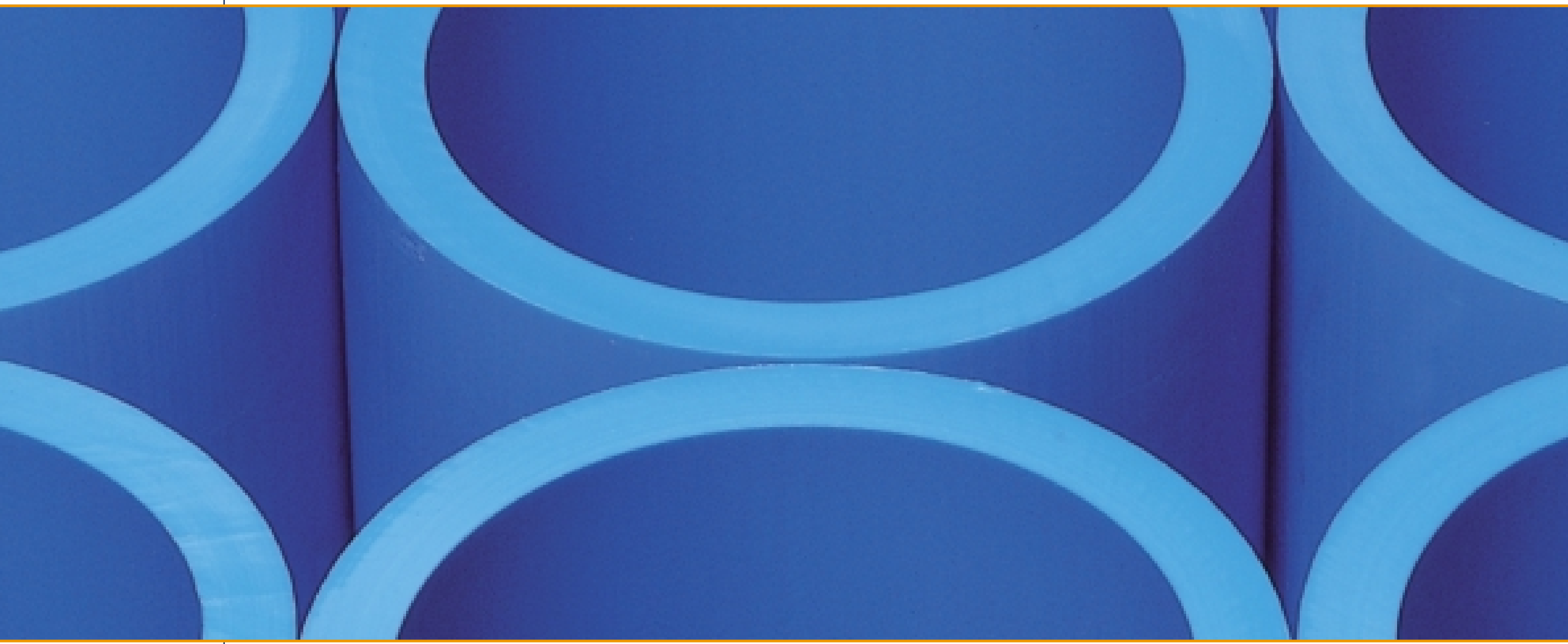
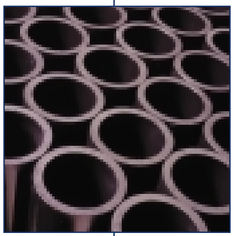
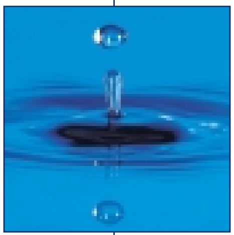
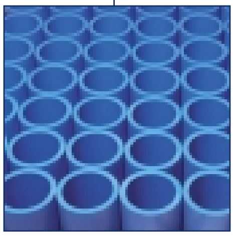




Polyethylene Water Systems Technical Guide





Technical Guide Content

Welcome to Wavin

Wavin Plastics Limited is part of the 1.7 billion (NLG) Wavin Group of companies. As a group, Wavin operates in twenty-six countries, making it one of the largest converters of plastic, the largest manufacturer of plastic pipe systems and the largest industrial re-cycler of plastics world-wide. UK Headquarters are located in Chippenham, where Wavin Plastics Limited is the leading plastics pipe systems manufacturer for the Building, Utility and Civil markets.

Flying the flag in Europe

Wavin was founded in 1955 by Johann Keller, Managing director of the Overijssel Water Company. Today the Wavin Group employs over 4500 people in 26 countries in Europe and South East Asia and works closely with over 40 licensees all over the world including Japan, the United States and South America.

Wavin Plastics occupies a 26-acre site on the outskirts of Durham City, employing over 140 people in the production of polyethylene and PVC-u pipe systems for the UK water industry, the agricultural market and the world-wide gas market.

Wavin Plastics pursues a policy of continuous development and investment. This has resulted in a major re-organisation of the manufacturing site, which now houses what is almost certainly the longest, most modern and technologically advanced polyethylene plant in Europe. This enables Wavin Plastics to offer pipe in long straight lengths up to 18 metres, as well as coils and drums up to 770 metres in length. With an investment of 1.4 million, the new layout incorporates the latest equipment from material conveying through extrusion to finished product handling, storage and despatch. In addition to the facilities at Brandon, applied research, technical support and product development are undertaken at the Wavin Advanced Centre for Research and Development in Holland.

Polyethylene Systems

Polyethylene pipe systems offer the water engineer many benefits:-

- Cost Saving with faster, easier installation
- Limited or no dig installation
- Maintenance free design life
- Corrosion resistance
- Suitability for renovation, lining and insertion
- No requirement for end load restraint for fusion welded systems
- Fully fused jointing ensuring water-tight system
- Flexibility, allowing for ground movement

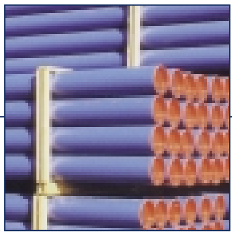
Wavin offers a choice of two materials:-

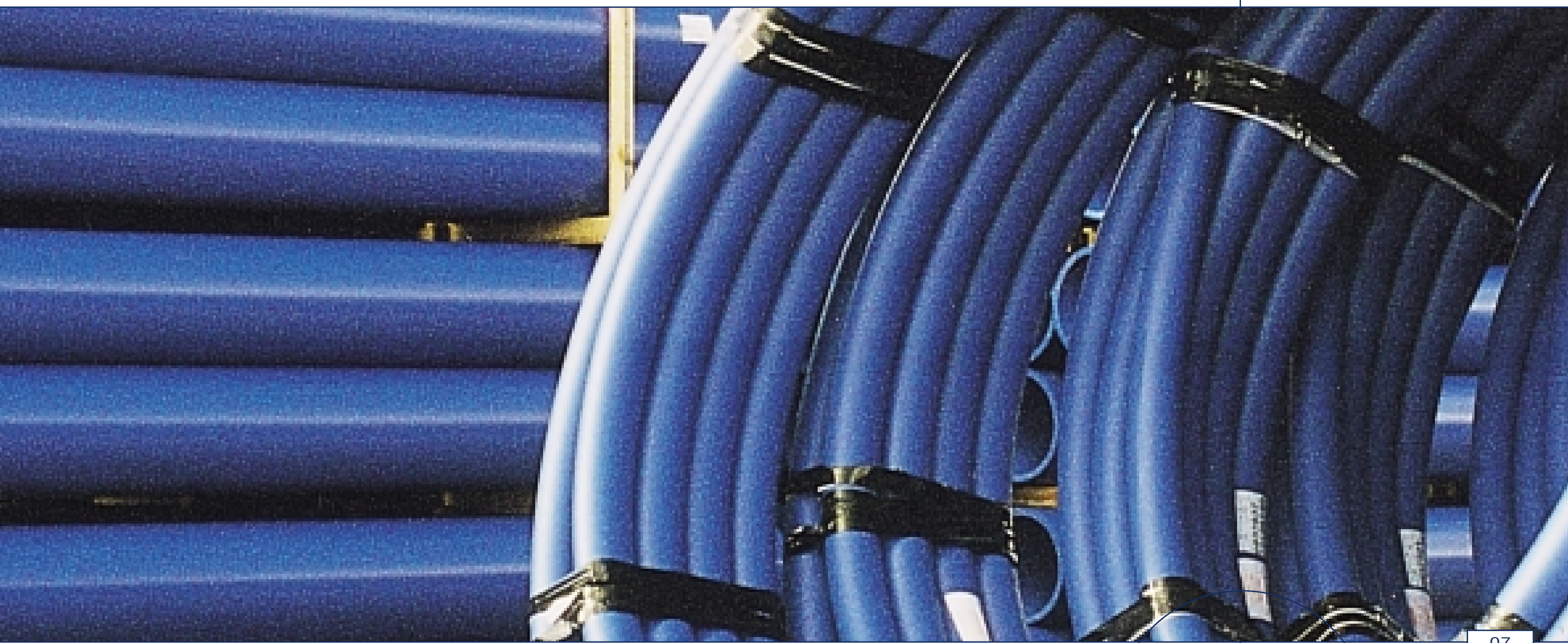
Medium density polyethylene (MDPE)

Medium Density Polyethylene (MDPE) with a strength classification, PE80, which refers to a pipe which has a minimum 50 years strength of 8Mpa. This enables operation at pressures up to 12.5 bar for an SDR 11 pipe, 8 bar for an SDR 17 pipe.

High performance polyethylene (HPPE)

High Performance Polyethylene (HPPE) with a strength classification, PE100, which refers to a pipe which has a minimum 50 years strength of 10Mpa. This enables operation at pressures up to 16 bar for an SDR 11 pipe or 10 bar for an SDR 17 pipe. Further details on the properties of these materials are given in the Design and Performance section of this guide.





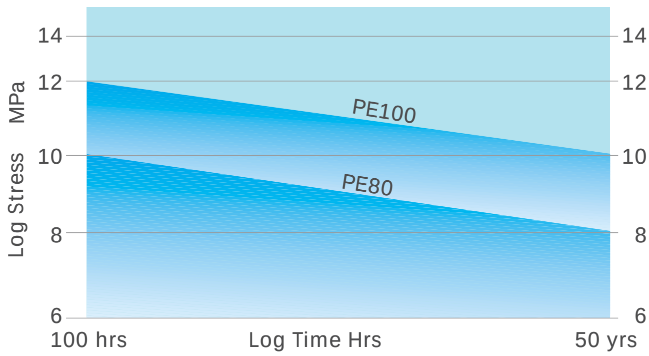


Figure 1. Material Classification

Polyethylene Systems

WavinSure
MDPE (PE80)

The WavinSure system is a range of blue MDPE (PE80) pipe and fittings suitable for use with below ground potable water.

The system meets the requirements of BS 6572: 1985 for sizes up to and including 63mm, for use at pressures up to 12 bar. Sizes 90mm and above meet the requirements of WIS 4-32-17 (pipe), 4-32-14 and 4-32-15 (fittings). This system allows for use at pressures up to 12.5 bar.

Details of the product range can be found in the Wavin Polyethylene Potable Water Systems Product Selector.

Wavin SupaSure
HPPE (PE100)

The Wavin SupaSure system is a range of blue HPPE (PE100) pipe and fittings suitable for use with below ground potable water.

The system meets the requirements of WIS 4-32-17 (pipe), 4-32-14 and 4-32-15 (fittings).

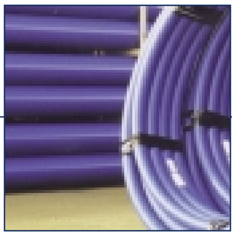
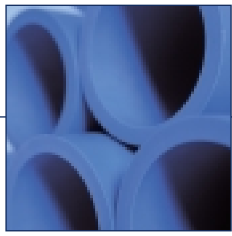
The material’s higher performance characteristics enable pipe systems to operate at pressures up to 16 bar.

Wavin TS
HPPE (PE100)

The Wavin TS system is a co-extruded 2 layer pipe which has an exterior layer of extremely tough polymer and an inner layer of standard PE100 material.

The system meets the requirements of WIS 4-32-17, for use at pressures up to 16 bar.

Wavin TS’ superior performance characteristics provides greater security against abrasion, notches and scoring when used in adverse installation conditions.

WavinBlack
MDPE (PE80)

The WavinBlack system is a range of black MDPE (PE80) pipe and fittings suitable for use with above ground potable and below ground non potable water.

The system meets the requirements of BS 6730: 1986 for sizes up to and including 63mm, for use at pressures up to 12 bar. Sizes 90mm and above meet the requirements of WIS 4-32-17 (pipe), 4-32-14 and 4-32-15 (fittings). This system allows for use at pressures up to 12.5 bar.

WavinJet
HPPE (PE100)

The WavinJet system is a range of black HPPE (PE100) pipe and fittings suitable for use with above ground potable and below ground non potable water.

The system meets the performance requirements of WIS 4-32-17, 4-32-14 and 4-32-15 (fittings).

The material’s higher performance characteristics enable pipe systems to operate at pressures up to 16 bar.

Details of the full product range can be obtained from the Wavin Sales Office.

Quality Control

All Wavin products are manufactured and tested under a Quality Management System that is third party certificated by the British Standards Institution against the requirements of BS EN ISO 9002 : 1994.
Wavin Plastics Ltd. is a firm of assessed capability under the British Standard Institution (BSI) scheme (Registration Number FM 00217) for the manufacture and supply of pipe and fittings conforming to the Water Research Centre (WRc) Engineering Specifications.

The Registered Firm Approval covers the manufacture and supply against the following specifications:

WIS 4-32-03
Specification for blue polyethylene (PE80) pressure pipe for cold potable water nominal sizes 90mm to 1000mm for underground or protected use.

WIS 4-32-09
Specification for black polyethylene (PE80) pressure pipe for cold potable water or sewerage, nominal sizes 90mm to 1000mm for above ground use.

WIS 4-32-13
Specification for blue higher performance polyethylene (PE100) pressure pipe, nominal sizes 90mm to 1000mm for underground or protected use for the conveyance of water intended for human consumption.

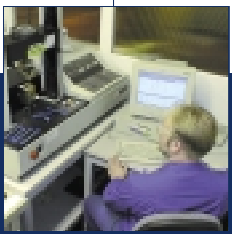
WIS 4-32-14
Specification for PE80 and PE100 electrofusion fittings for nominal sizes up to and including 630mm.

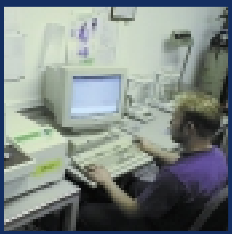
WIS 4-32-15
Specification for PE80 and PE100 spigot fittings and drawn bends for nominal sizes up to and including 1000mm.

WIS 4-32-17
Specification for PE80 and PE100 blue and black polyethylene pressure pipes, nominal sizes 20mm to 630mm for pressurised water supply and sewerage duties.

Wavin also manufacture blue polyethylene pipes up to nominal size 63mm for below ground use for potable water to BS 6572 : 1985 under a Kitemark Licence issued by BSI.

Black polyethylene pipes up to nominal size 63mm for above ground use for cold potable water are manufactured to BS 6730 : 1986 under a Kitemark Licence issued by BSI.





Wavin operate a policy of continuous improvement. Additional approvals, therefore, may be added to those detailed. Up to date information is always available from the Technical Services Helpdesk.

Wavin has continually maintained a commitment to quality and currently holds BSI Kitemark Licences for the following products:

BS 4962 : 1989
Plastic pipes and fittings for use as subsoil field drains.

BS 5255 : 1989
Thermoplastic waste pipe and fittings.

BS EN 1401-1 : 1998
PVC-u pipe systems for non pressure underground drainage and sewerage.

BS EN 7291 Parts 1&2 : 1990
Thermoplastic pipes and fittings for hot and cold water for domestic supply.

