Fischer Piping Systems Ltd.

* UFH = Under Floor Heating

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

What is PB-1 ?

Source: Shutterstock.com

Source: LYB

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

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

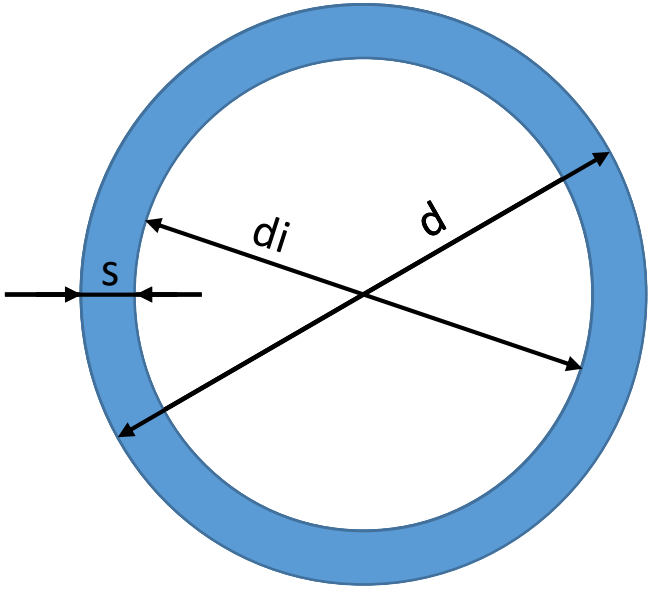
Pipe dimensions and SDR Classes

SDR	13,6		
d	s	di	Ai
[mm]	[mm]	[mm]	[mm²]
25	1,9	**21,2**	353
32	2,4	**27,2**	581
40	3,0	**34**	908
50	3,7	**42,6**	1.425
63	4,7	**53,6**	2.256
75	5,6	**63,8**	3.197
90	6,7	**76,6**	4.608
110	8,1	**93,8**	6.910
125	9,2	**106,6**	8.925
140	10,3	**119,4**	11.197
160	11,8	**136,4**	14.612
180	13,3	**153,4**	18.482
200	14,7	**170,6**	22.859
225	16,6	**191,8**	28.893
250	18,4	**213,2**	35.700

$SDR = d/s$

$di = d - 2 \cdot s$

$Ai = di^2 \cdot \pi / 4$



SDR = Standard Dimension Ratio

Pipe dimensions and SDR Classes

SDR		13.6			11			9			7.4			6		
	d	s	di	Ai	s	di	Ai	s	di	Ai	s	di	Ai	s	di	Ai
	[mm]	[mm]	[mm]	[mm²]	[mm]	[mm]	[mm²]	[mm]	[mm]	[mm²]	[mm]	[mm]	[mm²]	[mm]	[mm]	[mm²]
	25	1.9	**21.2**	353	2.3	**20.4**	327	2.8	**19.4**	296	3.5	**18.0**	254	4.2	**16.6**	216
	32	2.4	**27.2**	581	3.0	**26.0**	531	3.6	**24.8**	483	4.4	**23.2**	423	5.4	**21.2**	353
	40	3.0	**34**	908	3.7	**32.6**	835	4.5	**31.0**	755	5.5	**29.0**	661	6.7	**26.6**	556
	50	3.7	**42.6**	1,425	4.6	**40.8**	1,307	5.6	**38.8**	1,182	6.9	**36.2**	1,029	8.4	**33.2**	866
	63	4.7	**53.6**	2,256	5.8	**51.4**	2,075	7.1	**48.8**	1,870	8.7	**45.6**	1,633	10.5	**42.0**	1,385
	75	5.6	**63.8**	3,197	6.9	**61.2**	2,942	8.4	**58.2**	2,660	10.3	**54.4**	2,324	12.5	**50.0**	1,963
	90	6.7	**76.6**	4,608	8.2	**73.6**	4,254	10.1	**69.8**	3,826	12.3	**65.4**	3,359	15.0	**60.0**	2,827
	110	8.1	**93.8**	6,910	10.0	**90.0**	6,362	12.3	**85.4**	5,728	15.1	**79.8**	5,001	18.3	**73.4**	4,231
	125	9.2	**106.6**	8,925	11.4	**102.2**	8,203	14.0	**97.0**	7,390	17.1	**90.8**	6,475	20.8	**83.4**	5,463
	140	10.3	**119.4**	11,197	12.7	**114.6**	10,315	15.7	**108.6**	9,263	19.2	**101.6**	8,107	23.3	**93.4**	6,851
	160	11.8	**136.4**	14,612	14.6	**130.8**	13,437	17.9	**124.2**	12,115	21.9	**116.2**	10,605	26.6	**106.8**	8,958
	180	13.3	**153.4**	18,482	16.4	**147.2**	17,018	20.1	**139.8**	15,350	24.6	**130.8**	13,437	29.9	**120.2**	11,347
	200	14.7	**170.6**	22,859	18.2	**163.6**	21,021	22.4	**155.2**	18,918	27.4	**145.2**	16,559	33.3	**133.4**	13,977
	225	16.6	**191.8**	28,893	20.5	**184.0**	26,590	25.2	**174.6**	23,943	30.8	**163.4**	20,970	37.4	**150.2**	17,719
	250	18.4	**213.2**	35,700	22.7	**204.6**	32,878	27.9	**194.2**	29,620	34.2	**181.6**	25,901	41.6	**166.8**	21,852

