CI/SfB | 53/In6 | June 2005

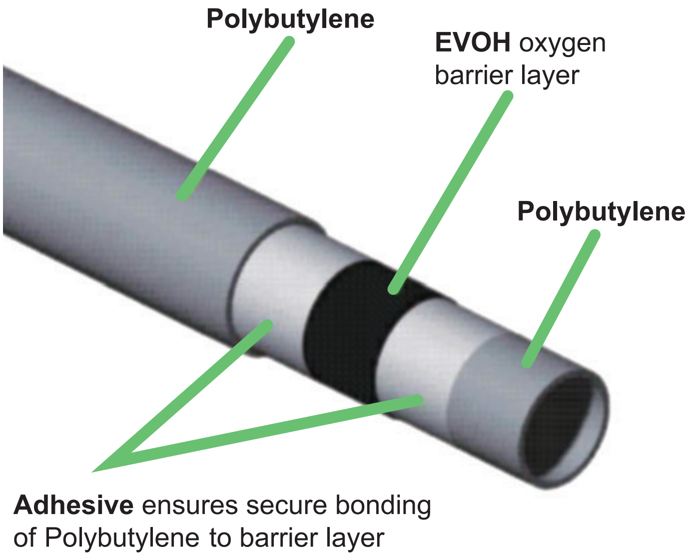
Environmental and Performance Characteristics of Polybutylene Pipe

PIPE USAGE

Polybutylene pipe is widely used for heating and plumbing applications in domestic, commercial and industrial properties. Its principal uses include hot and cold water services, central and underfloor heating installations. As property owners seek increasingly cost and energy efficient methods of controlling internal temperatures within buildings, it is also specified for combined underfloor heating and cooling systems and for embedded coil technologies where pipe systems are incorporated, during manufacture, in pre-cast/moulded wall or ceiling elements.

TYPES OF PIPE

Pipes used for hot and cold water services, often referred to as 'Standard' pipes, are normally single layer extrusions. For central and underfloor heating/cooling applications and embedded coil technology applications it is essential to specify a 'Barrier' pipe. Such pipes need to incorporate an internal oxygen barrier.



Oxygen barrier pipe is not required in potable water applications. Barrier pipes were originally introduced for central heating applications to comply with British Gas requirements. They are now also used in underfloor heating applications. Barrier pipe construction ensures that oxygen cannot permeate through the pipe wall over time and enter the circuit. The introduction of oxygen into the system could potentially contribute to corrosion within metallic parts of associated boilers and control manifolds.

Oxygen barrier layers should ideally be fully protected between the inner and outer pipe walls. Such designs are produced using a five layer co-extrusion process and advanced manufacturing technologies.

The adhesive used to secure the EVOH barrier is a non-soluble Polyolefin. The EVOH layer itself is affected by moisture and so is best positioned where it is fully protected from such exposure ie between the inner and outer pipe walls.

Where the EVOH layer is external it may be adversely affected either by condensation or by water from flowing screeds.

In combined heating and cooling systems it is essential to select a pipe that has an integral, fully protected internal barrier. This is because in cooling mode there is a possibility that misting will accrue on any exposed sections of pipework. Over time, it is thought that this could adversely affect an externally positioned barrier polymer.

It is thought the high moisture content of flowing screeds could also have a detrimental effect on external barriers.

Having the barrier layer located on the outer surface is also less desirable since the barrier may be susceptible to damage as a result of on site handling and installation. In the case of pipes containing aluminium, damage may expose the aluminium layer which could lead to cementatious attack.

CHARACTERISTICS

Polybutylene has an unrivalled balance of properties to satisfy the demands of the hot and cold pressurised water pipe market. The main aspects which distinguish it from other candidate materials are its flexibility and superior resistance to stress over long periods of time at high temperatures.

Flexibility is a key factor because it eases installation across a broad range of internal temperature conditions. The relative flexibility of different plastics is indicated by the table top right showing typical flexural elasticity values for different Polyolefin pipe materials.