WIS 4-31-08 : 2001
Oriented Polyvinyl Chloride (PVC-0) pressure pipes for underground use.

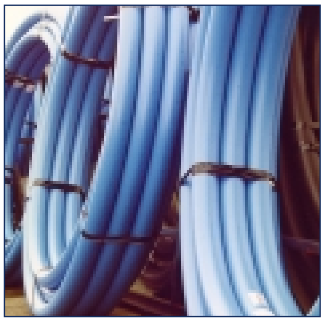
Additionally Wavin have supplied polyethylene pipe and fittings to British Gas since 1975 and have maintained their approval status up to and including 500mm SDR 11 pipe in PE80 and PE100.

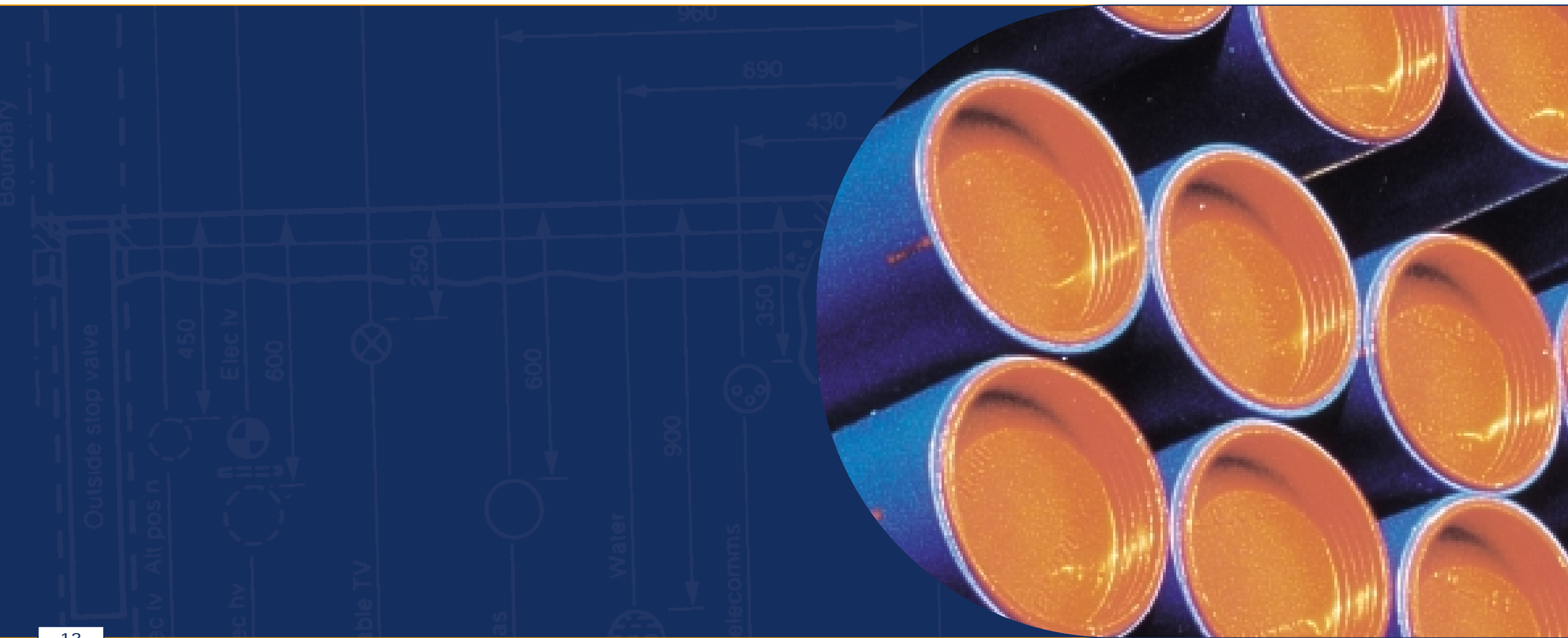
Product Details

Wavin Polyethylene Pipe Systems are manufactured from PE80, commonly known as Medium Density Polyethylene (MDPE) and PE100, High Performance Polyethylene (HPPE) and can be used for both pressure and non-pressure applications. Wavin have been manufacturing polyethylene pipe systems since the early 1970's and since then have been at the forefront of materials and manufacturing technology. This has resulted in Wavin becoming the leading plastics manufacturer in Europe.

Polyethylene is now an established pipeline material for water, gas and industrial uses and provides a cost effective, reliable pipe system with excellent properties such as corrosion resistance, chemical resistance and flexibility.

Wavin Polyethylene Pipe Systems are available for numerous applications and are colour coded, following NJUG guidelines for each specific use.





Pipe Diameter (mm)	Nominal Bore (ID) mm – SDR 11	17	21	26
20	15.25	•	•	•
25	20.3	•	•	•
32	25.8	•	•	•
50	40.4	•	•	•
63	50.9	•	•	•
90	72.9	78.7	81.0	•
110	89.1	96.3	99.0	•
125	101.2	109.5	112.5	•
160	129.6	140.3	144.0	147.4
180	145.9	158.0	161.9	165.8
225	182.4	197.3	202.4	207.4
250	202.8	219.6	224.9	230.4
280	227.1	245.9	251.9	258.0
315	255.6	276.6	283.4	290.3
355	288.1	311.5	319.4	327.6
400	324.6	351.2	360.0	368.7
450	360.1	395.2	404.9	414.8
500	406.3	438.9	449.9	460.9
560	454.7	493.9	503.7	516.3
630	511.5	553.1	566.8	580.8

Figure 2. Pipe Dimensions.

- **Light Blue/Dark Blue**
  Below ground potable water pipework
- **Black**
  Below ground pressure and non-pressure foul water pipework

  Above ground potable water pipework

  Above ground industrial pipework
- **Yellow**
  Below ground gas systems, up to 5.5 bar
- **Orange**
  Below ground gas systems, up to 7 bar

Pipe Marking

All Wavin Polyethylene pipe products are marked for traceability in accordance with National or International Standards and the following information is repeated at metre intervals along the pipe.

Pipe Marking Details:

- Date of manufacture
- Machine No.
- Pipe Diameter
- Shift No.
- Product Standard
- Company Identification
- Material Grade
- Sequential metre marking
- SDR
- Nominal Pressure rating

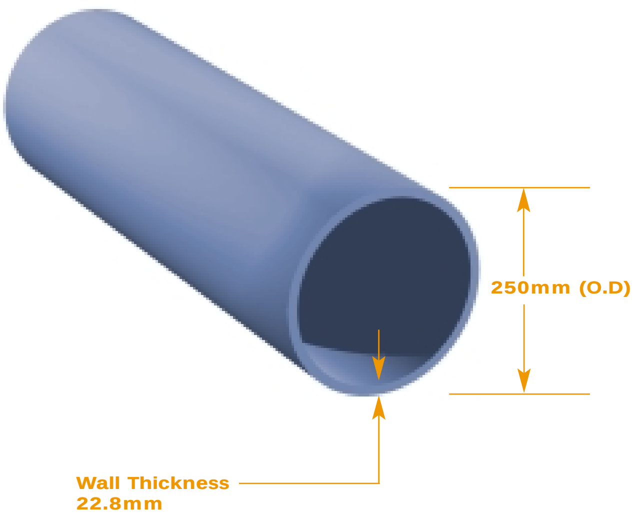


Figure 3. SDR - Relationship between pipe O.D. and wall thickness.

Standard Dimensional Ratio (SDR)

The Standard Dimensional Ratio (SDR) is used to describe the relationship between pipe diameter, wall thickness and therefore the pressure rating of the pipe.

The relationship between the pipe OD and wall thickness remains constant for all pipe sizes for a given pressure rating, and can be expressed in the following equation.

$$SDR = \frac{\text{Pipe Outside Diameter (Minimum)}}{\text{Pipe Wall Thickness (Minimum)}}$$

$$\text{eg: } SDR\ 11 = \frac{250}{22.8}$$

Characteristics & Properties

PROPERTY	UNITS	PE80	PE100
Density	Kg/M^3	Blue 944 Black 949	Blue 950 Black 959
Poisons Ratio	–	0.4	0.4
Melt Flow Rate @ 2.16 Kg Load @ 5 Kg Load	 g/10 min g/10 min	 0.2 1.0	 <0.15 <0.5
Tensile Strength @ Yield	MPa	18	23
% Elongation @ Break	%	>600	>600
Modulus of Elasticity	MPa	700	1000
Softening Point Brittleness Temp	°C °C	116 <-70	124 <-100
Coefficient of Linear Expansion	$°C^{-1}$	1.5×10^{-4}	1.3×10^{-4}
Thermal Conductivity	W/M °C	0.4	0.4

Figure 4. Material Properties Table.

Weather Resistance

Polyethylene is a tough material and generally is resistant to the effects of the UK climate. WavinBlack PE systems are manufactured with a carbon black additive which gives full protection against UV radiation and is therefore perfectly suitable for use above ground.

WavinSure PE systems for below ground water use are intended for short term above ground storage only and should not be stored in excess of 12 months, unless specific protection is provided. For further information please refer to the Handling and Storage section of this guide.

Abrasion Resistance

Polyethylene has an extremely low co-efficient of friction and therefore has significant advantages over other pipe materials for the transportation of abrasive slurries and in its resistance to abrasion.

WavinBlack polyethylene pipe has been used extensively for pumped slurry applications over many years and has been used for power station fly ash, china clay slurry, quarries and sand slurries. Field use and laboratory testing has shown that the performance of PE exceeds metallic pipe systems. This coupled with its flexibility, lightweight and ease of installation makes it the ideal choice for abrasive slurry applications.

The external effects of abrasive backfill materials have only a negligible effect on PE. Where pipe has been damaged by a sharp object and the cut or gouge exceeds 10% of the pipe wall thickness, the damaged section should be cut out and replaced. For further advice contact the Wavin Technical Services Helpdesk.

Low Temperature Usage

Site practices in the UK do not generally allow pipe laying to continue below 0˚C, however there may be instances during installation or pipeline operation where temperatures below 0˚C are encountered.

The mechanical properties of PE, operating pressure and impact resistance are maintained at temperatures as low as -60˚C and therefore the moderate UK winter temperatures do not pose any particular problems to the performance of PE pipe.

Polyethylene is a particularly low thermal conductor and will delay the freezing of water within the pipe. Where the water does become frozen, the flexibility of PE and its ability to expand without rupture ensures the security of the pipeline.

Expansion & Contraction

Polyethylene has a co-efficient of linear expansion of approximately 1.5 x 10 -4˚C -1 which is approximately 10 times greater than metallic pipes. Expansion is an important factor which should therefore be considered in the design of pipelines where a significant variation in temperature is expected, particularly above ground pipework.

For design purposes pipe expansion can be more practically understood if we consider the expansion as 1.5mm/10˚C/ m. In above ground installations careful consideration should be given to the positioning of support brackets and anchor points and the use of fully end load bearing joints. Where possible expansion and contraction may be accommodated at changes of direction. Where non-end load bearing fittings are used it is important that such fittings are securely anchored to prevent pipe pullout.

With below ground installations new pipelines should be allowed to stabilise to ambient temperatures before making the final tie-in connections, partial backfilling of the pipe will assist in minimising the effects of direct sunlight.

PIPE EXPANSION/CONTRACTION (mm)						
PIPE LENGTH (M)	5˚c	10˚c	15˚c	20˚c	30˚c	40˚c
1	0.75	1.5	2.25	3.0	4.5	6.0
2	1.50	3.0	4.50	6.0	9.0	12.0
5	3.75	7.5	11.25	15.0	22.5	30.0
8	6.0	12.0	18.0	24.0	36.0	48.0
10	7.50	15.0	22.5	30.0	45.0	60.0
15	11.25	22.50	33.75	45.0	67.5	90.0
20	15.0	30.0	45.0	60.0	90.0	120.0
50	37.5	75.0	112.5	150.0	225.0	300.0
75	56.25	112.5	168.75	225.0	337.5	450.0
100	75.0	150.0	225.0	300.0	450.0	600.0
150	112.50	125.0	337.5	450.0	675.0	900.0
200	150.0	300.0	450.0	600.0	900.0	1200.0

Figure 5. The expansion and contraction of PE pipe in mm for a temperature variation range over pipe lengths up to 200 metres.

Chemical Resistance

The exceptional resistance of PE to chemical attack is well known and generally there are no naturally occurring ground conditions which affect the material.

Polyethylene does not corrode, rot, pit or lose its mechanical strength properties through electrical or chemical reactions with backfill soils.

Polyethylene does not, under normal operating conditions, support the microbiological growth of algae, bacteria or fungi, nor is it affected by these conditions.

Polyethylene may be affected by certain chemicals and care must be exercised when considering re-development of old industrial brownfield sites.

Where soil conditions are unknown or known to be harmful, a soils analysis should be carried out to determine any likely contaminants.
The harmful chemicals can be grouped into 3 main types:

- Oxidisers, eg very strong acids
- Cracking Agents, eg detergents
- Solvents, eg hydrocarbons (petrol, oil)

The degree of resistance to any chemical is dependent on concentration, temperature and the working pressure, all of which may have an effect on the lifetime of the pipeline.
The effects may be detrimental to the pipes strength or permeate the pipe wall causing tainting of the potable water supplies.

Where pipework is to be laid in suspect conditions, eg: brownfield sites and petrol forecourts, expert advice should be sought before installing polyethylene. If conditions are such that the use of polyethylene would not be suitable, Wavin have developed ‘Trigon’ – a multi-layered barrier pipe specifically for carrying potable water through contaminated land. The Wavin Trigon system consists of three layers; an inner polyethylene core pipe which is approved for transporting potable water, followed by a layer of aluminium which acts as a barrier, and an outer sheath of polyethylene which is marked with distinctive brown stripes for easy identification.

Please contact the Wavin Technical Services Helpdesk for any further information.

Characteristics & Properties

Pressure Rating

MDPE (PE80) has a minimum required strength (MRS) derived from a 50 year extrapolated 97.5% lower confidence limit of 8 MPa and HPPE (PE100) has a MRS of 10 MPa. The Hydrostatic Design stress for both materials is determined by applying a safety factor of 1.25. The design life for the Water Industry requires a minimum life of 50 years, therefore the design stress for PE80 and PE100 is as follows:

PE80 = 5 MPa
PE100 = 8 MPa

Polyethylene pipe pressure rating is generally referred to in bar; 1 bar is approximately equivalent to 10.2 metre head. A harmonised UK Polyethylene Pressure Pipe specification has been developed alongside ISO/CEN working groups. The table below gives the pressure ratings and SDR's for PE80 and PE100 pipe.

DIAMETER	PE80 SDR	PE80 MAX WORKING PRESSURE (BAR)	PE100 SDR	PE100 MAX WORKING PRESSURE (BAR)
20(mm)	9	12.5	•	•
25-63(mm)	11	12.5	•	•
90-315(mm)	11	12.5	11	16
	17.0	8	17.0	10
	26	5	26	6
355-630(mm)	11	11.5 – 8	11	16
	17.0	8 – 5	17.0	10
	26	5 – 3.5	26	6

Figure 6. Pressure Rating

Electrolytic Reaction/ Electrical Conduction

Polyethylene is a poor conductor of electricity and does not suffer from electrolytic corrosion when in contact with metal components (valves etc) or when connected into existing metal pipelines.

As a non-conducting material PE should not be used for the earthing of electrical equipment nor can it be used as a conductor for frost protection systems. Similarly PE should not be used where there are high levels of static electricity, eg. in mines.

Permeability

Polyethylene under normal operating conditions is impermeable to gas and is used almost exclusively for Natural Gas and LPG gas systems. PE pipework for potable water can be laid in close proximity to PE gas mains following the NJUG recommendations for pipe separation distances. The presence of naturally occurring gas, such as is found in landfill sites, similarly has no effect on PE pipework.