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

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

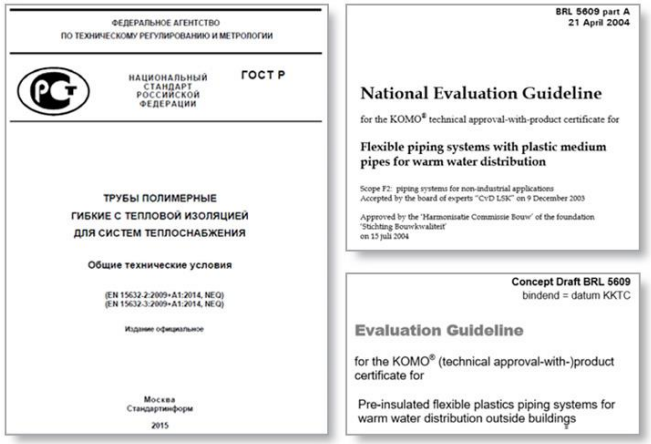
The Dutch guideline BRL 5609 and the Russian standard GOST 56730 for district heating system have the same requirements

Service pipe	Operating Pressure		
	6 bar	8 bar	10 bar
PB-1	SDR 13.6	SDR 11	SDR 9
PEX	SDR 11	SDR 9	SDR 7.4
PE-RT II	SDR 9	SDR 7.4	SDR 6

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

T_{design}		T_{max}		T_{mal}	
°C	time years	°C	time years	°C	time hours
80	29	90	1	95	100