Polybutylene is non-corrosive, resists frost damage and is unaffected by hard, soft or aggressive water conditions. It is creep resistant and offers high impact strength meaning that if it is 'crushed' on site - for example due to an operative walking over it - it will return to its original shape.

Relative Flexibility of Different Plastics

The lower the figure, the greater the flexibility.

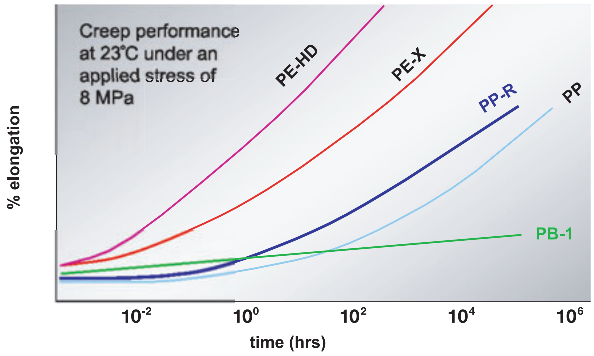
	Cross-linked Polyethylenes			PE-RT	PB
Cross-linking method	PE-Xa Engel Process	PE-Xb Silane Process	PE-Xc Irradiation		
Flexural Elasticity Modulus Method ISO 178	400	550	350	550	250

Polybutylene-1: Excellent Creep Resistance

Physical properties of Polybutylene are summarised in the following table.

The values shown are typical mid-range figures and should not be considered as a specification. (Several different grades of Polybutylene are produced with properties tailored to satisfy different application requirements.)

PB-1 deforms less over time under an applied stress



Pipe Fluid Mass Transfer Performance

Mass Transfer Performance is critical to system efficiency and the ability to select smaller pump sizes, with attendant energy savings.

	PB-1	PP-R	PE-X	PVC-C
Pipe OD, mm	40	40	40	40
Pipe ID, mm	32.6	26.6	29.0	31.0
Pipe wall thickness, mm	3.7	6.7	5.5	4.5
Standard Dimension Ratio (SDR)	11	6	7.3	9
Pipe inner section area, mm^2	835	556	661	755
Flow speed @ 2 litres/second, m/s	2.4	3.6	3.0	2.6
Pressure loss @ 2 litres/second, mbar/m	18	50	33	24

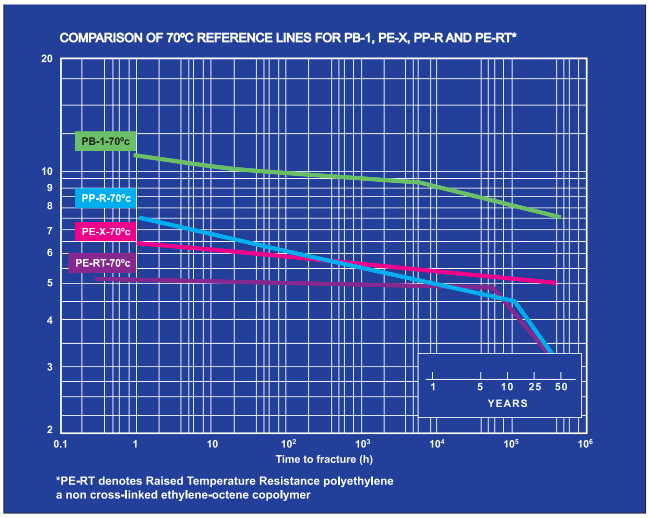
Material Properties	Method	Unit	Performance
Physical Properties			
Melt flow rate MRF 190°C/2.16 kg	ISO 1133	dg/min	0.4
Density	ISO 1183	g/cm^3	0.937
Hardness Shore D	ISO 8608	-	53
Mechanical Properties			
Tensile strength at yield	ISO R 527	MPa	20
Tensile strength at break	ISO R 527	MPa	35
Elongation at break	ISO R 527	%	300
Flexural Elastic Modulus	ISO 178	MPa	350
Notched Impact Strength at 20°C	ISO 180	kJ/m^2	no break
Notched Impact Strength at 0°C	ISO 180	kJ/m^2	40
Thermal Properties			
Melting point range	DSC[a]	°C	127 – 129
Vicat Softening Temperature	ISO 306	°C	113
Coefficient of linear thermal expansion	ASTM D696		1.3×10^{-4}
Thermal conductivity (20°C)	ASTM C 177		0.19
Glass transition temperature	DMTA[b]	°C	-18
Specific Characteristics			
Environmental Stress Cracking (at 50°C in 10% Igepal C0630 solution)		h	15,000 no failure
Wet abrasion (sand slurry test, 23°C, 100h)		%	1