Rapid Crack Propagation

PE80 and PE100 polyethylene materials are very tough and it is difficult to initiate brittle failure, even in the laboratory on pipework at very low temperatures. Failure is typically of a ductile nature and extensive testing has shown RCP failure will not occur in a pipeline full of liquid. Only when air is present at levels greater than 10% is RCP likely, and with modern PE materials any crack is arrested very quickly.

Therefore under normal distribution mains conditions, RCP failure is most unlikely. For further information contact the Wavin Technical Services Helpdesk.

Notch Sensitivity

Polyethylene is known to be extremely durable in normal use and it is not uncommon for pipes to be scratched and scuffed during handling and installation, particularly with re-habilitation methods such as slip lining and mains bursting.

This sort of typical site damage will have no adverse long-term effect on the pipe provided the damage does not exceed 10% pipe wall thickness. If the damage is greater than 10% the pipe should not be used. Further details on Rapid Crack Propagation and Notch Sensitivity can be found in the Design and Performance section of this guide.

Operational Pressures for Elevated Temperature Use

Polyethylene is a thermoplastic material and a loss in strength occurs with increasing temperature. The maximum operating pressure for any specific pipe is based upon a 50 year design life at 20˚C. Any increase above 20˚C will result in a reduction in the maximum allowable operating pressure or lifetime or possibly both. Polyethylene pipe systems should not be operated above 60˚C. The following chart gives the reduction factors to be applied to the maximum operating pressures at 20˚C.

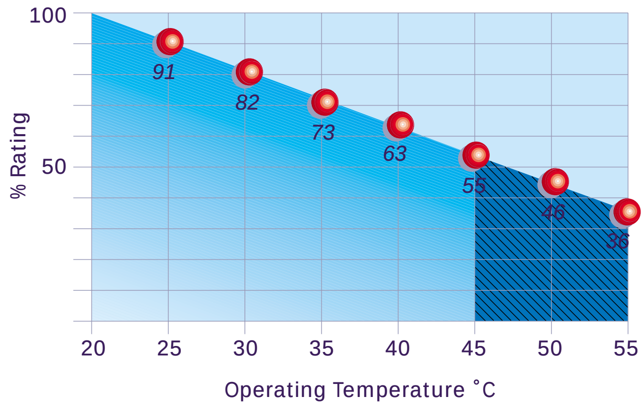


Figure 7. Pressure Reduction Factors for PE Pipe at Elevated Temperatures
If the temperature falls within this range the life expectancy of the pipe can be affected.
Please contact the Wavin Technical Services Helpdesk for further details.

Hydraulic Properties

Polyethylene pipe has an extremely smooth bore giving exceptionally good flow characteristics. As polyethylene is non-corrosive and maintains its smooth bore throughout its lifetime there is no deterioration in its hydraulic performance.

Polyethylene pipe is classed as hydraulically smooth and the hydraulic frictional co-efficients used for design purposes are as follows:

- Colebrooke - White Ks 0.003 mm
- Hazen Williams C = 150

All pipelines carrying water or slurries will see pressure losses due to the friction between the liquid and pipe wall. These are general losses due to fluid flow. In addition there are point losses caused by fittings in the system.

Flow Calculations

Pipe sizing and pressure drop can be determined using the Flow Charts overleaf. These are based on the Colebrook - White Formula. Using the required design flow rate (l/sec) the following data can be determined:

- Pipe Diameter (mm)
- Frictional Head Loss (m/1000 metres)
- Flow Velocity (m/sec)

Fittings Formula

Determining the pressure drop in fittings is more complex. However, using a simple formula to give an equivalent increase in pipe length, pressure drop can be carried out using the following formula;

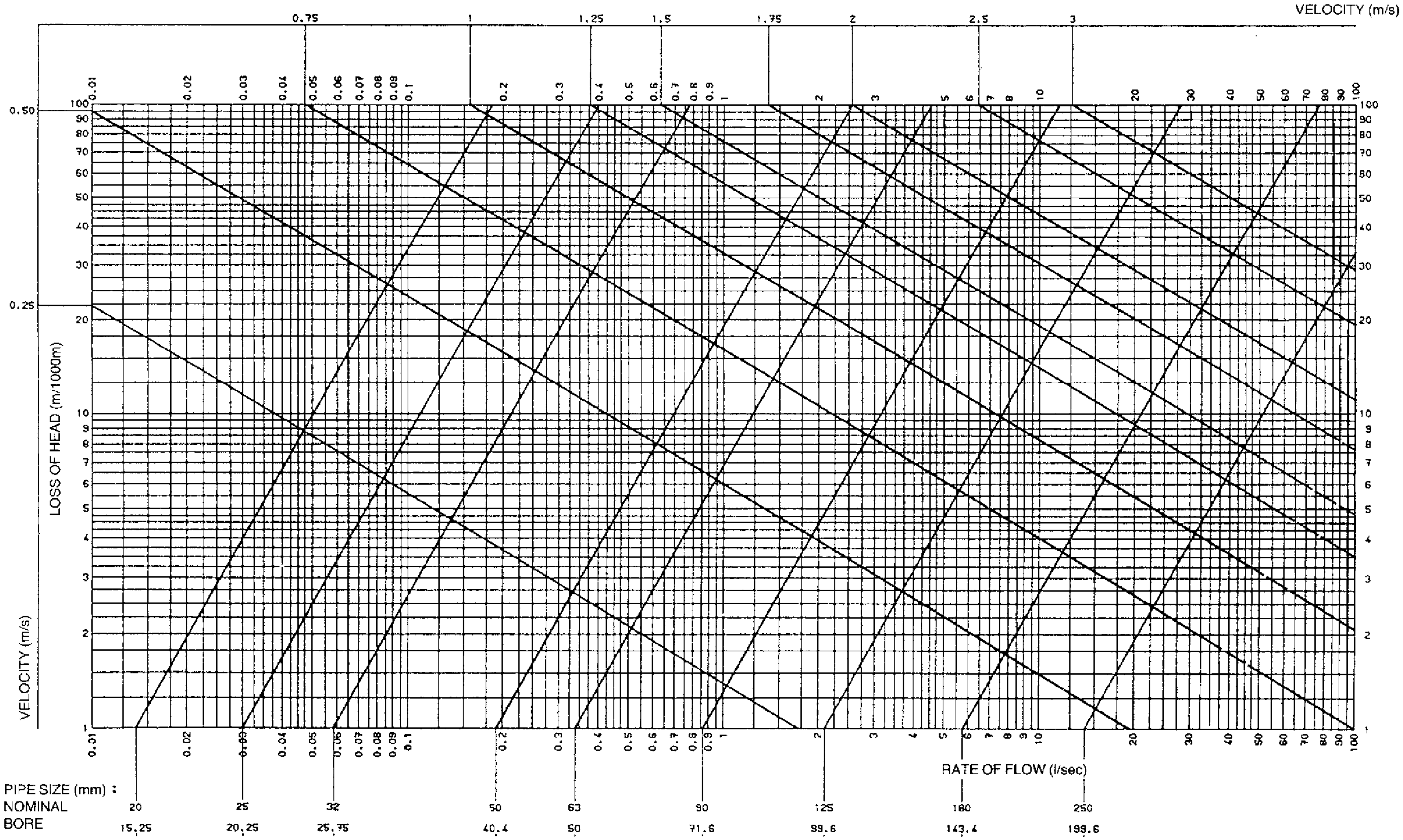
L = F x ID

where L = equivalent pipe length in metres
F = Fittings constant
ID = Internal diameter of the fitting

BEND	FITTING	F
90˚	Elbow	0.030
45˚	Elbow	0.015
90˚	Tee (straight through)	0.020
90˚	Tee (side branch)	0.075
90˚	Long Radius bend	0.020
45˚	Long Radius bend	0.010

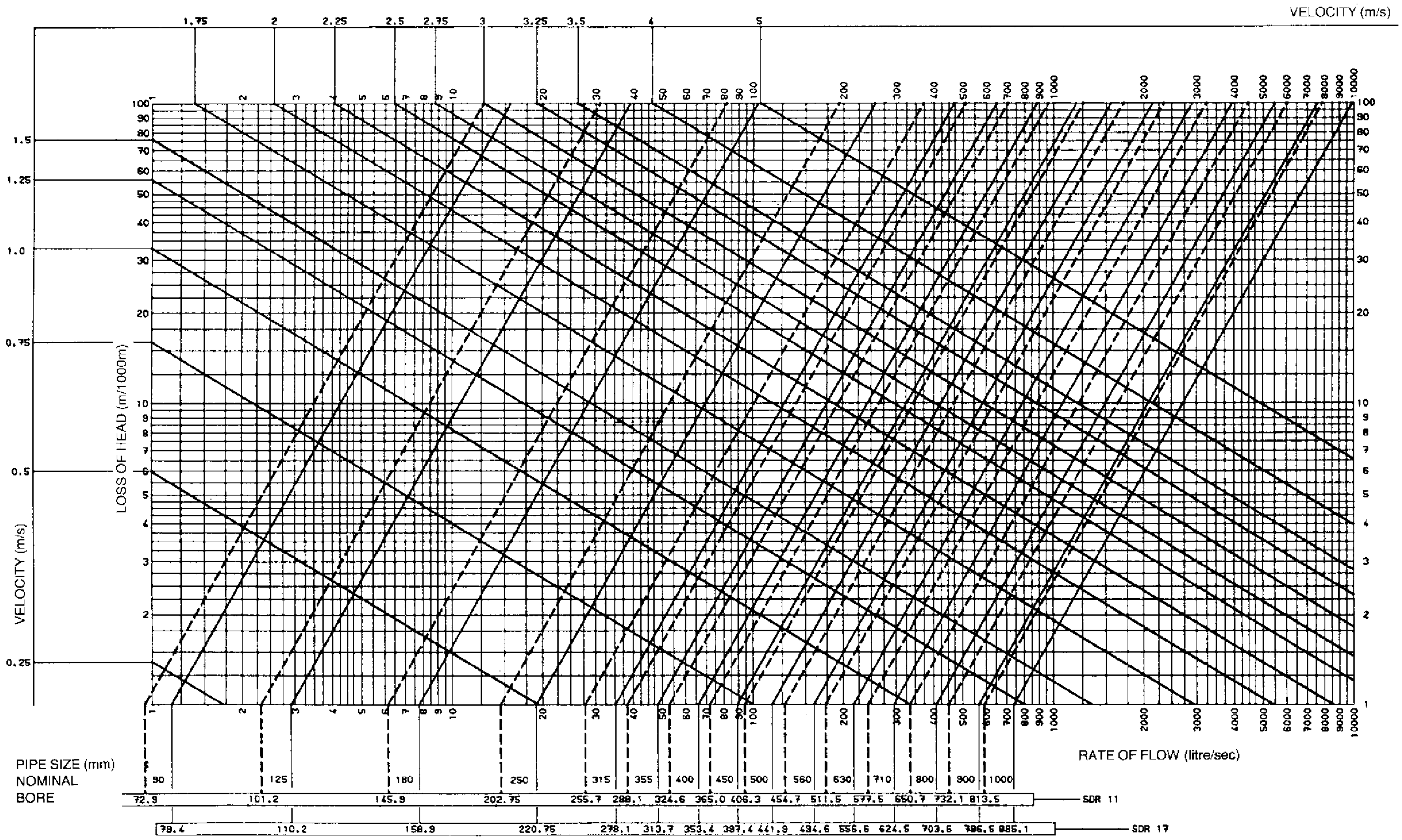
Figure 8. Fittings Constant

FLOW DIAGRAM FOR WAVIN POLYETHYLENE PIPE SIZES 20mm TO 315mm



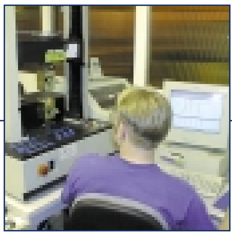
PLEASE NOTE: THIS DIAGRAM IS FOR WATER AT 15°C, AND UTILISES A ROUGHNESS FACTOR (ks) OF 0.003mm

FLOW DIAGRAM FOR WAVIN POLYETHYLENE PIPE SIZES 90mm TO 1000mm



PLEASE NOTE: THIS DIAGRAM IS FOR WATER AT 15°C, AND UTILISES A ROUGHNESS FACTOR (ks) OF 0.003mm

Design & Performance Testing



General Information

Although a polyethylene pipeline, like any other pressure system, is primarily designed to take the wall stresses produced by the internal pressure of the system, it is important to consider other potential loading conditions. This is particularly true if full benefit is to be made of the flexibility of the system in the use of modern installation techniques.

For example, in close-fit insertion or moleplough operations there is a tendency to score the outside diameter of the pipe. Therefore it is essential to ensure that the pipe has sufficient resistance to the growth of cracks that could arise from these external notches. This and many other potential hazards are taken into account in the design and performance testing of the Wavin range of polyethylene water systems to ensure that they have a long and maintenance free service life under design operating conditions.

In addition to a sound design philosophy, it is also necessary to work to a rigorous Quality Assurance testing scheme if this high level of performance is to be maintained in day-to-day production. This is best carried out under a third party certification scheme where an external body regularly checks test procedures and product performance.

This provides the end user with complete assurance of quality for the product range.

At the present time the Wavin range of polyethylene water systems are manufactured and tested in accordance with Water Industry or British Standards. However, discussions are currently taking place within the various European Committees to develop the CEN specifications and certification schemes.

The views expressed in this section represent the current thinking within these European Standards Committees.

Design for Internal Pressure

The burst pressure of polyethylene pipe is time dependent and therefore it is necessary to define the strength of the material at a reference lifetime.

The lifetime chosen for this reference value is 50 years - it should be noted that this does not mean that the pipeline will fail after 50 years, as the various safety factors that are incorporated into the design mean that the actual lifetime will be many times greater.
In order to generate the burst strength of the material at 50 years, a number of pipe samples are pressure tested to failure at lifetimes between 10 and 10,000 hours. The results of these tests are graphically or numerically analysed to obtain the minimum required strength (MRS) at 50 years. A graphical representation of this process is shown in Figure 9.

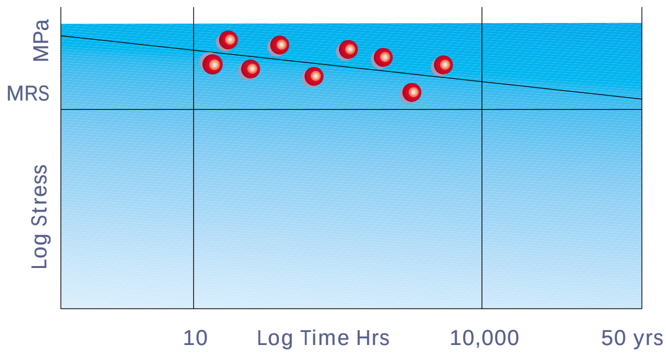


Figure 9. Hydrostatic Pressure Test Curve

Within the CEN and ISO Standards, it is recommended that the MRS value is based upon the 97.5% lower confidence limit obtained by regression analysis, in accordance with the method outlined in ISO / DTR 9080.2.

Within the Wavin range of polyethylene water systems, two basic polymers are included – Medium Density Polyethylene (MDPE) and High Performance Polyethylene (HPPE).

MDPE has a minimum required strength of 8MPa and is designated PE80 while HPPE has a minimum required strength of 10MPa and is designated PE100 as shown in the following table.

TYPE	MRS
PE80	8.0
PE100	10.0

Figure 10. MRS Classification at 20˚C

Within the classification system developed at ISO/CEN, there has also been considerable discussion of the application of design factors that should be used to determine the allowable operating pressures (PFA) of a particular plastic pipe system. This design factor is applied to account for any ‘unknown’ loading or environmental conditions.

The classification group has recommended minimum values only, which allow the pipeline engineer to use additional factors if difficult conditions exist (eg surge, elevated temperature or poor ground conditions).