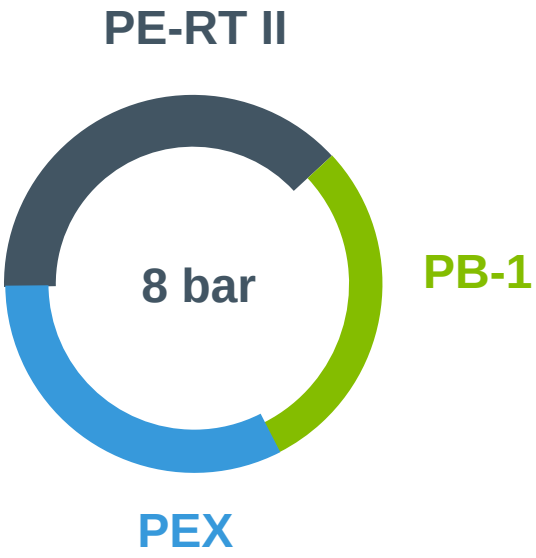


Dutch guideline BRL 5609 & Russian standard GOST 56730

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

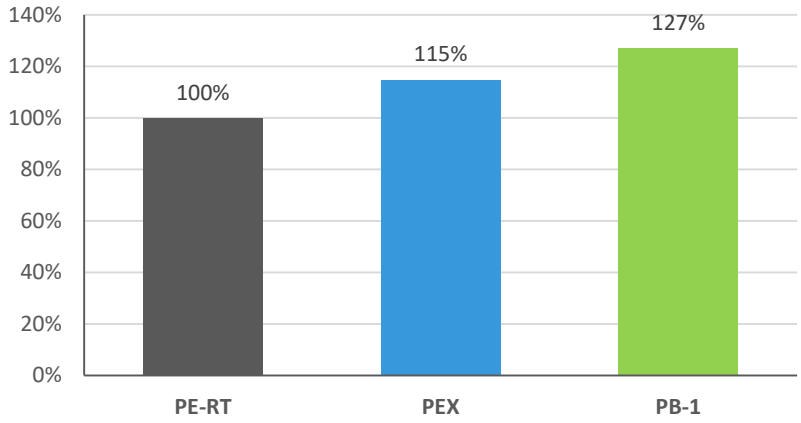


	SDR	outside diameter [mm]	wall thickness [mm]	pipe cross section [mm²]	weight per meter [kg/m]
PE-RT II	7.4	50	6.9	1,029	0.934
PEX	9	50	5.6	1,182	0.780
PB-1	11	50	4.6	1,307	0.666