PERFORMANCE RELATIVE TO ALTERNATIVE PLASTICS MATERIALS

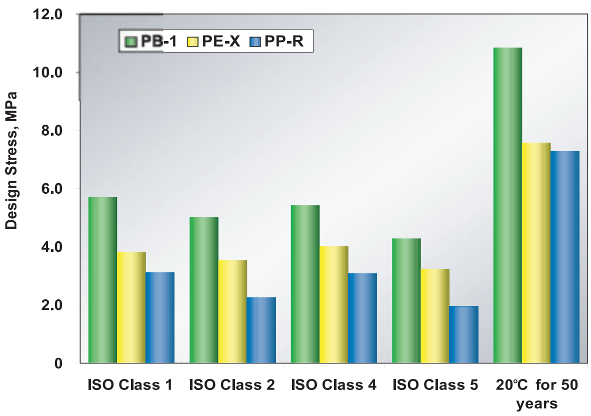
There are three piping systems standards:
ISO 15876 for Polybutylene
ISO 15875 for PE-X
ISO 15874 for the three types of Polypropylene.

The data presented in these standards provides a useful means of comparison of the performance of these three alternative plastic materials.

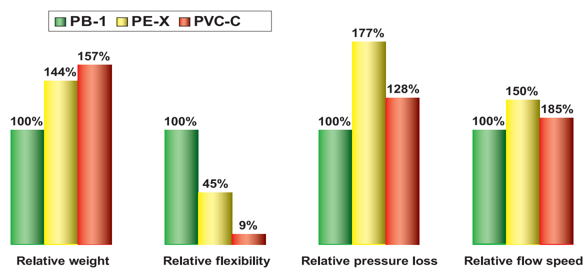
The following chart shows the performance of Polybutylene PE-X, PP-R and PE-RT at 70°C on an equivalent scale. After 10 years' exposure to continuously



Pressure Performance - PB-1 vs. PP-R vs. PE-X



PB-1, PE-X and PVC-C Compared



Pipes made from PB-1 have:

- Up to two-thirds the weight of PE-X & PVC-C
- Double the flexibility of PE-X; 10 times better than PVC-C
- Almost half the pressure loss of PE-X

Comparison of Polymers used in Plumbing

	PB-1	PP-R	PE-X	PVC-C
Impact Toughness	●●●	●●	●●●	●
Chemical Resistance	●●●	●●●	●●●	●●●
Flexibility	●●●●	●●	●●●	●
Creep Resistance	●●●●	●●	●●●	●●●
Thermal Pressure Resistance	●●●●	●●	●●●	●●●
CLTE-induced stress	●●●●	●●	●●●	●●

●●●● Excellent
●●● Good
●● Fair
● Poor

applied stress, Polybutylene retains 40% more strength than PE-X and almost double that of PP-R and PE-RT. There is no ISO standard dealing with the expected strength of PE-RT. The data presented in this chart was obtained from a published ISO 9080 evaluation of PE-RT.