For polyethylene pipeline systems, the recommended design factor is 1.25, which enables the allowable operating pressure to be calculated for each system using Lame’s formula for thick walled pipes:

Hoop stress: $\sigma = \frac{P}{2t}(D - t)$

where:

σ = Hoop stress		MPa
P = Max. operating pressure		bar
D = Outside Diameter		mm
t = Wall thickness		mm

Therefore:

$$\sigma = \frac{P}{2}\left(\frac{D}{t} - 1\right)$$

Now the Standard Dimensional Ratio (SDR) is related to the diameter and wall thickness of the pipe by the formula:

$$SDR = \frac{D}{t}$$

Therefore:

$$\sigma = \frac{P}{2}(SDR - 1)$$

or

$$P = \frac{2\sigma}{(SDR - 1)}$$

If this equation is applied to polyethylene pipe systems it is possible to calculate the allowable operating pressure (PFA) as shown below:

$$PFA = \frac{2 \times MRS}{(SDR - 1)\,\alpha}$$

where:

α = minimum design factor

This equation gives the stress in MPa. For conventional use, and to express the pressure in bar rating, the value in MPa is multiplyed by 10. For example:

For PE80:

$$PFA = \frac{2 \times 8 \times 10}{(SDR - 1) \times 1.25} = \frac{128}{(SDR - 1)}$$

For PE100:

$$PFA = \frac{2 \times 10 \times 10}{(SDR - 1) \times 1.25} = \frac{160}{(SDR - 1)}$$

Design & Performance Testing

In calculating the operating pressure, it is normal to round up or down the values to the nearest useful pressure class shown in the table on the right.

It should be noted that the above represent the maximum operating pressures for the pipeline and additional consideration may cause engineers to reduce the operating pressure to a lower level. For example, on large diameter PE80 pipelines where rapid crack propagation may be of concern (please refer to the section on Fast Fracture).

	PRESSURE CLASS (BAR)		
TYPE	SDR 11	SDR 17	SDR 26
PE80	12.5	8.0	5.0
PE100	16	10	6

Figure 11. Pressure Class for Polyethylene Systems

When operating a pipeline above 20˚C, it is important to allow for the reduction in the strength of the material at elevated temperatures. Within the ISO TC 138 SC5 committee some work has been carried out to establish the relationship between the maximum operating pressure and the operating temperature of the pipeline.

Their recommendations are given in Figure 12.

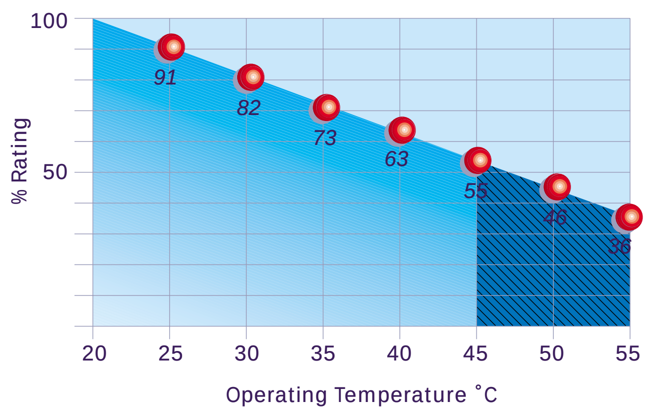


Figure 12. Pressure Reduction Factors for Polyethylene Pipe at Elevated Temperatures

If the temperature falls within this range the life expectancy of the pipe can be affected.

Please contact the Wavin Technical Services Helpdesk for further details.

Notch Sensitivity

Many materials may be extremely strong in laboratory tests but when they are notched or scored in handling they can become very brittle. The classic material in this category is glass, which is brittle enough to snap along a defined line when it is lightly scored. When laying pipelines it is common for the pipe surface to become lightly scored.

This is particularly true when the pipe is being inserted into an existing main, or where trenchless laying methods are being used. In order to ensure that brittle failure will not develop in the short or long term from these surface notches, it is usual to carry out elevated temperature pressure tests on notched pipe samples. It should be noted that this test is only used within the UK, although discussions are now taking place within ISO/CEN committees for a wider adoption of these tests.

In practice, during installation it is recommended that pipe with notches up to a maximum of 10% of the wall thickness can be used.

TEST CONDITIONS				
Type	Notch Depth	Temp˚C	Stress (MPa)	Life (hrs)
PE80	20%	80	4.0	170
PE100	20%	80	4.6	170

Figure 13. Test Conditions for Polyethylene Systems

Fast Fracture

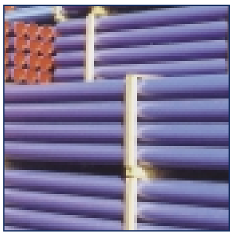
For virtually all materials it is possible for a dynamic crack to grow along the pipe length provided that sufficient energy is available to overcome the material's resistance to crack growth. Fractures of this type have travelled many kilometres in welded steel pipelines and are only arrested by a valve or other pipeline fittings.

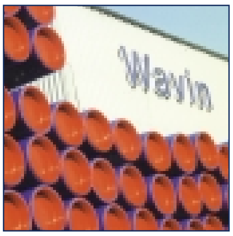
Over the past 10 years considerable test work has been carried out to investigate the relevance of this mode of fracture to polyethylene pressure pipelines.

The conclusions of this work may be summarised as follows:

- Crack propagation cannot occur if the pipeline is full of water. However, if the pipeline contains 10% or more air then propagation can occur.
- Cracks will not propagate through fittings including flanges or electrofusion couplers. Therefore the crack will be limited to one pipe length in these cases.
- Crack propagation cannot occur in small diameter pipelines and therefore only large pipelines need be considered:
  PE80 - pipe diameter 250mm or above.
  PE100 - pipe diameters above 500mm.
- The critical pressure at which rapid crack propagation will occur is dependent upon the pipe material and the pipe diameter. (see Figure 14).

If, in a particular scheme, it is important to design against rapid crack propagation, the maximum working pressures given in figure 14 should be used. For information on the suitability and maximum operating pressure of Wavin Polyethylene systems outside of the information given, please contact the Wavin Technical Services Helpdesk.





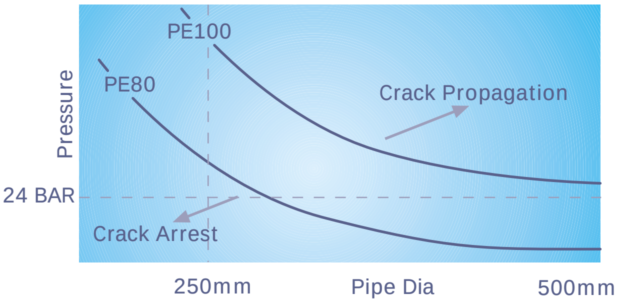


Figure 14. Critical Pressure Curve for Polyethylene Pipe

Other design Considerations

In designing any pipeline system, it is necessary to consider other factors that may influence the performance of the pipe. In most cases, sufficient data will have been gathered to provide formal design recommendations, but in other situations advice should be sought from the Wavin Technical Services Helpdesk.

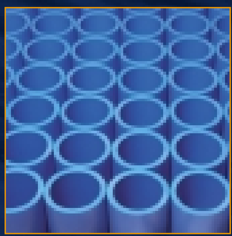
Additional Design Details

- Yield Strength
  PE100 23 N/mm^2
  PE80 18 N/mm^2
- Linear Thermal Co-efficient of expansion
  PE80 1.5 x 10 -4˚C-1
  PE100 1.3 x 10 -4˚C-1

This equates to the following more useful terms:

- PE80 0.15mm/m/˚C
- PE100 0.13mm/m/˚C

(eg for 1 metre of PE80 pipe its length increases 0.15mm for every 1˚C rise in temperature).



Quality Assurance Testing

Continuous performance tests are carried out on Wavin polyethylene pipe systems during manufacture. These are:

TENSILE TESTS

Test specimens from pipe production are tensile tested to determine the yield strength and elongation at break. Typical minimum results give elongation at more than 600%.

DELAYED BURST TEST

For PE80 pipe, samples taken at regular intervals are subjected to a circumferential wall stress of 12 MPa for a period of one hour at 20˚C. The pressure is steadily increased until the pipe bursts, and it must be at a stress greater than 16MN/m^2. For PE100 the same test is carried out at a wall stress of 12.5 MPa for 100 hours.

ELEVATED TEMPERATURE TEST

Samples from all production of pipe from PE80 material are notched to 20% of wall thickness at four points around the circumference and subjected to a wall stress of 4.0MPa (8 bar for SDR 11) at 80˚C for a minimum period of 170 hours, to establish comparative performance trends in relation to the resistance of the system to failure by stress cracking. For PE100 material, the notched pipe is subjected to a wall stress of 4.6MPa (9.2 bar for SDR 11). The purpose of this test is to monitor the stress crack resistance of the system and to ensure that crack growth does not occur in less than the required test life represented by the test.

Product Information

Pipe Lengths

Pipe up to and including 180mm diameter is supplied in either straight lengths or as coils, 250mm diameter pipe and above is supplied in straight lengths. Straight pipe is supplied in bundles supported by wooden timbers.

Straight Lengths

Straight pipe can be supplied in lengths of up to 18m. This is of particular benefit for pipe diameters of 250mm and above for which coils of pipe are not available. Details on handling and transportation are given in the Handling section of this guide. To optimise space, export shipping standard lengths are 5.8m (20’ containers) and 11.65m (40’ containers), and are nested (smaller diameter inside larger diameter) where possible. Longer lengths are available dependent on site location and access. Please contact Technical Services for details.

FREE STANDING COIL DIMENSIONS

Nominal Dia. (mm)	Length (M)	Width (mm)	Width (mm)	Internal Dia. (mm)	Internal Dia. (mm)	External Dia. (mm)	External Dia. (mm)
		SDR 11	SDR 17	SDR 11	SDR 17	SDR 11	SDR 17
90	50 100	280 370	280 370	1800 1800	2500 2500	2300 2800	2900 3000
125 PE 80	100	510	510	2500	2500	3200	3200
125 PE 100	100	510	510	2500	3000	3200	3700
180	100	600	600	3000	3000	4000	4000

Figure 15. Free Standing Coil Dimensions

For information regarding 110mm, 140mm and 160mm please contact Wavin Technical Services Helpdesk.

Free Standing Coils

Coils of up to 100 metres in length are available in pipe sizes 90mm – 180mm (see figure 15.)
These coils offer the benefit of a reduced number of joints compared to straight lengths and are particularly useful in constricted urban environments.

Special attention must be given to handling these coils; details are given in the Handling and Installation sections of this guide.

Standard Coils

Coils of 50 and 100 metre lengths are available in pipe sizes up to and including 180mm. 150 metre coils are available up to and including 75mm. Figure 17 gives details of the coil dimensions. Other coil lengths may be available upon request.

LOOSE COILS PER LOAD

Pipe Diameter	50M Coils	100M Coils
20 mm	450	400
25 mm	400	400
32 mm	300	250
50 mm	100	40
63 mm	100	40
75 mm	35	40
90 mm SDR 11	40	20
90 mm SDR 17	28	20
125 mm	15	12
180 mm SDR 11	8	6

Figure 16. Loose Coils per Load

COIL DIMENSIONS

Nominal Dia. (mm)	Length (M)	Width (mm)	External Dia. (mm)	Nominal Dia. (mm)
20	25 50 100 150	85 130 150 165	840 860 900 920	780 780 780 780
25	25 50 100 150	110 140 180 205	855 880 930 955	780 780 780 780
32	25 50 100 150	130 165 200 245	876 908 972 1004	780 780 780 780
50	25 50 100 150	160 260 280 280	1400 1450 1550 1650	1300 1300 1300 1300
63	25 50 100 150	190 255 380 400	1436 1489 1562 1625	1300 1300 1310 1310

Figure 17. Coil Dimensions

Drum Lengths

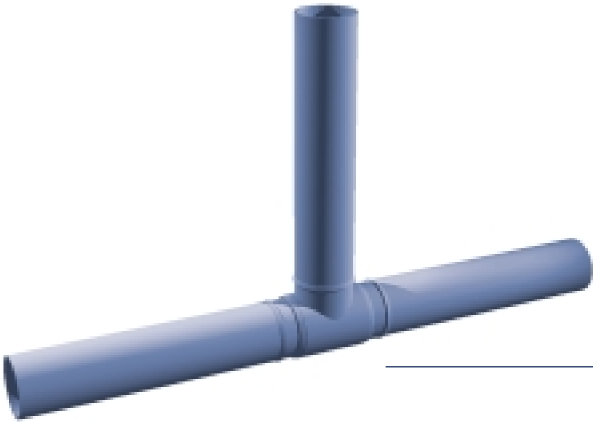
Drums of pipe up to 770 metres in length are available in diameters 90mm, 125mm and 180mm. Figure 18 gives some details. Drums are ideal for rural applications with trenchless laying techniques, reducing the number of joints and utilising the flexible nature of polyethylene.

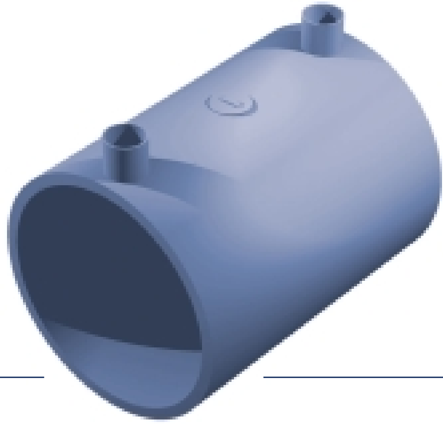
DRUM LENGTHS

Pipe Diameter	Length (M)
90 mm	770
125 mm	440
180 mm	220

Figure 18. Drum Lengths

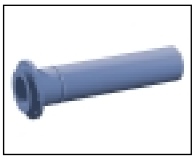
Fittings Range

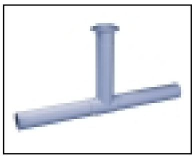


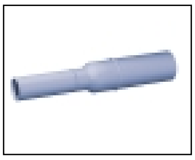


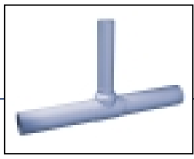
Pupped Fittings

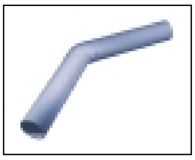
Pupped fittings are available in all ranges in sizes above 63mm. These fittings comprise of an injection moulded centre body with 500mm length of pipe (pups) butt welded to it as a standard. These fittings are primarily designed for butt fusion, but can also be used with electrofusion couplers. The illustrations (right) show some of these fittings.

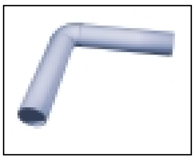








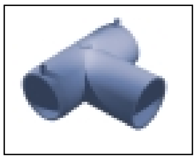


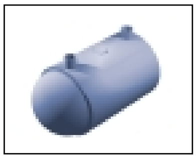


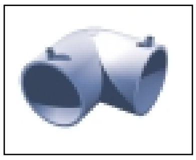
Electrofusion Fittings

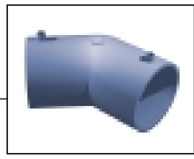
Electrofusion Fittings are available for use with Wavin polyethylene systems. These socket fittings consist of an injection moulded polyethylene body with an integral heating element. Some of the fittings available are shown right.

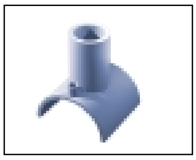
Details on jointing using electrofusion fittings are given in the Installation section of this guide.