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

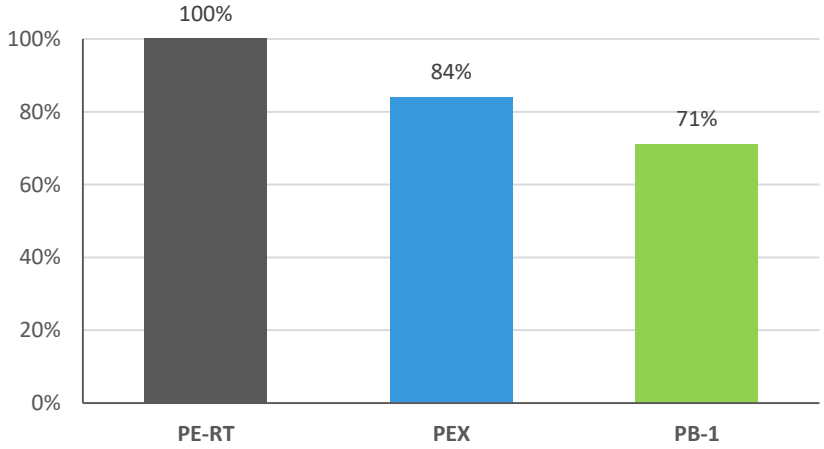
Example 1 - pipe diameter ø50mm

Inside cross section area



PB-1 offers **the highest available inside cross section area**

Material content per meter pipe

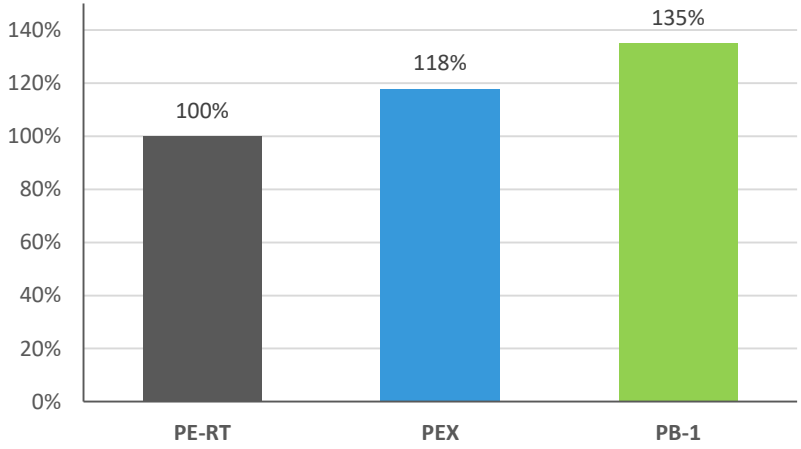


PB-1 provides **substantial material savings** vs. PE-RT and PEX

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

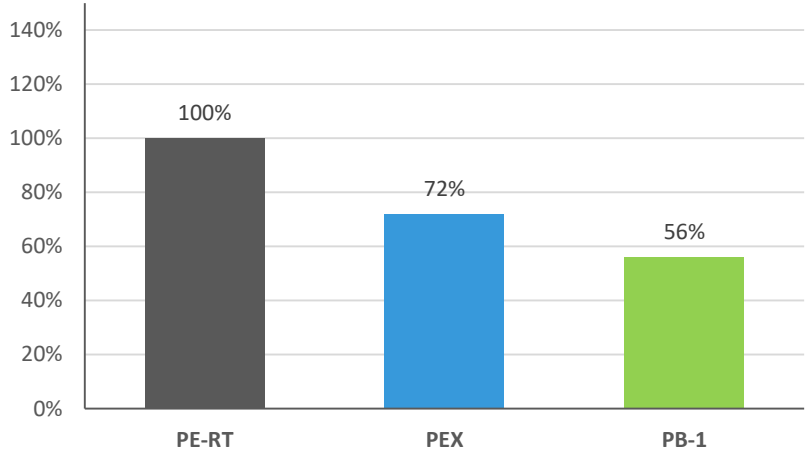
Example 1 - pipe diameter ø50mm

Flow rate at same pressure



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

Pressure loss at same flow rate