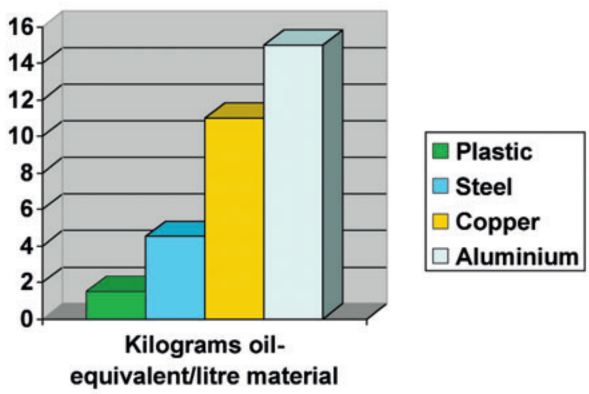
PROTECTING THE ENVIRONMENT

Manufacture & Energy Consumption

Polybutylene is produced from crude oil by refining and polymerisation. The polymer is extruded to create the finished pipe. Polybutylene pipe has markedly less embodied energy than many competing materials, by virtue of the ease with which raw materials can be transported and manufacturing efficiency. The environmental impact of the production process, in terms both of energy usage and emissions, is markedly less than is the case for alternative metal pipe systems and many other plastics.

For both metals and plastics the production of pipes and fittings involves raising the temperature of the raw materials above their melting/softening points. The temperatures involved, however, are much higher for metals in comparison with plastics, with consequential differences in energy usage.

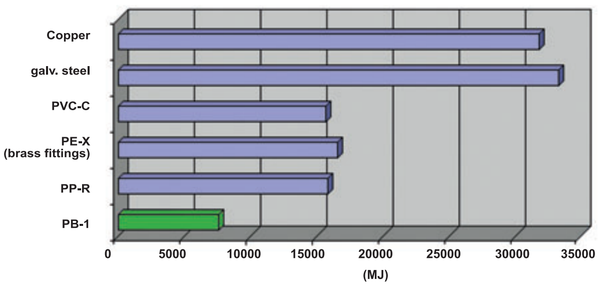
The amount of energy required to manufacture 1 cubic litre of material is indicated in the chart below, with comparisons for alternative metallic pipe materials.



The weight of a piping network is not considered to be a factor in building installations but it is important in assessing the overall energy efficiency of a piping system. Due to their much lighter weight, plastic materials exhibit a distinct advantage over metal pipes in this respect. The total energy consumption to manufacture metal pipes required for the piping system of, for instance, a 16-family housing complex is significantly higher than for plastic pipes.

The following figure shows the energy equivalent value, which takes into account the total weight and the associated energy consumed in producing the complete piping network in each of the different materials.

Energy Equivalent Value of the Complete Piping System for a 16-Family Housing Complex



Standards Compliance
The standards adopted by manufacturers vary.

Hep$_2$O® Underfloor Heating Pipe is covered by British Board of Agrément Certificate 92/2823.

Hep$_2$O® is manufactured within a Quality Management System, which satisfies BS EN ISO 9001 requirements.

Hep$_2$O® is manufactured in accordance with ISO 14001: 1996 to prevent pollution and reduce the adverse impact of activities on land, air, water, property and the public.

FM 01415

EMS 77364
EMS 82340

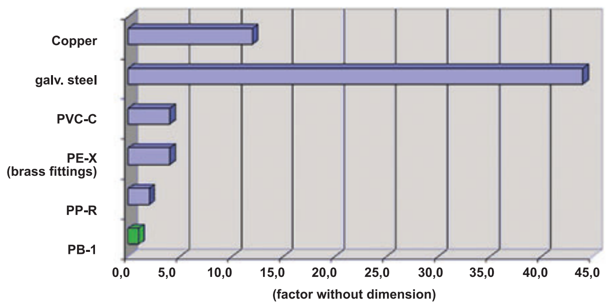
Environmental Impact
Comparisons between Polybutylene and other materials used for pipe manufacture indicate that plastics such as Polybutylene have markedly less environmental impact, in terms of pollution.

To quantify the environmental impact of emissions, the Technical University of Berlin developed a standardised comparison method referred to as VENOB (Vergleichende Normierende Bewertung). This environmental analysis compares energy consumption in relation to emissions in air, water and soil during each stage from raw material sourcing to the installation of a piping system. The University evaluated six different materials used for drinking water pipe installations according to DIN 1988 part 3 on the basis of a 16-family housing complex with central hot and cold water distribution at 4 bar pressure.