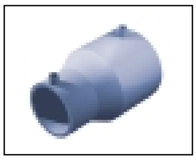


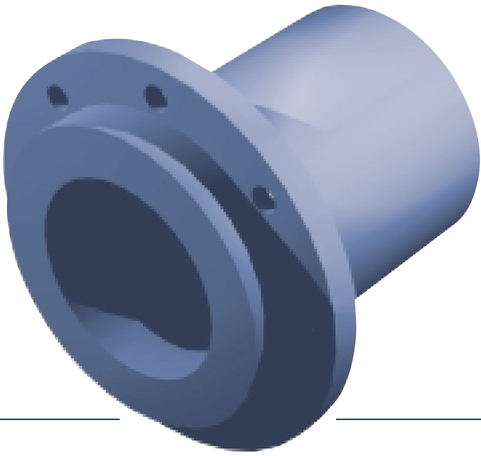


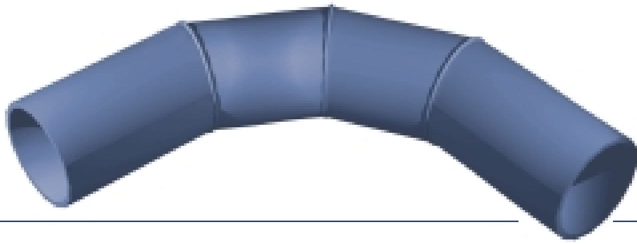










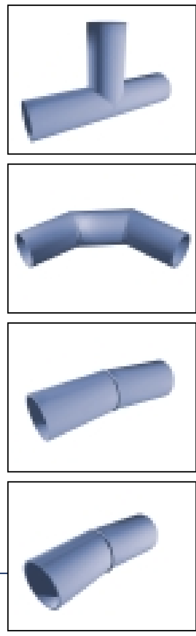


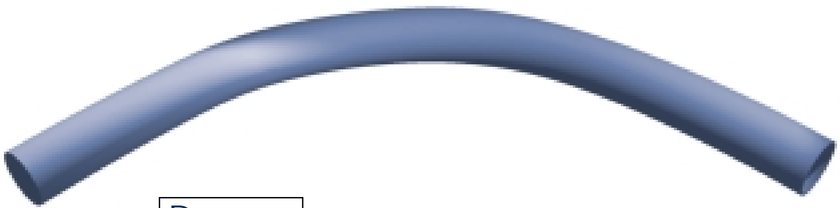
Spigot Fittings

Wavin polyethylene spigot fittings are available in all ranges. These fittings (shown right) are completely injection moulded and and are designed for use with electrofusion fittings.

Mitred Fittings

A range of mitred (or segmented) fittings are available to supplement the range of pupped fittings. These fittings (shown right) are manufactured from pipe using a computer controlled automatic butt fusion machine, and are available in sizes 63mm and above.





Drawn Bends

Wavin offer a range of long radius drawn bends in all ranges, in sizes 90mm and above. These fittings involve a specified length of polyethylene pipe pulled to a defined angle and are suitable for use with butt fusion and electrofusion couplers. Drawn bends are available in 90˚, 45˚, 22.5˚ and 11.25˚ angles as standard.

For details of the full range of polyethylene fittings, please consult the Wavin Potable Water Product Selector.

Jointing

General Information

Polyethylene pipe systems are relatively simple to joint and install. Two jointing methods are available to cater for the components that are used to build an operational system.

- Fusion Welded Joints

  a) Butt Fusion
  b) Electrofusion

- Mechanical fittings

Fusion Welding

Both Butt Fusion and Electrofusion use specialist equipment to carry out field jointing. Modern machine developments now provide totally automatic jointing, eliminating the risk of operator error and providing a full record of joint history for Quality Assurance of site welding.

Machinery can be either purchased or hired from manufacturers and detailed product literature is available together with familiarisation courses to ensure correct use of the machinery.
Operatives should however receive full training. Courses are provided by the WTI (Water Training International), and training is available from Wavin either at its Durham based Customer Training facility or at the customers premises.

Butt Fusion

Butt Fusion jointing involves the fusing together of two pipe ends in a specialist machine which prepares the pipe ends, heats them and brings them together under pressure to form a homogeneous weld.
The joint is fully end load resistant and is at least as strong as the parent pipe.

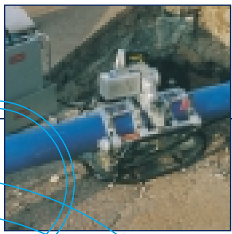
With Butt Fusion it is essential only similar grades of PE are welded, eg:

PE100 – PE 100 ✓
PE100 – PE80 ✗

and similar SDR's are used, eg:

SDR 11 – SDR 11 ✓
SDR 11 – SDR 33 ✗

Reference should be made to the Water Industry Specification WIS 4 - 32 - 08, Issue 2, 1994, which details all site fusion welding methods and covers the single and dual pressure methods. Dual pressure welding was introduced as a result of investigations into joint quality by the WRc and this procedure should be used for all pipes with a wall thickness greater than 20mm. Due to the low pressures involved in the dual pressure procedure, only fully automatic machines should be used; manual machines may still be used for single pressure Butt Fusion jointing.




Equipment Required

- Butt Fusion machine, inclusive of trimmer, heater plate and hydraulic pump.
- 110v Generator, fuel
- Welding Tent/Base board
- Pipe support rollers
- Clean water, lint free cloths
- External de-beading tool
- Bead gauge
- Pipe end covers
- Indelible marker pen
- Pipe cutting tools

Procedures of Manual Butt Fusion

- Ensure the pipe ends are clean and if necessary, wash with clean water and dry.
- Cut the pipe ends square and clamp securely in the B/F machine.
- Align and level the pipes with pipe support rollers.
- To prevent cooling of the heater plate blank off the free pipe ends.
- Trim the pipe ends until a continuous shaving is seen from each pipe end.
- Remove loose shavings and importantly, do not touch the prepared pipe ends.
- Close the clamps and check for good alignment of the pipe ends, the allowable mismatch is; 90mm-315mm pipe, 1 mm 355mm-630mm pipe, 2 mm Re-trim if mismatch is greater than these values.
- Open and close the clamps, noting the gauge pressure to close the clamps - This is the drag pressure. The fusion (jointing) pressure is obtained by adding the drag pressure to the hydraulic ram pressure given on the machine data plate.
- Place the heater plate in the machine, checking it is clean and undamaged and up to temperature, 225˚C - 240˚C.
- Close the clamps and apply the previously determined pressure until a bead of 2-3mm is formed.
- Reduce the pressure in the system to between 0 and drag, the heat soak time commences. Ensure the pipes maintain contact with the heater plate.
- Upon completion of the heat soak time, remove the heater plate and close the clamps immediately, (within 10 seconds).
- Maintain the required fusion (jointing) pressure for the specified cooling period.
- Remove the joint & allow to cool for a similar period.
- Clearly mark the joint and bead for identification with an indelible pen.
- Check the joint is free from any contamination, and check the bead widths meet the specified limits and are uniform.
- Remove the external bead and twist in several positions. If the bead splits at any position the joint should be cut out and re-made.

Jointing

Additional Notes for Butt Fusion

- If the heater plate requires cleaning this should be done when the plate is cold. The plate can be washed with clean water and lint free cloth and dried thoroughly. Isopropanol may be used to remove any oil or grease.
- Washing the heater plate may not remove very fine dusty particles, therefore at the start of each welding session a dummy weld should be carried out for pipes up to 180mm in diameter. For pipe sizes greater than 180mm, two dummy welds should be made. An actual joint need not be made, the dummy weld can be aborted at the end of the heat soak period. Pipe offcuts may be used.
- In very cold conditions, below 5˚C, additional space heating must be provided in the fusion welding tent to maintain the required minimum ambient temperature for welding.
- Electrofusion "wet wipes" should not be used after the pipe ends have been trimmed, if any contamination does occur the pipe ends should be re-trimmed.

Electrofusion

Electrofusion fittings incorporate an electrical heating element which is energised via an E/F control box to heat the elements.

When the fitting is energised the material next to it becomes molten and in turn causes the pipe surface to melt, resulting in a molten pool of material fusing the materials of fitting and pipe. Once cooled this produces a fully fused and leak free joint.

Details of electrofusion procedures are given in WIS 4-32-08, Issue 2, 1994 and reference should be made to this document for further guidance.

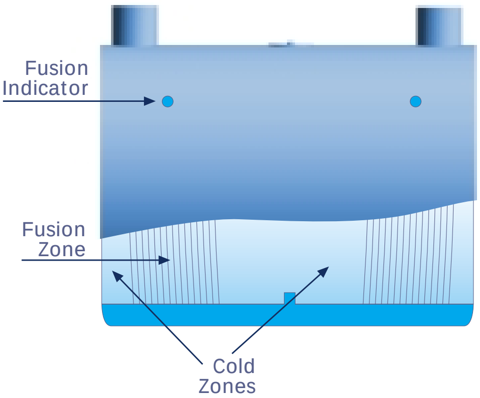


Figure 19. Cross section through an Electrofusion Coupler

Electrofusion Fitting Design

The design of an E/F fitting is crucial to its performance and is dependent on the position and pitch of the heating coil.
The heat distribution should be consistent throughout the fusion cycle and over the full fusion area. The melt must be adequately controlled within the hot and cold zones to ensure a fully welded, homogeneous joint. The different zones of an E/F fitting are shown in Figure 19.

Automatic & Manual Fittings

Many manufacturers now offer Automatic and Manual fittings and it is important to ensure the E/F control unit is compatible with the fittings being used. Most control units can be operated in both Automatic and Manual mode.

Saddle Fittings (Tapping Tees)

Two styles of saddle fittings are available;

- stack loaded saddles
- under clamp saddles

Both styles provide a service connection to polyethylene mains and differ only in the manner they are clamped during fusion.

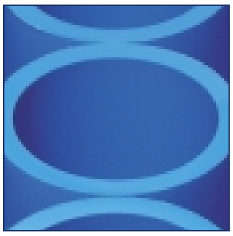
Stack loaded saddles are located with a stack loading tool which delivers the force required during fusion through the stack of the fitting, whereas, with underclamp saddles the jointing force is provided by a clamp device, located beneath the fitting and pulls the fitting down onto the pipe.
The correct tooling must be used for each style of saddle.

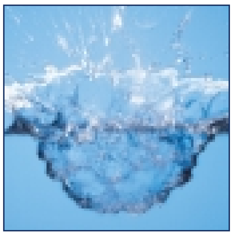
Equipment Required

A number of manufacturers produce E/F control boxes and the ancillary tooling required. The correct tooling must be used to ensure consistently reliable joints and this may be either purchased or hired from the tooling manufacturer or their agents. The site equipment should include:

- E/F control unit
- 110 volt generator
- 3 - 3.5 KVA for 39.5 volt fittings
- 6 - 7 KVA for 80 volt fittings
- Jointing shelter
- Pipe scraping tool, including mechanical scrapers for pipe end preparation and hand scrapers for saddle joints
- Pipe cutting tool
- Marker pen, solvent wipes, lint free cloths/paper towels

Jointing





Principles of EF Jointing

- Pipe ends must be cut square and de-burred.
- If necessary clean the pipe ends with clean water and dry.
- Clearly mark the depth of entry, plus 25mm, around the pipe circumference. Use the fitting as a guide, without removing from its sealed bag at this stage.
- Using the mechanical pipe-scraping tool, remove the entire pipe surface over the marked area in a continuous ribbon of material if possible.

NOTE: Do not touch the cleaned scraped surface.

Mechanical scrapers are preferred over hand scrapers as skill and practice is required with hand scraping and can be quite time consuming for larger diameter pipes.

- Remove the fitting from its bag, check it is clean and undamaged, and assemble onto the pipe ends clearly marking the depth of entry with a marker pen.
- Securely clamp the joint assembly with the appropriate clamps.
- Attach the control unit leads, check the generator has sufficient fuel and commence the fusion cycle following the control unit instructions for the type of fitting being used.
- Check the melt indicators have risen, these indicate the fitting has been energised and has completed a fusion cycle.
- Allow the joint to cool for the required time, full fusion details are given on each fitting.

Additional Notes for Electrofusion

- Jointing must always be carried out in dry and dust free conditions.
- Do not use rasps/files or abrasive sheets to prepare pipe ends.
- Always use the correct clamps for jointing.
- When jointing coiled pipe, additional re-rounding and pipe straightening tooling should be used to assist in the process.
- Do not extend control unit leads to the fittings and ensure the lead between generator and control unit is not excessive as an unacceptable power drop can be created.
- If the fusion cycle stops in mid-cycle first check for any control unit faults. Check for fuel. If the fault can be rectified, welding can re-commence providing the joint has cooled to ambient temperature and the fusion time is re-set for a further full cycle.
- For live connections, tapping into the water main should be carried out after all joints have cooled for a minimum of 30 minutes.
- Where E/F couplers are to be used for repair situations the existing main should be completely dry with no running water.

Mechanical Joints
Compression Fittings

There are numerous manufacturers of compression fittings suitable for use with polyethylene pipe, they are all based on the same design principle where an elastomeric ring seal is compressed between pipe and fitting. Some fittings require the use of pipe bore inserts to provide sufficient rigidity for the compression seal to be effective.

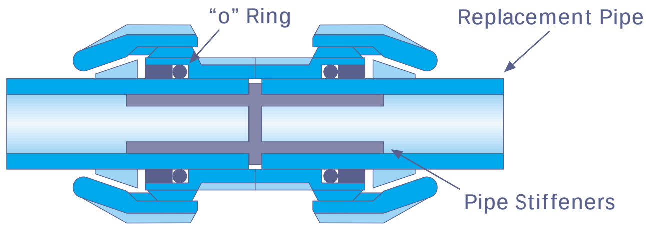
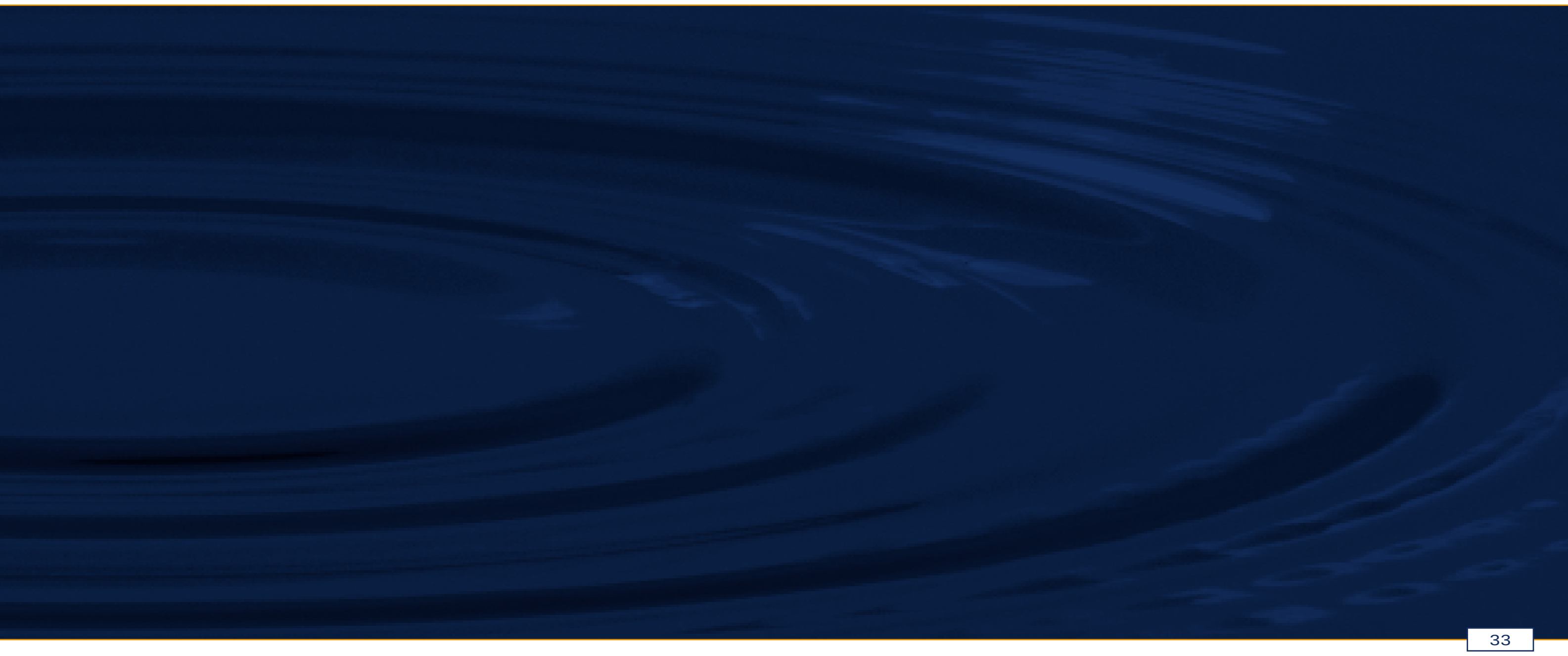


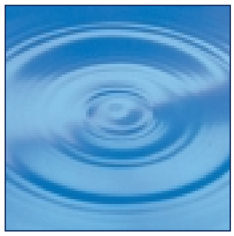
Figure 20. Cross Section through an Elastomeric Ring Seal

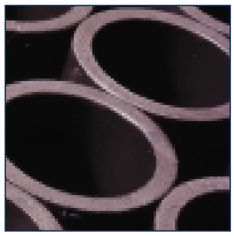


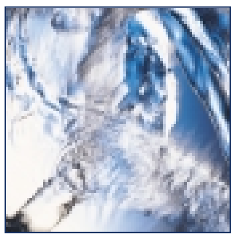
Flanged Joints

One of the simplest and earliest methods for connecting PE pipe to valves, hydrants and existing pipe materials is to use a polyethylene stub flange.
Stub flanges are supplied pre-fabricated with either spigot or pupped pipe lengths and steel backing ring, drilled to suit metric PN16 flanges. Other flange drillings are available upon request.