PB-1 pipes yield same output at **reduced energy consumption / pump capacity**

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

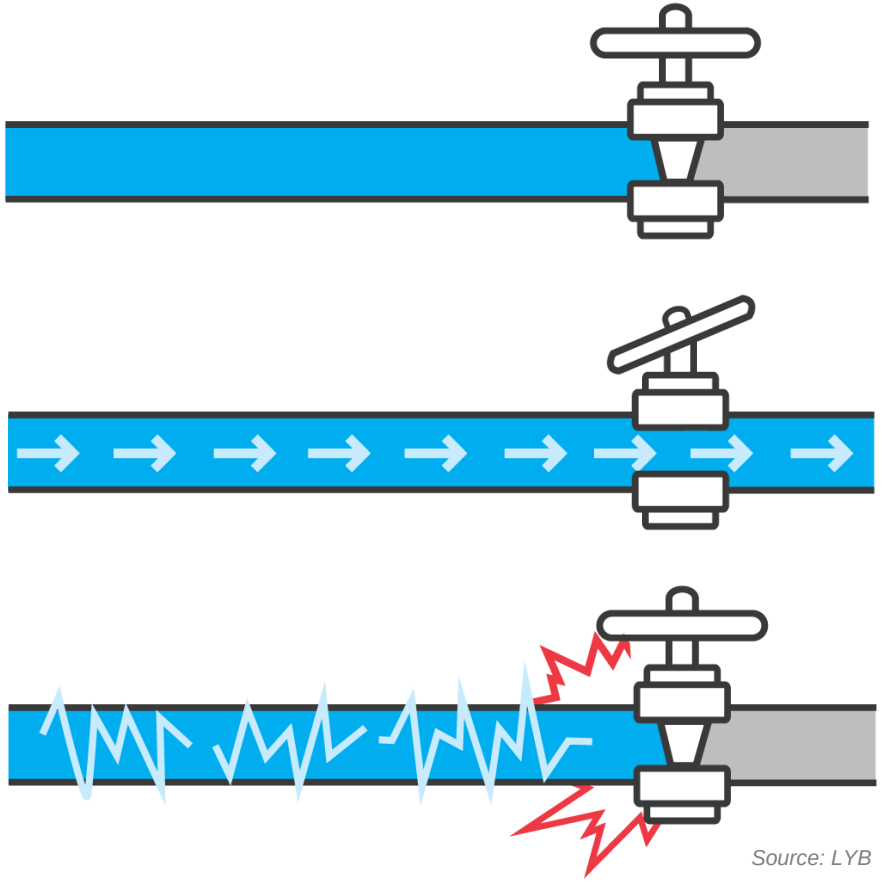
What does higher SDR-Class mean in practice? - Water hammer

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

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

The maximum theoretical value of the pressure surge p_s is:

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

v_0 = **velocity** of the medium [m/s]

a = **propagation rate** of the pressure wave [m/s]

ρ = density of the medium [kg/m³]

p_s = pressure surge – **water hammer** [N/m²]