The following charts illustrate the standardised comparison (VENOB) of the various pipe materials' impact on the environment. (The lower the figures, the less the environmental impact.)

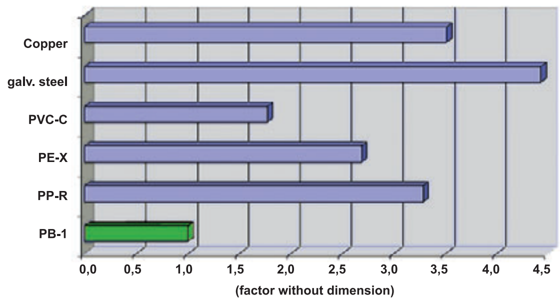
Soil Pollution

Standardised Comparison (VENOB) of Various Pipe Materials Impact on the Environment – Emissions in Soil



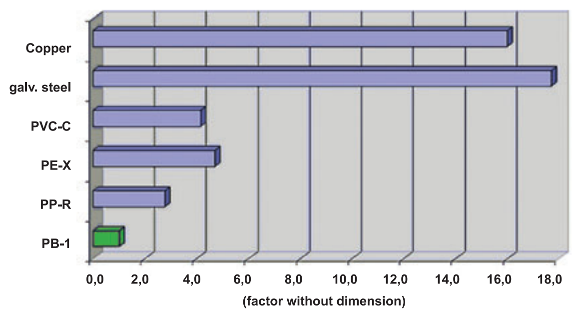
Water Pollution

Standardised Comparison (VENOB) of Various Pipe Materials Impact on the Environment – Emissions in Water



Air Pollution

Standardised Comparison (VENOB) of Various Pipe Materials Impact on the Environment – Emissions in Air



INSTALLATION

Polybutylene flexibility assists in routing pipe runs through and around building elements. In underfloor heating applications this feature is of importance in easing the installation of heating circuits in concrete, timber and suspended floors. Pipe flexibility is even more important in heating and cooling projects as it allows sufficient pipework to be installed to meet the design criteria and the performance requirements applicable.

Site Safety

Health and safety are key concerns in all construction projects. Pipe flexibility contributes to the maintenance of safety standards. This is particularly the case in underfloor heating applications. This is because Polybutylene can readily be handled and laid in a wide range of temperatures. This is in contrast to some other materials (eg Cross-linked Polyethylene), which can require to be pre-tempered prior to laying. This calls for the use of boilers on site and the circulation of hot water through pipe before it is clipped into position. Associated safety risks include exposure to water at high temperatures and the handling of pipes made heavy by the water circulating through them.

Pipe Jointing

In hot and cold water services applications, pipe is jointed by means of advanced technology, push-fit joints which provide exceptional joint security.

The use of joints in underfloor heating systems, however, should be avoided and underfloor heating industry guidelines and industry best practice advise against joints in the floor. However, in circumstances where site damage has occurred, Polybutylene pipe systems can be fusion welded to create a joint with the same performance characteristics as the pipe. (This is not possible with Cross-linked Polyethylene.)

Whether in heating only or heating and cooling applications, it is bad practice to use mechanical type manipulative fittings in a repair situation (or general installation) as this may compromise the integrity of the pipe system due to differential thermal expansion over a long period of time. Fusion welded Polybutylene joints do not suffer from expansion problems as the fusion weld maintains the molecular integrity of PB.

Metal or multi-material fittings can also suffer from cementatious attack within the screed or, within the structural slab, which will require extensive remedial work to correct.

It is imperative not to put a joint in any building element that is inaccessible ie structural slab, post tensioned floor or below reinforced floor etc.

PERFORMANCE IN SITU

The performance of Polybutylene pipe has been proven through long-standing, trouble-free service in applications worldwide. Polybutylene has been used successfully in pipe applications for over 30 years. In Austria and Germany, district heating and underfloor heating schemes of the early 1970s are still offering trouble-free operation.