As polyethylene pipe is sized on the O.D. and Ductile Iron, for example, is sized by its internal bore, allowances must be made for differences in pipe bore and discrepancies in corresponding mating flanges. This occurs more with larger diameter pipes and a flange converter will be required in these instances to ensure compatibility of pipe bores.







Jointing

Flange Convertor

Where a change in pipe bore is not acceptable, a steel flange converter can be used to maintain a clear bore, the diagram below shows a typical flange configuration for a 450mm PE stub flange to a 400mm D.I. flange.

TYPICAL BOLTING TORQUES (PE TO PE)			
Pipe Diameter	Nominal Flange	Bolts	Torque (nm) ± 10%
63 (mm)	50 (mm)	M16 x 4	35
90 (mm)	80 (mm)	M16 x 8	35
125 (mm)	100 (mm)	M16 x 8	35
180 (mm)	150 (mm)	M20 x 8	60
225 (mm)	200 (mm)	M20 x 12	80
250 (mm)	250 (mm)	M24 x 12	100
315 (mm)	300 (mm)	M24 x 12	120
355 (mm)	350 (mm)	M24 x 16	150
400 (mm)	400 (mm)	M27 x 16	200
450 (mm)	450 (mm)	M27 x 20	250
500 (mm)	500 (mm)	M35 x 20	300

Figure 21. Typical Bolting Torques

Stub Flange Jointing Procedure

Jointing is straight forward and the following guidelines can be used.

- Ensure the mating flange faces are clean and free from damage.
- Select the appropriate size and grade of gasket for the application.
- Align both flange faces before bolting up. Ensure the pipes/components are aligned and do not impose any bending stresses on the joint.
- Jointing compounds are not necessary.
- Use only clean undamaged nuts, bolts and washers of the correct size.
- Ensure the gasket is aligned and centred before bolting .
- Assemble the joint and finger tighten all nuts / bolts and progressively tighten all bolts in a diagonally opposing sequence as follows, using a torque wrench:
  - 5% of final torque
  - 20% of final torque
  - 50% of final torque
  - 75% of final torque
  - 100% of final torque
- For evenness of tightening it is advisable to use two operators for flanged joints larger than 180mm diameter.
- If practical, final torquing up should be repeated after the joint has relaxed for 1 hour.
- It is important the joint is tightened evenly and in sequence to ensure a leak free joint, this is as important as the use of recommended final torque values.

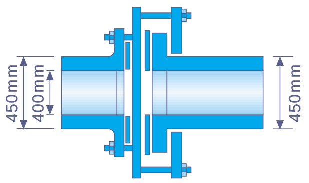


Figure 22. Flange Convertor

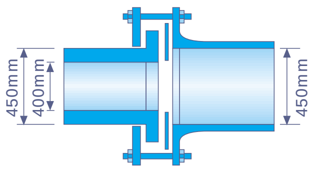


Figure 23. Standard Stub Flange Joint

Testing & Commissioning

Site Pressure Testing

The traditional testing procedure used for most pipeline materials throughout the Water Supply Industry is given in BS CP 312 : Part 3 : 1973 : Section 10.
These procedures are generally intended for linearly elastic materials, eg ductile iron and steel, and are not suitable without modification for visco elastic materials such as polyethylene. Pipe manufactured from such materials exhibit creep and stress relaxation. With a PE pipe sealed under a test pressure, there will be a reduction in pressure (pressure decay) due to the visco elastic (creep) response of the material.
This will occur even in a leak free system. This pressure decay is non-linear in an unrestrained pipe. In view of this characteristic the WRc have developed a pressure test which accounts for the effects of creep and stress relaxation. The full test procedure with detailed background data is given in the WRc "Manual for Polyethylene Pipe Systems for Water Supply Application", 1994. For further guidance reference should also be made to the manual.

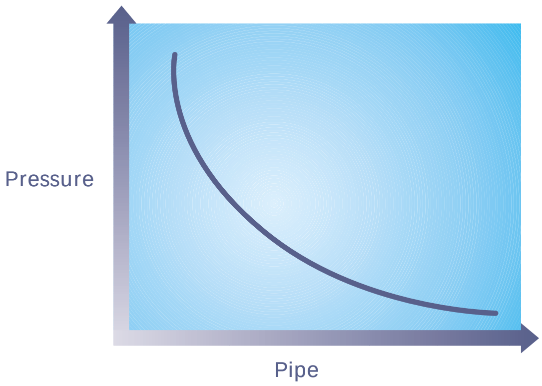


Figure 24. Test Pressure Curve

Test Pressures

PE pipe systems should be pressure tested up to a maximum of 1.5 times the rated pressure of the pipe. However, for practical purposes it is usual and may only be necessary to pressure test up to 1.5 times the pipeline working pressure.

Test Section Preparation

- Test in sections of 1000 metres or less.
- Pipework should be backfilled, with joints left exposed at the engineers discretion.
- Pipework must not be tested at temperatures in excess of 30˚C.
- Air valves should be placed at all high points in the system.
- Data loggers with pressure transducers should be used to provide a precise analysis of the pressure test data and can provide the engineer with an early indication of any leakage.
- For on site calculations a pocket calculator is sufficient.

Test Procedure

- Upon reaching the test pressure, the test section is isolated.
- Pressure loading time is used as the base reference point, (t_1).
- A correction factor, $0.4t_L$, is used to calculate ratios (N), this accounts for the pipeline beginning to relax during the pressurisation period.
- Take a first reading of pressure P_1 at t_1 where t_1 is equal to the pressure loading t_L.
  Corrected value = t_{1c}
  $t_{1c} = t_1 + 0.4t_L$
- Take a second reading of pressure P_2 at a decay time of $7t_L$ this is time t_2.
  Corrected value = t_{2c}
  $t_{2c} = t_2 + 0.4t_L$.

Calculate $N_1 = \dfrac{\log P_1 - \log P_2}{\log t_{2c} - \log t_{1c}}$

For a pipeline without leaks, N_1 should be:

a) 0.08 to 0.10 for pipes without constraint (eg sliplined, or not backfilled)
b) 0.04 to 0.05 for pipes with compacted backfill
If the resultant values are significantly less than those specified, this indicates that there is too great a volume of air in the pipeline. This air must be removed before a re-test can be satisfactorily carried out.

- Take a further reading of pressure P_3 at a decay time of not less than $15t_L$, this is time t_3.

$t_{3c} = t_3 + 0.4t_L$
Calculate $N_z = \dfrac{\log P_z - \log P_3}{\log t_{3c} - \log t_{2c}}$

The ratio N_2 should again be as those identified above. The test sensitivity can be increased by extending the value of t_3.

- If an unacceptable leak is indicated, all mechanical joints should first be checked, followed by checks on any Butt or Electrofusion joints.
- If a further test is necessary, a period of at least five times the first test period should elapse before re-testing. This allows the pipeline to recover from the previous pressurisation.

Commissioning Procedure

- Upon the successful completion of a test, the remaining pressure in the pipeline should be released slowly.

Following successful pressure testing all new mains, lined or re-furbished, should be commissioned in the following manner and in accordance with any local requirements:

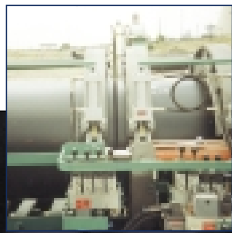
- Cleaning and/or swabbing of the main
- Filling and sterilisation
- Flushing and/or neutralisation
- Refilling the main
- Bacteriological sampling
- Acceptance certification
- Introduction of the main into service

Installation

Wavin PE80 and PE100 polyethylene pipe systems provide a cost effective and simple to install pipe system.

Polyethylene is a thermoplastic material resulting in a lightweight, flexible pipe, which is totally corrosion resistant and leak free with proven fusion welded and mechanical jointing methods.

The following notes give a general guidance into the use of PE, and should be read in conjunction with the WRC "Manual for Polyethylene Pipe Systems for Water Supply Applications, 1994 and BS COP 312, Parts 1 and 3 Plastic Pipework".



Buried Pipework

One of the key strengths of polyethylene is its ability to be fusion welded, either by Butt or Electrofusion. This results in a continuous, flexible pipe string which can be easily snaked into pre-dug trenches. Where site conditions permit welding can be very easily carried out above ground. Polyethylene lends itself to a number of minimum dig and no-dig techniques, many of which were developed specifically around PE pipe systems, eg:

- Narrow Trenching
- Ploughing
- Moling
- Pipe Bursting
- Slip Lining
- Folded PE, lining systems
- Directional Drilling

Conventional Open Cut Trenching

Excavation and disposal of waste spoil are major factors in pipe installation. Landfill taxes are becoming a significant cost and environmental factors are forcing Engineers to look at new installation methods to minimise the disruption and amount of waste spoil generated.

The current practice in the UK is to lay service pipes at 750mm cover and mains at 900mm cover, measured from the pipe crown.

The width of the trench should be the minimum of pipe O.D. plus 250mm to allow for the correct compaction of sidefill. The location of cables and pipes from other utilities should be identified prior to excavation and generally at least 3 pipe lengths should be excavated prior to pipe installation to allow for obstructions to be avoided.

Polyethylene may in some instances be laid directly onto the trimmed trench bottom where the soil is uniform, fine grained and free from large stones and flints.

In other cases the trench should be excavated to a depth to allow for a minimum 100mm bed of gravel, crushed stone or coarse sand. A sand/gravel mix is also acceptable, provided the gravel is less than 20mm in size.

Further details on bed and fill materials are given in WIS 4-08-01.

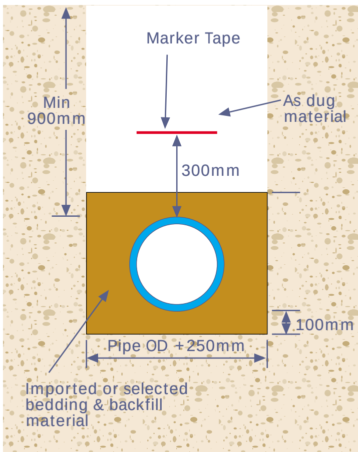
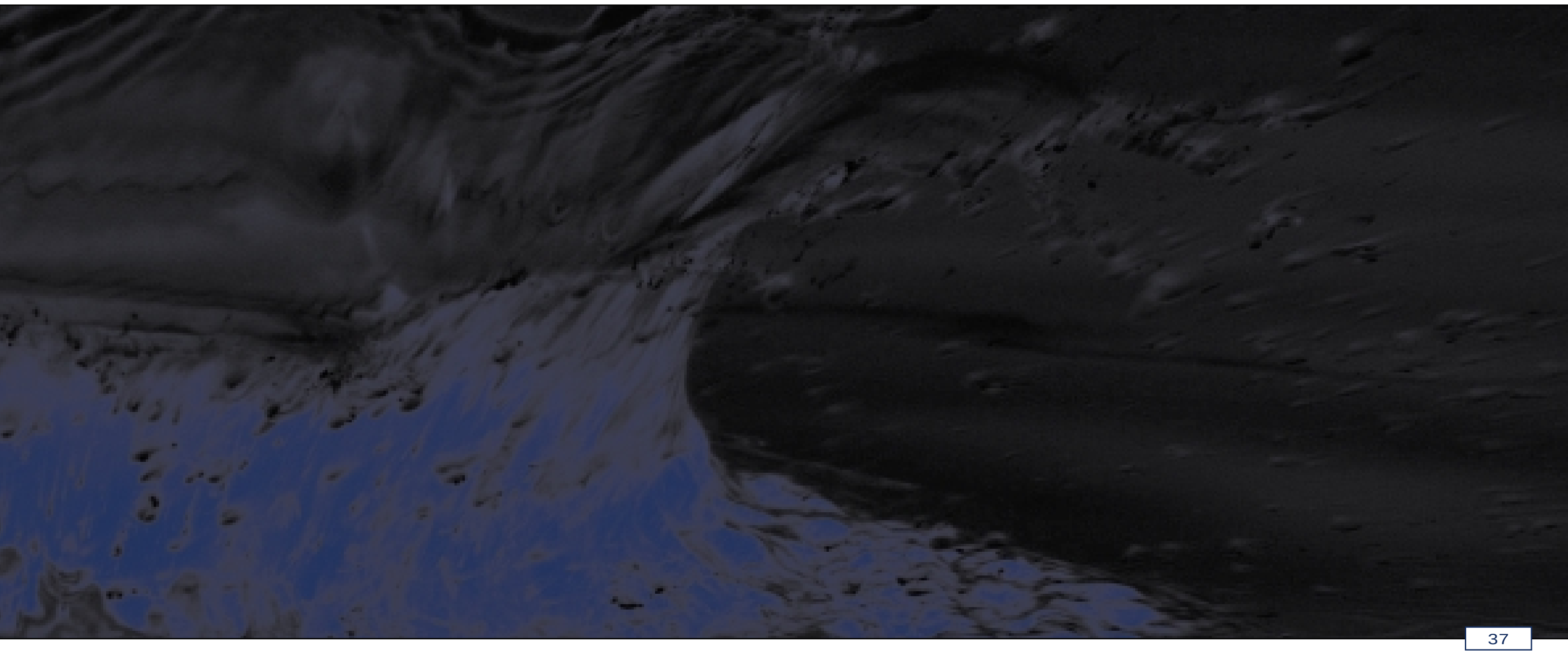


Figure 25. Typical Open-Cut Trench Detail

Backfilling

Polyethylene is a flexible material and can deform under load without damage. It is however, important that any deformation is minimised and that the placement of the correct sidefill and initial backfill materials is carried out correctly with adequate compaction. A minimum 100mm cover should be placed above the crown of the pipe, with heavy compaction equipment not being used with less than 300mm cover. Backfilling can then proceed in 300mm layers. Trench reinstatement in Highways is covered in the NRASWA "Specification for the Reinstatement of Openings in Highways", 1992. This code was introduced with the aim that all highway reinstatement is completed as soon as possible to a consistent prescribed performance criteria.

Trench backfilling should commence as soon as possible after pipe laying to give the pipe protection from damage from objects possibly falling into the trench. To protect the pipe from potential future interference damage it is good practice to install a marker tape 300mm above pipe crown. Marker tapes can also include a tracer wire to allow future identification of the pipeline.