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

ISO 10508

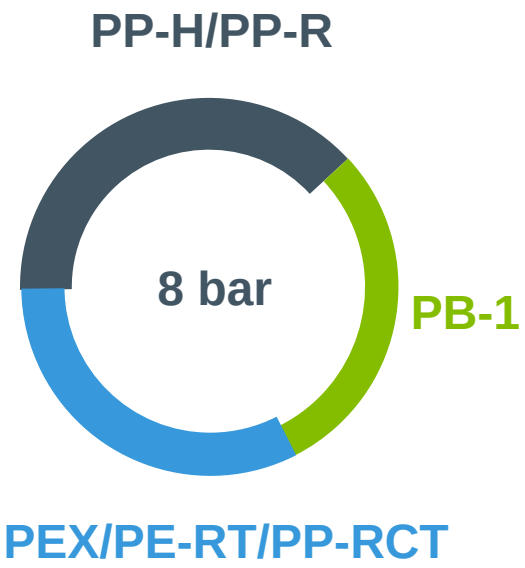
Plastic piping system for hot and cold water installations – Guidance for classification and design

	T_{design}		T_{max}		T_{mal}		
Application class	°C	time years	°C	time years	°C	time hours	Typical field of application
1	60	49	80	1	95	100	Hot water supply (60°C)
2	70	49	80	1	95	100	Hot water supply (70°C)
3	20	0.5	50	4.5	65	100	Low temperature
	30	20					underfloor heating
	40	25					
4	20	2.5	70	2.5	100	100	Underfloor heating and
	40	20					low temperature radiators
	60	25					
5	20	14	90	1	100	100	High temperature radiators
	60	25					
	80	10					

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



	SDR	wall thickness [mm]	pipe cross section [mm²]	Weight per meter [kg/m]
PP-H/PP-R	6	8.3	875	1.03
PEX/PE-RT/PPRCT	9	5.6	1,182	0.78 / 0.79 / 0.75
PB-1	13.5	3.7	1,425	0.54

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

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

	SDR	wall thickness [mm]	pipe cross section [mm²]	velocity [%]	propagation rate [%]	water hammer [%]
PP-H/PP-R	6	8.3	875	**100**	**100**	**100**
PEX/PE-RT/PPRCT	9	5.6	1,182	**74**	**82**	**61**
PB-1	13.5	3.7	1,425	**61**	**40**	**24**

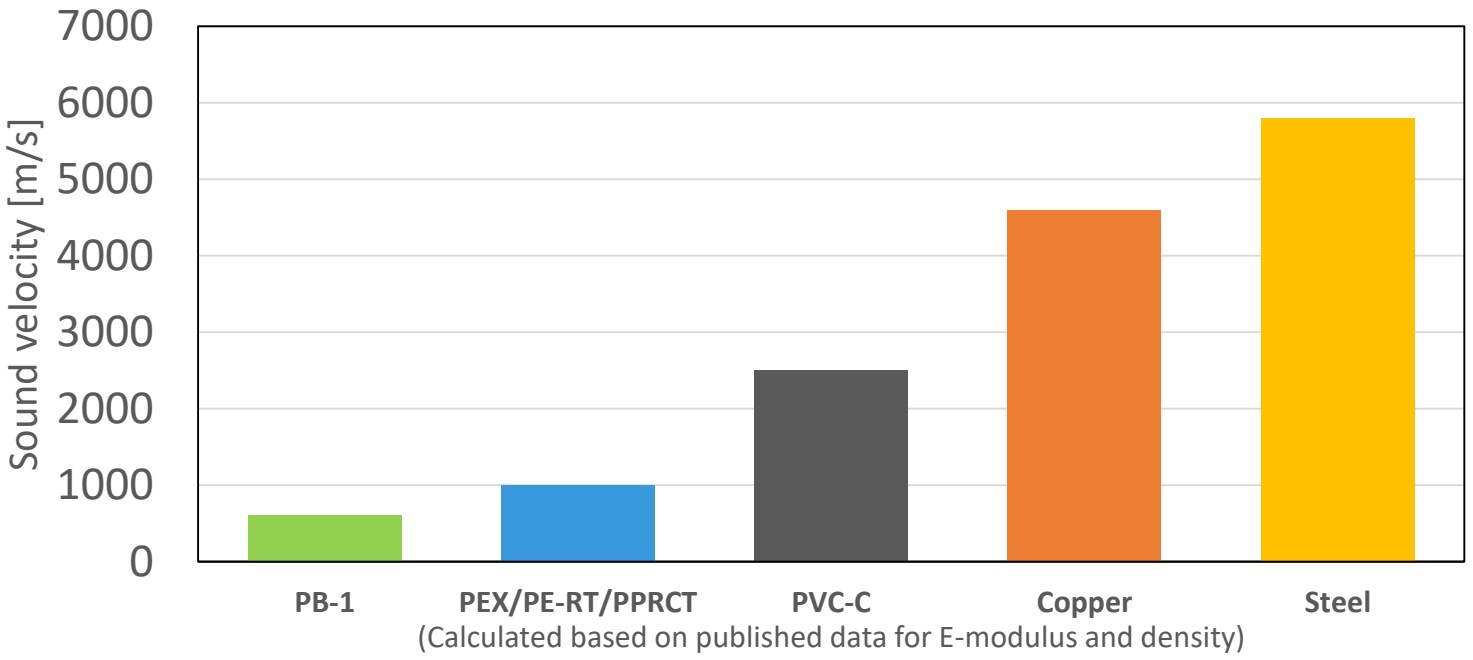
The higher the SDR Class, the lower the water hammer at a given flow rate