Since the first installations, advances in both material technology and production processes, combined with the introduction of stringent standards, have further enhanced the performance of Polybutylene piping systems.

International standard protocols now specify a minimum performance for Polybutylene hot water pipes of 70°C, 10 bar pressure, for 50 years.

Product Warranty

Product warranties vary according to manufacture. Warranties up to 50 years are available on Polybutylene pipes, reflecting their proven long-term performance even in the most arduous applications.

RECYCLING

Recycling of Polybutylene is possible because the molecular structure of the material is not altered by the production process. This is in contrast to some alternative materials where the manufacturing process alters the chemical structure of the plastic, making it impossible to retrieve the original molecular state.

Therefore, should the requirement arise, Polybutylene pipe can be recycled and converted back into granular form ready for re-use in the production of other plastics-based products. This type of recycling is not possible with other plastics materials such as Cross-linked Polyethylene and multi-layer pipe.

The manufacturing processes of both extrusion (pipe) and injection moulding (fittings) are managed to minimise waste. ISO 15876 and British Standard BS 7291 allow the use of manufacturers' own reprocessable material in the manufacture of Polybutylene pipes or of associated Polybutylene fittings. This must be compiled of manufacturer's own clean reworked material and be of the same grade as any material to which it is added. No other rework material is permissible. Production waste can be re-granulated and used for the manufacture of 'lower' specification products.

The incineration of Polybutylene does not produce any harmful by-products. Incineration plants recover heat energy produced from the burning of waste. The recoverable heat energy of Polybutylene is identical to that of heating oil (44000 kJ/kg) and significantly better than coal.

Polybutylene does not produce toxic or corrosive gases.

POLYBUTYLENE FEATURES SUMMARY

Features and Benefits of Polybutylene	Physiologically safe – will not taint water
Standard and barrier pipes available	Minimal internal resistance reducing hydraulic pumping head
High flexibility even at very low temperatures	Safe installation procedures – no requirement for pre-tempering of pipe
Resistant to stress	Pipes can be fusion welded, if required
Non-corrosive	No flame, specialist tools or chemicals required during installation therefore no risk to installers
Resistant to frost damage	50 year warranty
Inert to water hardness/softness	Readily recycled
Unaffected by chemical inhibitors	Recycled material has same recoverable heat energy as heating oil
Pipework does not encourage micro biological growth	Does not produce toxic or corrosive gases when burnt
High impact strength	Proven in installations since the 1970s and on many high profile construction projects
Creep resistant	Suitable for heating and cooling applications
Fully protected internal barrier	No intrinsic resale value
Low energy consumption in manufacture	Multitude of coil lengths for economical installation with minimal waste
Produced in compliance with ISO 14001	Size and type of coil specifically engineered for embedded coil technology
Low environmental impact in terms of soil, water and air pollution	UK manufacture, reducing whole life cost due to transportation

PROJECT LIST

Polybutylene pipe systems have been used in many of the world's most prestigious buildings, as well as numerous commercial, industrial and domestic properties.

A380 Airbus wing factory
British Museum
Canary Wharf
Imperial War Museum of the North
Portcullis House
Scottish Parliament
Welsh Assembly

They are extensively used in hospital and healthcare environments and widely specified for local authority, government and defence-related property developments.

They are a preferred form of heating in many educational establishments and over 400 schools in the UK now benefit from underfloor heating installations utilising Polybutylene pipe systems.

Thousands of commercial and industrial developments, from prestige office developments to warehouses and production facilities, achieve high levels of comfort, combined with significant energy savings, as a result of specifying underfloor heating.

INFORMATION SOURCES:

Basell Polyolefins
Hepworth Plumbing Products
Polybutene Piping Systems Association
Structural Conditioning
Technical University of Berlin
Warmafloor

Warmafloor (GB) Ltd Underfloor heating and cooling specialists Tel: 01489 581787 www.warmafloor.co.uk