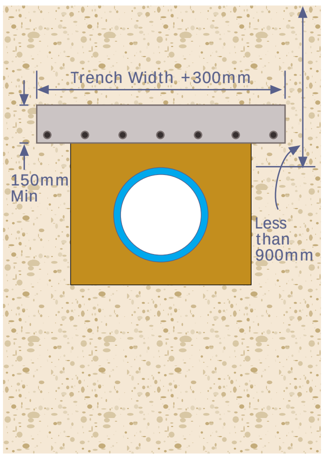


Figure 26. Recommended Protection for Shallow Pipes

Shallow Cover

There may be situations where pipes cannot be laid at the recommended depths of cover. In these situations for highways or traffic areas the pipe should be protected by placing a 150mm thick reinforced concrete bridging slab above the pipe. A 150mm thick granular cushion should be placed between the pipe crown and concrete, figure 26 details the typical application.

Installation Techniques

As discussed earlier a number of techniques have been developed to maximise the benefits of using polyethylene, these techniques are briefly discussed below.

Narrow Trenching

A modification of traditional open-cut trenching. Using either narrow backhoe buckets or chain trenchers, trenches 100mm wider than the pipe being installed are excavated. Coiled, drummed or pre-welded pipe strings can be quickly installed. Significant savings can be achieved through reductions in less excavated spoil, less imported fill materials and reduced labour.

Ploughing Techniques

Developed from agricultural machines laying land drainage, these machines are used for laying cross-country water and gas pipelines.

Pipes are laid with little disruption to the land which is quickly reinstated to agriculture. Pipe is installed continuously through a hollow plough with bed & surround material plus marker tape installed simultaneously as required.

Installation

Pipe Bursting

This is an ever-increasing method of re-habilitating an existing pipeline where a non-structural lining method would be unacceptable. With pipe bursting the existing pipe is cracked open and the new PE pipe is drawn into the hole created, and provides either a size for size replacement pipe or by use of reamers the original main can be upsized.

The present day hydraulic bursting tools are capable of cracking out both pipes and fittings in very demanding situations, and further adaptations are now capable of splitting ductile iron and steel mains.

With this technique, damage to adjacent utilities plant is possible and therefore care is required in the planning and operation of bursting.

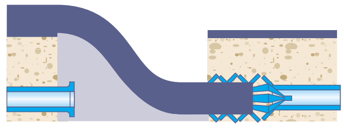


Figure 27. Typical Bursting Operation

Moling

Moling has become an established no-dig method for the installation of small diameter service pipes and mains, and can give significant cost savings over open-cut trenching. Excavation is limited to launch and reception pits and moling is ideally suited for road crossings and installations under expensive paved areas and gardens where open-cut trenches would be very disruptive.

Note: The presence of other services should be established prior to moling.

The impact mole is an air driven percussion tool, which drives a borehole and usually pulls a new polyethylene pipe directly in behind it.

The technique can also be used on carriageways in a technique known as "pipe stitching" where pipe is installed from pit to pit.

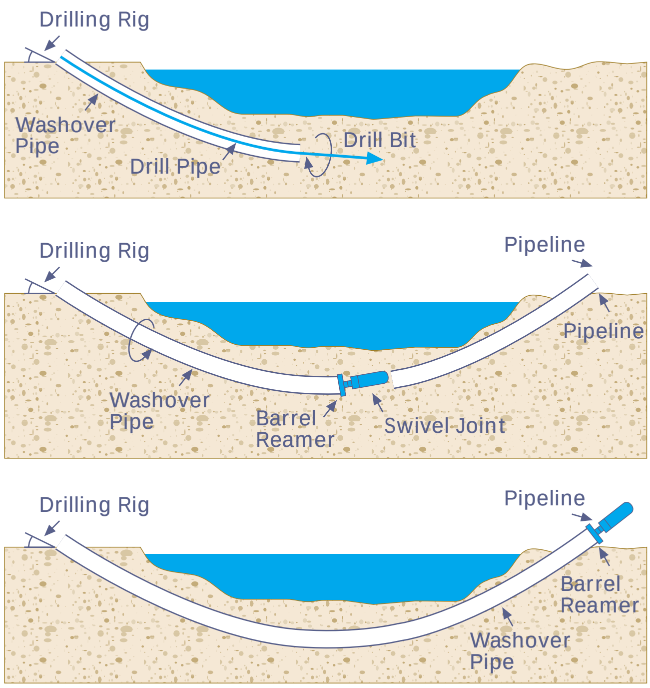


Figure 28 Typical Directional Drilling Operation

Directional Drilling

This technique has also become an established installation method for PE pipe and is used for road, rail and river crossings where open-cut work would be usually impracticable and prohibitively costly.

The hole is bored by either high-pressure liquid jets or with drill bits, and fully steerable systems are available by monitoring transmitters in the cutting head.

The operation involves drilling a small diameter 'pilot' hole beneath the obstacle and the final hole size is achieved by progressively back reaming up to the diameter required.
The PE pipe (coil or pre-welded string) is finally pulled through on the last pass. Experienced contractors are necessary with this technique to ensure the PE string is not over stressed on the final pull through.

Slip Lining

The insertion of a smaller diameter PE pipe, slip-lining, into an existing pipeline is one of many no-dig techniques for re-habilitation of ageing pipelines.

With slip-lining there is inevitably a reduction in pipe bore, although this can be minimised by thorough cleaning of the old main and choosing the largest possible pipe size for insertion.

The smaller bore is also compensated for by the greatly improved flow characteristics of polyethylene and in many cases the higher operating pressure capability of the new pipe. Pressure grouting of the annular gap provides structural rehabilitation of the existing pipe and reinforces the overall strength of the new pipe. Grouting may also offer a more economical total installation by allowing the use of a thinner walled PE pipe. Consideration should be given to the resistance of the pipeline to grouting pressures and this will be dependent on pipe SDR and ovality (especially coiled or drummed pipe).

PERMISSIBLE GROUTING PRESSURES FOR PE PIPES

Deformation SDR	0% Permissible Grouting Pressure (KN/M^2)	1%	3%	6%
33	13	12	10	7
26	27	25	20	15
17	96	88	73	59
11	417	383	317	242

Figure 29. Permissible Grouting Pressures

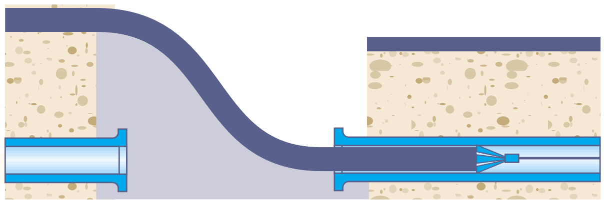


Figure 30. Typical Slip Lining Operation

Close Fit Insertion Methods

A number of methods are available for the structural lining ofexisting pipes, maximising the overall cost savings of using the existing 'hole in the ground'.

Two methods rely on physically reducing the outside diameter of the liner pipe to provide a clearance gap for insertion. Both work by either passing the pre-welded pipe through rollers or a reducing die. The pipe is either re-expanded using water pressure or allowed to recover naturally when the winch load has been removed.

Wavin have developed and patented their own re-habilitation method based on reducing the liner pipe O.D. by physically deforming the pipe into a 'C' shape. This product which is factory formed is known as 'Compact Pipe' and is available in a range of diameters and SDR's .

For further details on Compact Pipe please contact our Technical Services Helpdesk.

Thin Wall Polyethylene Liners

For pipelines, which are still structurally sound and require rehabilitation for leakage or water quality problems, thin wall PE liners can provide the solution. With SDR's of 33 - 61 the pipe is either factory or site formed into a folded profile to reduce its diameter for ease of installation into the existing main.

Lengths of up to 700m can be pulled in, in one operation, and when in place the folded pipe is reverted with mains water, to form a close-fitting liner.
The technique is particularly effective on small diameter mains, 3 - 12" diameter, with the full system comprising termination fittings and ferrule connections.

Pipe Bending

One of the major benefits of PE is its flexibility and this can be utilised to full advantage for buried pipework. Gradual changes of direction up to 11.5˚ can normally be accommodated by the pipe itself, without the need for additional fittings and the costs of jointing.

The accepted rule of thumb for Wavin PE pipe systems (warm conditions for SDR 11 pipe) is, Bend radius = 15 x pipe O.D.

For colder weather and SDR 17 pipe a safe bending radius is 25 x pipe O.D.
In very cold winter temperatures this increases to 35 x pipe O.D. Where thinner walled SDR 26 and SDR 33 pipes are being used these values should be increased by 50%. Fittings and pipe joints should not be included in bent pipe sections; formed bends and elbows should be used instead to prevent undue stresses in the pipeline.

Pipe Detection

For future location of PE pipelines and in line with good pipe laying practice, the simplest and most economical method is to lay a marker tape/ mesh which incorporates a tracer wire. This should be installed 300mm above the pipe crown and also provides protection from any future third party damage.

Pipe Anchorage & Thrust Blocks

A key feature of a welded PE pipeline is that it is a fully end load resistant system and thrust blocks are not required at changes of direction/diameter or branches, providing significant time and cost benefits to the total installed cost of the system. It should be remembered that any connection to a non-end load-bearing fitting will require anchorage to prevent pipe pull-out.

Where heavy ancillary plant is installed on a PE pipeline, provision should be considered for concrete support. This should provide support both for the dead weight and resist any turning movements under operating conditions, eg. valves and hydrants.

Pipe Entry into Structures

Pipe entry into rigid concrete or brickwork structures needs to take account of a number of design factors and should include:

- Differential settlement. This can usually be accommodated by the flexibility of the pipe itself and by incorporating a flexible annular seal to the pipe sleeve through the structure.
- Watertight seal. The protective sleeve should provide both a watertight seal to the structure and to the PE pipe passing through the sleeve.
- In some situations PE pipe may be connected to the structure by a rigid flanged joint. To prevent undue stresses through movement and settlement, support can be provided by a reinforced concrete plinth. The plinth should extend one pipe diameter or 300mm (min) from the flange face, with pipe straps bolted to the plinth.

ABOVE GROUND PIPEWORK, MAX. SUPPORT SPACINGS (M)			
Pipe Diameter (mm)	SDR 11	SDR 17	SDR 26
32	0.60	•	•
63	0.80	•	•
90	0.95	0.80	•
110	1.00	0.90	•
125	1.15	1.00	•
160	1.40	1.30	1.20
180	1.50	1.40	1.30
225	1.80	1.60	1.50
250	2.00	1.80	1.70
315	2.25	2.10	1.90
355	2.75	2.50	2.30
400	3.00	2.75	2.50
450	3.25	3.00	2.80
500	3.50	3.20	3.00
560	3.75	3.50	3.20
630	4.00	3.70	3.40

Figure 31. Maximum Support Spacings for Above Ground Pipework. For availability of pipe sizes above 630mm, please contact the Wavin Sales Office.

Above Ground Installation

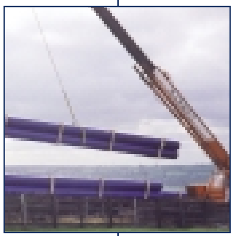
Where polyethylene pipe is to be installed above ground, WavinBlack PE systems should be used, providing protection against the effects of ultra-violet. Where blue PE systems are specified, the pipe requires protection against exposure to sunlight.

As polyethylene is a flexible pipe material, adequate pipe support must be provided to prevent sagging. Pipe supports should be designed to support both the pipe weight and its contents and also accommodate the weight of any heavy fittings, valves etc. The pipe brackets, straps or plinths should have flat surfaces, and be 0.5 x pipe O.D. or 100mm min wide (whichever is the greater) and have non-abrasive surfaces to prevent damage to the pipe. The support and bracketing design should allow for the stresses generated from thermal movement and if, for aesthetic reasons pipe deflection is unacceptable, continuous pipe support should be provided.

The above table gives recommendations for maximum support spacings for pipe full of water at an ambient temperature of 20˚C or below. At temperatures of 40˚C and above, continuous support is required. Above ground pipework should ideally be installed at or near the maximum operating temperature. The pipe will therefore be in its expanded state when installed.

As the pipeline cools, any contraction will be resisted by the pipe clamps, and when re-heated to its normal operating temperature, pipe sagging between supports will be minimised. Polyethylene is a good insulation material (thermal conductivity 0.4 w/m˚C) and will help prevent or delay the freezing of the pipe contents.

The pipe itself will not fail if the contents do freeze as PE can safely expand to cater for the increased volume. It is, however, good practice for operational reasons to insulate pipework to prevent freezing and to ensure that the insulation is waterproofed. Pipework should be protected from possible impact damage and provision should be made for draining down horizontal pipe runs at low points in the system.



Contaminated Ground

Polyethylene is resistant to most naturally occurring ground contaminants. However, the greater use of previously developed land (brownfield sites) is resulting in a greater potential exposure to harmful contaminants.

The main concern for potable water pipework is the risk of long term mechanical damage to the material and of more importance, the contamination may cause water quality problems, taste and odour, due to permeation through the pipe wall. Former industrial sites pose the greatest problem. Development of the following sites should be carefully assessed:

- Coal workings, including coking and town gas production.
- Chemical works
- Gas works
- Paint and varnish works
- Wood plants (preservatives)
- Landfill sites
- Garages/petrol stations

Where there is a known risk of contamination, professional guidance should be sought on soils analysis to identify the range and degree of contaminants. The analysis can then be used to determine the suitability for polyethylene potable mains and services and whether suitable protection can be provided.

In some instances where contamination is negligible protection can be given with a clean sand/granular surround and a heavy gauge polyethylene membrane lining to the trench. If conditions are such that the use of polyethylene would not be suitable, the ‘Trigon’ barrier pipe has been developed specifically for carrying potable water through contaminated land. Further guidance is available from the Wavin Technical Services Helpdesk.

Handling & Storage

General Principles

Wavin polyethylene pipe systems are tough and relatively light and easy to handle although they can be damaged by sharp objects through scoring or gouging.

Therefore it is important that pipe and fittings are handled sensibly and with care, for the operatives safety as well as for the protection of the pipe and fittings.

Pipes and fittings should not be dropped or thrown from vehicles, or dragged across rough ground which may cause scoring. Pipe with scoring in excess of 10% of wall thickness should be clearly marked as damaged and discarded.

Polyethylene is unaffected by freezing conditions. Pipe can, however, become very slippery and extra care should be exercised during handling and installation. In general all protective packaging should remain in place as long as practicable before use.

All packaging should be disposed of sensibly according to the requirements of the site.

Storage

Pipe, whether bundles, coils or loose pipe must be stored in a manner which is both safe and which keeps the product free from damage. Pipe ends in particular should be protected, as distortion or damage may cause difficulties in jointing.

Pipe and fittings should be stored away from risk of damage from exhausts and other heat sources. Care is required to avoid any contact with solvents and oils, eg. spillage from site diesel tanks and exhausts.

Pipe and large fabricated fittings can be stored externally for up to a year. However for longer term storage cover should be provided to avoid UV damage. Electrofusion fittings should be stored under cover and kept dry. Fittings packaging must be kept intact up to the point of use.

Loose Pipes

Individual pipes should be stacked on level ground, free of stones and sharp objects, with timber batten supports at 1m centres. The pipe can be stored in pyramid fashion up to 1m high and should be securely staked to avoid collapse.
See Figure 32.

Pipe strung out on site should be protected from damage, eg coned off or within a barrier system and pipe end caps should be left in place to prevent the ingress of dirt, vermin etc.

Figure 32. Loose Pipe Storage

Bundled Pipe

Pipe bundles should be stored on level ground and can be stored up to 3m high.

Small Diameter Coils

Small diameter coils, which are film wrapped and delivered on pallets, should remain on the pallet and stored on flat ground until required. Individual film wrapped coils should be stored flat on level ground. Again ensure there are no large stones or sharp objects, which may damage the pipe.