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

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

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

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

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**

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

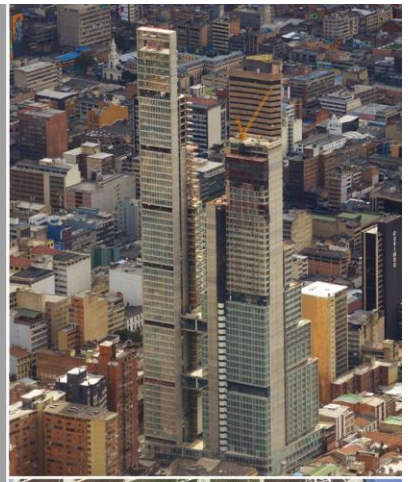
Benefits:

- 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

Source: Shutterstock.com



Source: Shutterstock.com
Source: Nueva Terrain S.L.

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:

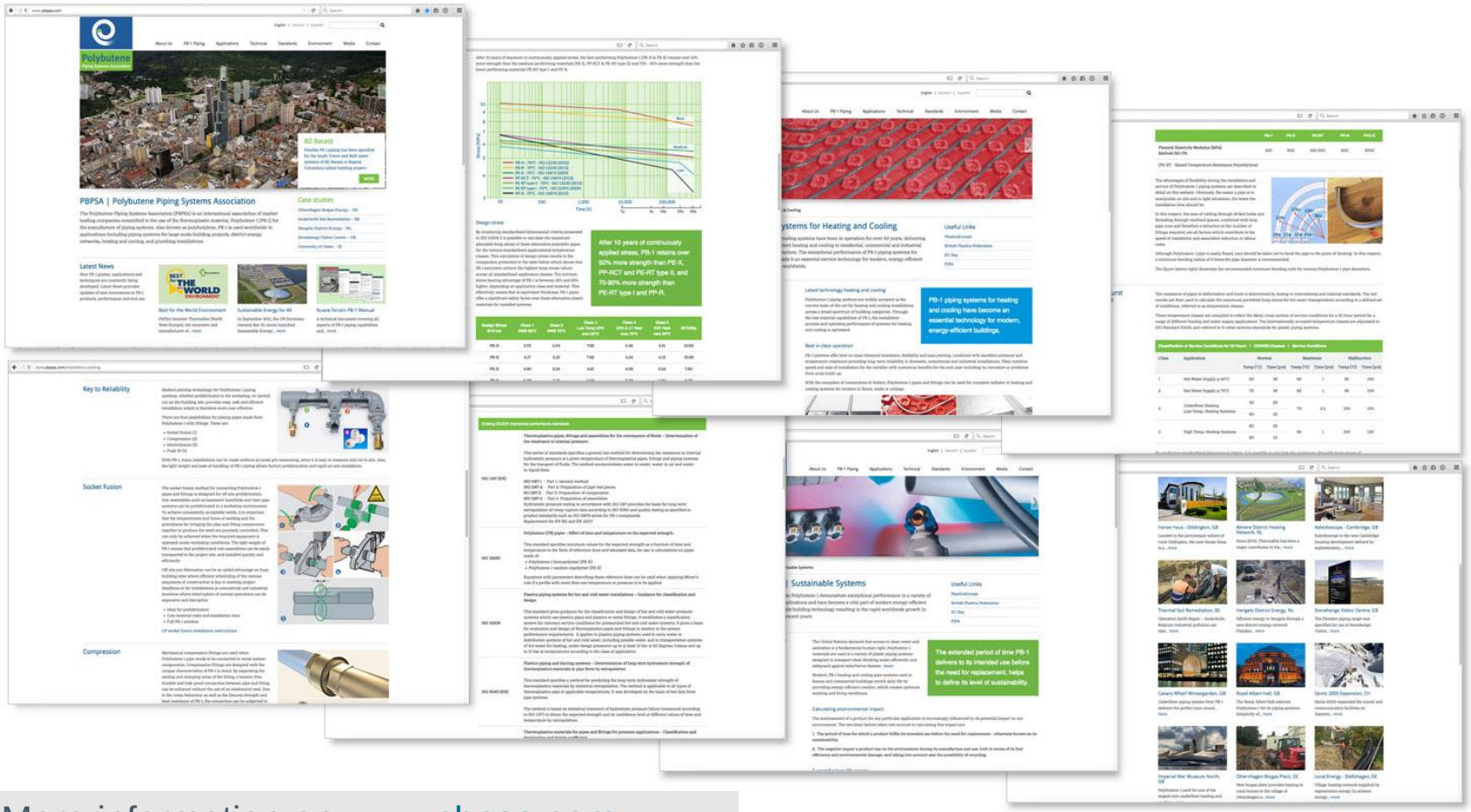
- The low thermal expansion and inherent flexibility of PB-1 allowed the unique shape of the building to be followed, reducing installation time
- Heat loss was reduced by 40%
- Pipe-borne noise emissions in the auditorium were reduced by 90%

More information on www.pbpsa.com

Source: Shutterstock.com
Source: Georg Fischer Piping Systems Ltd.

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

Patrick van Beek
Marketing Manager PB-1

LyondellBasell
Basell Sales & Marketing Company BV
Delftseplein 27E
3013 AA Rotterdam
The Netherlands

Tel. + 31-10-275 5756
Mob. + 31-6-2903 3160
E-mail patrick.vanbeek@lyb.com

www.lyb.com

Werner Rothhöft
Application Development & Technical Service

LyondellBasell
Basell Polyolefine GmbH
Industriepark Höchst, C 657 R211
D-65926 Frankfurt am Main
Germany

Tel. + 49-69-305 3587
Mob. + 49-172-614 8428
E-mail werner.rothhoeft@lyb.com

www.lyb.com

Thank you for your attention

Disclaimer

Before using a product sold by a company 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 OR ANY WARRANTY) OTHER THAN AS SEPARATELY AGREED TO BY THE PARTIES IN A CONTRACT.

LyondellBasell prohibits or restricts the use of its products in certain applications. For further information on restrictions or prohibitions of use, please contact a LyondellBasell representative.

Users should review the applicable Safety Data Sheet before handling the product.

PB-1 may not be used in the manufacture of pipe applications intended for sale or shipment to North America, without prior written approval by Seller for each specific product and application.

Any technical advice, assistance, recommendations, testing or reports provided by the LyondellBasell (“LYB”) family of companies to you for any reason, including, but not limited to (i) the selection, processing or use of a LYB product, (ii) the storing, handling or usage of a LYB product, or (iii) the modification of a LYB product in an end-use application, or (iv) assistance about technical feasibility of applications, or (v) assistance about design and simulation methods or procedures (collectively, “Technical Assistance”) is given and accepted at your sole risk and without any warranty whatsoever. LyondellBasell will have no liability or responsibility for the use of, results obtained from, or any other aspects of the Technical Assistance, including, but not limited to, the preparation and delivery hereof. You are encouraged to verify independently any such Technical Assistance.