Free Standing Coils

Free standing coils (FSC's) up to 180mm diameter can potentially cause injury if handled in the wrong manner, therefore FSC's should be stored flat on battens up to a maximum of 2.5 metres high. Timber battens should also be placed between coils to enable fork truck access or for slinging purposes.

Transport

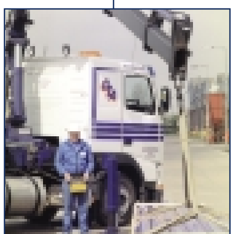
Pipe should be transported on a flat bed vehicle, which is free from any sharp objects, nails etc. Full loads direct from the factory can be offloaded with a vehicle mounted Hi-Ab crane and are often delivered direct to site.

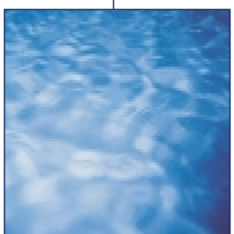
Pipe bundles should be offloaded by crane or fork truck. With crane offloading the bundles can be lifted with wide band slings; chains, hooks or steel rope should not be used.

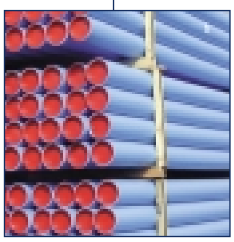
Fork truck and side loader offloading should be carried out by trained operators only; care is required to avoid damage by the metal fork blades.

Free standing coils (FSC's) are delivered on dedicated caged vehicles and off-loaded by Hi-Ab crane. They should be handled on site by fork truck or crane with slings for lifting into the trailer/dispensers.

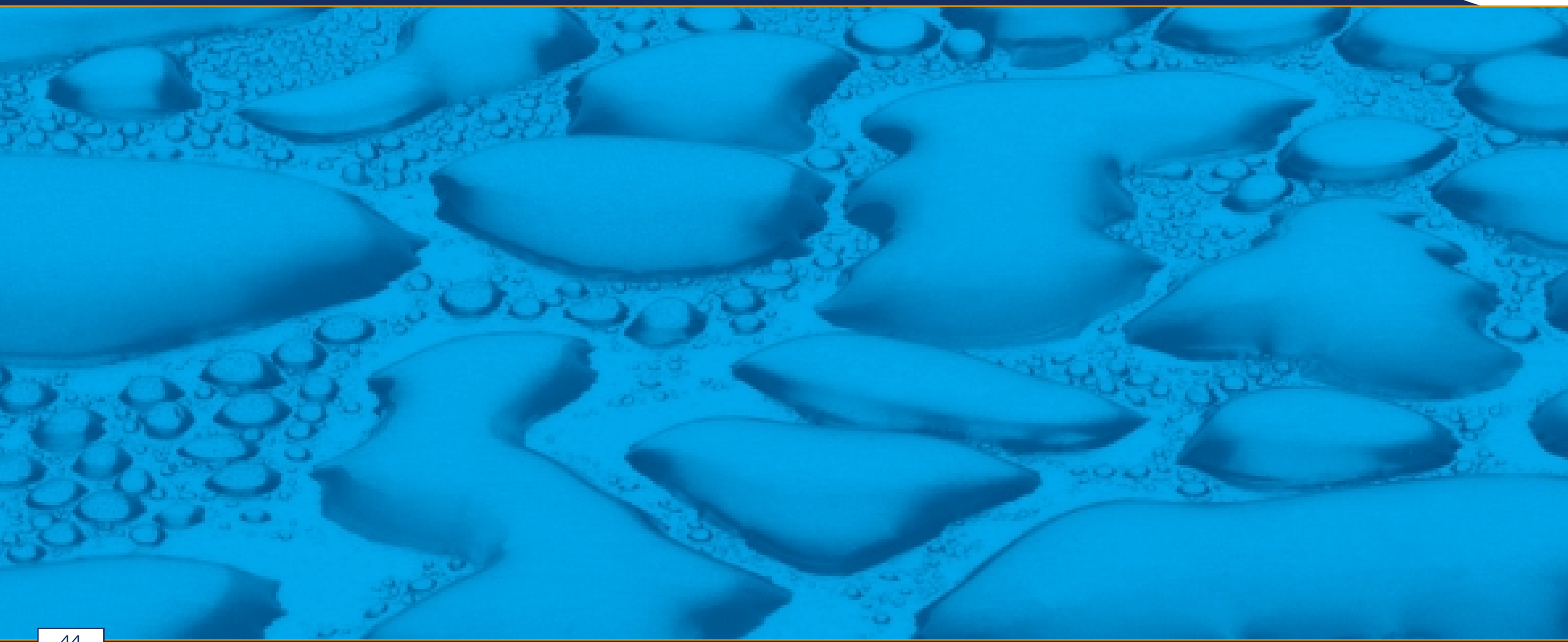
FSC's are banded in individual layers to allow the pipe to be dispensed in a safe and controlled manner; particular care should be taken with pipe ends so that they are secured when pipe is released from the coil dispenser.







Handling & Storage



Safety Note

FSC's contain a great deal of stored energy and should be handled by trained operatives only, with the correct dispensing and handling equipment.

Drums

In addition to FSC's Wavin also offer drummed pipe, which provide longer lengths of pipe, eg up to 220m of 180mm pipe.

Drums are delivered direct to site on a low loader and are normally dispensed direct from the vehicle by pulling off with a JCB for example. Drums give an economical option for long pipe runs and our Field Engineers are available to advise on the optimum use of drums.

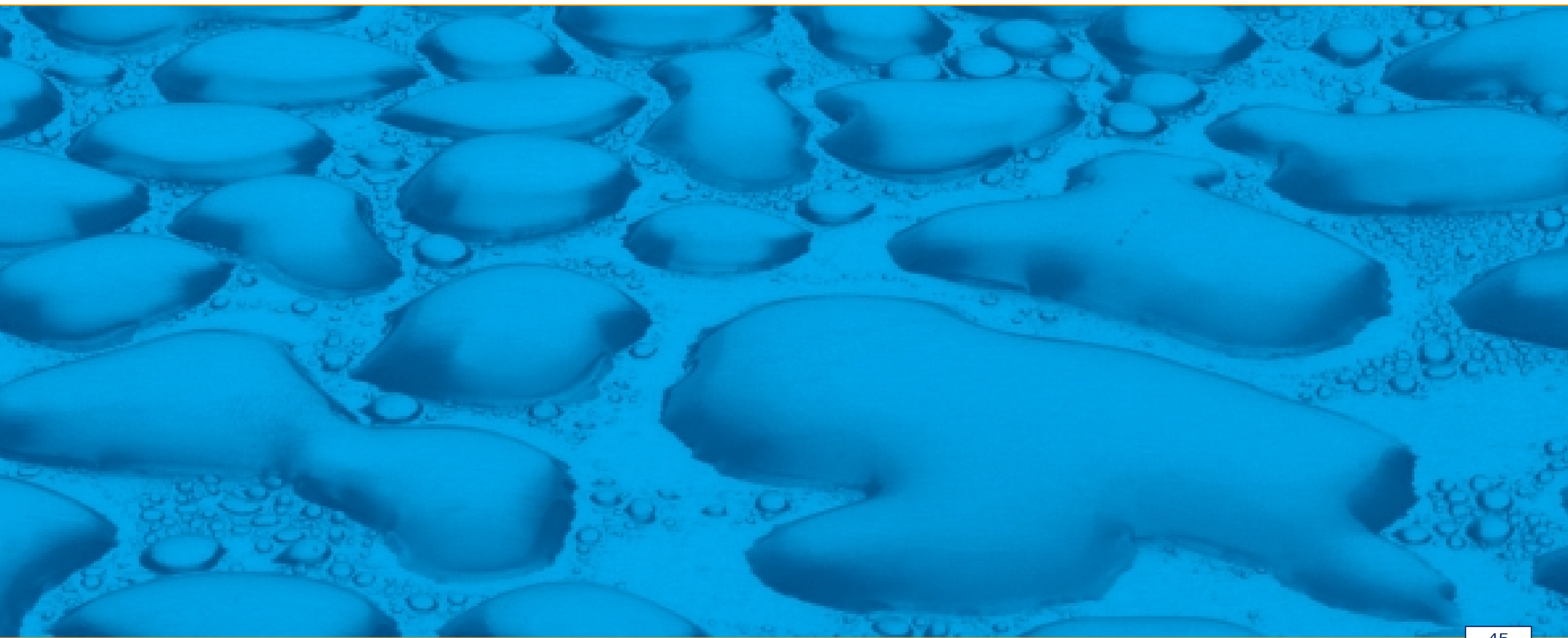
Fittings Information

Electrofusion fittings should be stored under cover and kept dry, fittings should be kept boxed and in their sealed bags up to the point of use.

Larger diameter fabricated fittings can be stored externally for up to 1 year. However they must be stored to avoid damaging the pipe ends, as this may cause problems in jointing. As with pipe, fittings should not be stored close to heat sources or exhausts or where there may be a risk of contamination from chemicals, solvents and oils.

Small Diameter Coils

All small diameter pipe 20 - 32mm are film wrapped and palletised, individual coils should be cut from the pallet as required. Pipe should be dispensed from the centre of the coil as required, with the pipe end plug being replaced to prevent the ingress of dirt.



Health & Safety

Wavin have been involved in the manufacture and supply of plastics pipe systems to the Water Industry for 45 years and with polyethylene pipe products for over 25 years.

At all stages in the supply chain, from manufacturing through to transport and delivery to the customer's site, Wavin are committed to the safety of all personnel involved in the handling of their products, and actively promote safe practices throughout all of its operations.

Ingestion

Polyethylene is classified as chemically unreactive and regarded as being biologically inert. Ingestion of PE in any form should, however, be avoided.

Physical Contact

PE is not considered to be a skin irritant. However, when cutting or scraping PE, dust particles may cause eye irritation and appropriate protective eyewear should be used.

Inhalation

PE does not release harmful fumes at normal ambient temperatures. Inhalation of PE dust can irritate the respiratory system and where possible cutting or scraping operations should be carried out in well-ventilated areas.

Fire Hazards

Polyethylene will melt at 120 - 135˚C and above 300˚C will degrade to produce carbon dioxide, carbon monoxide, water and small amounts of various hydrocarbons and aldehydes. These gases may ignite and provide heat to accelerate the process.
Burning, molten droplets of material may be released which could ignite adjacent materials.

Avoid inhalation of smoke or fumes as the combustion of PE may release toxic materials.
Do not allow PE dust particles to accumulate as in extreme circumstances there can be a risk of dust explosion.
All electrical equipment should be carefully sited and earthed, likewise with the siting of any potential heat sources.
In the event of fire, any fire extinguisher may be used, powder extinguishers are very effective in quenching flames.

Water sprays are especially effective in rapidly cooling and damping down a fire but are not recommended.

Handling

Polyethylene pipe and fittings should be handled in accordance with instructions in the Handling Section of this guide and also in accordance with the instructions in the WRc Polyethylene Manual.

Particular care should be observed when handling large diameter pipe and fittings and during cold frosty weather. Appropriate safety clothing and equipment should be used at all times when handling PE pipes and fittings.

Safety Caution

When handling or dispensing coils or drummed PE pipe extreme care should be taken, especially with 90mm diameter and larger pipe where a coil-dispensing trailer must be used.

Operatives should be adequately trained and experienced in the use of large diameter coiled pipe.

Safety in Jointing

Fusion welding of PE pipe and fittings produces molten PE and will adhere strongly to skin if allowed to come into contact and cause severe burns. Protective gloves should be worn during the jointing process and when handling hot equipment.

Jointing should always be carried out in well-ventilated areas. Fusion welding procedures produce small quantities of fumes and inhalation of fumes should be avoided or minimised.

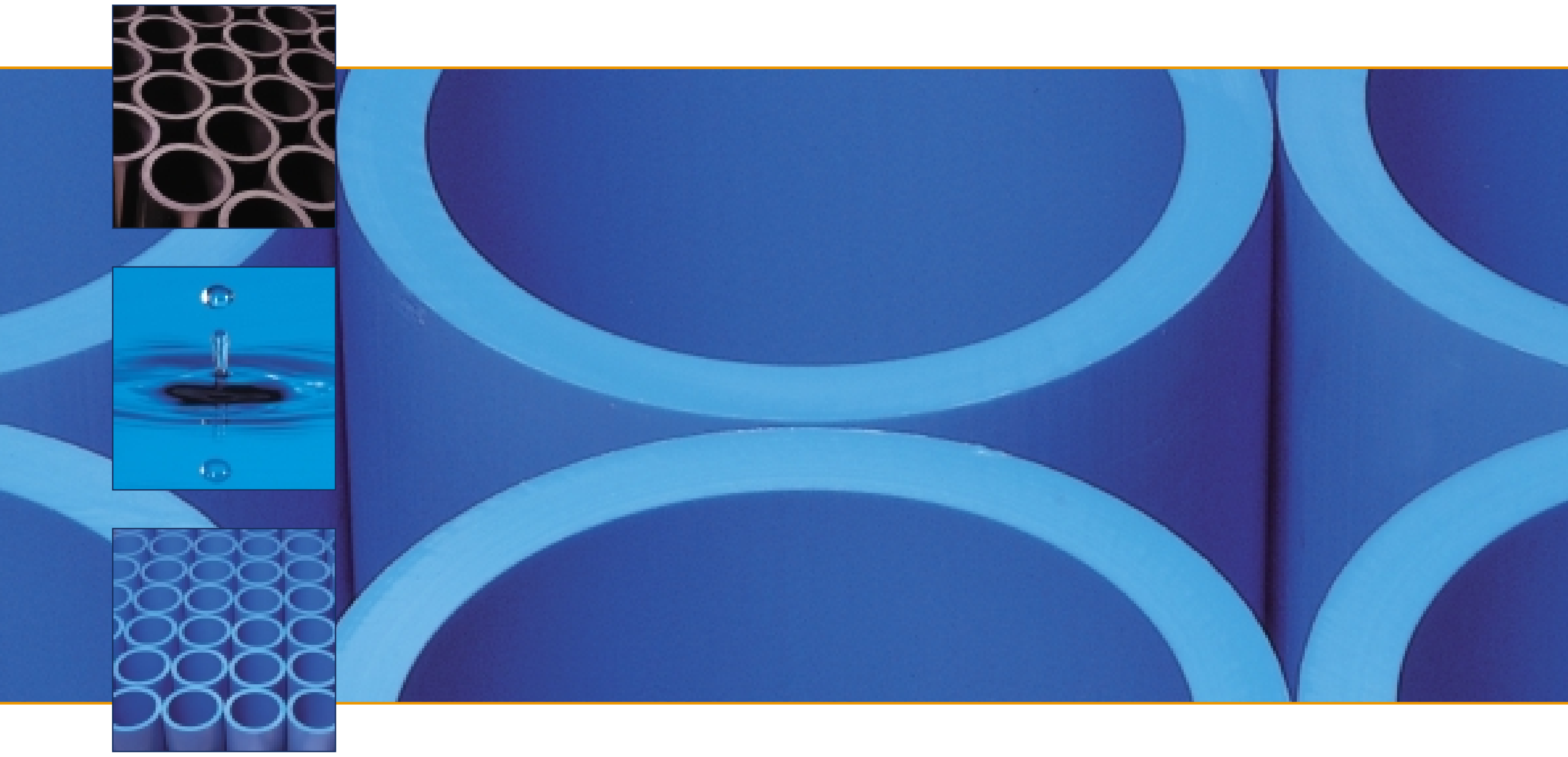
The Electrofusion jointing process can cause the ejection of molten material if the joint assembly is incorrectly carried out. Operatives should wear safety gloves and goggles during jointing and avoid standing directly over the joint area.

Environment

Polyethylene is biologically inert and is not considered to be dangerous to the environment.

Waste polyethylene material can be reprocessed into new pipe products or other products and there is a growing market for such waste materials.

For further details on re-cycling of waste polyethylene please contact the Wavin Technical Services Helpdesk.



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