Hepworth

POLYETHYLENE PIPES AND FITTINGS

FOR PRESSURISED WATER, GAS AND INDUSTRIAL APPLICATIONS

+GF+ GEORG FISCHER PIPING SYSTEMS

TECHNICAL GUIDE

Hepworth

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INTRODUCTION

Hepworth PME (Qatar) WLL was established in 2003 and is the leading manufacturer and supplier in Qatar of quality thermoplastic piping systems to the building & construction, civil engineering and industrial market sectors.

Hepworth PME (Qatar) WLL operates a management system based on ISO 9001, ISO 14001 and ISO 45001. In 2009 Hepworth PME (Qatar) WLL became the first plastic pipe manufacturer in Qatar to achieve "kitemark" third party certification on its soil & waste and drainage products, clearly demonstrating the company's commitment and dedication to supplying its customers with the highest quality piping systems.

Hepworth PME (Qatar) WLL products are manufactured to relevant British, European, ASTM and International Standards, quality, performance and reliability are the hallmarks synonymous with the Hepworth brand name and provide complete piping systems solutions incorporating pipes, fittings, manual and actuated valves, measurement and control systems and jointing equipment and accessories from a selected group of international manufacturers who further enhance the scope of supply to accommodate other aspects of water and gas flow management. Encompassing diverse fields such as irrigation to firefighting and district cooling to domestic water supply, complete systems and individual components can be sourced from one professional outlet.

Hepworth PME (Qatar) WLL has the following advantages:

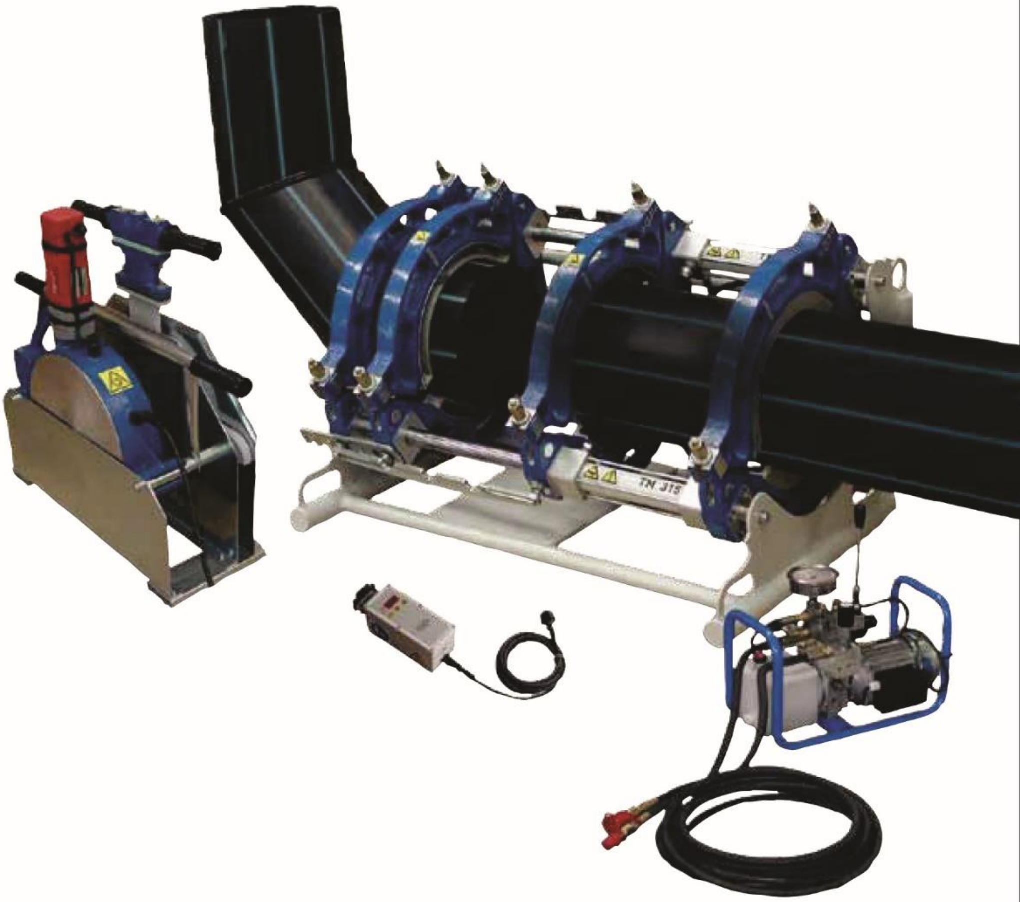
- ✓ Quality of Products
- ✓ Excellent Training and Technical support
- ✓ Comprehensive range of pipes, fittings and accessories from a single source
- ✓ Stringent and Independent Quality Control Unit
- ✓ Substantial stock
- ✓ Trustable Customer Service
- ✓ Direct Delivery to your Site/Shop
- ✓ Competitiveness
- ✓ Specified by Consultant
- ✓ Knowledge and Competence of Staff

Hepworth Management System

Quality Assurance

Hepworth PME (Qatar) WLL operates a management system based on ISO 9001, ISO 14001 and ISO 45001. We also maintain several BSI Kitemark licenses. Strict quality control procedures are routinely conducted throughout the production process to ensure that our products are fully compliant with the relevant specifications. We are audited on a regular basis by British Standards Inspectorate including testing of samples in the UK facility to further ensure that we are operating within the scope of our Kitemark licenses. Measuring and test instruments used in our laboratory are routinely verified and are traceable to International Standards. Our commitment to quality control thus serves to assure the client that our products are of the highest quality and provide and excellent service life.

- an optimum process organization
- a certified Quality Management System in accordance with ISO 9001:2015
- a certified Environmental Management System in accordance with ISO 14001:2015
- a certified Occupational Health and Safety Management System in accordance with ISO 45001:2018
- established active continuous improvement processes (CIP), which utilize the knowledge and experience of our staff
- a continuous evaluation and improvement of our Personnel Management System



Polyethylene Pipes

Polyethylene pipes according to ISO 4427, ISO 4437 and BS EN 1555 are extruded in our factory in Doha, Qatar with diameters ranging from 20mm to 800mm SDR's (Standard Dimensional Ratio)* of SDR 11 and SDR 17 are the most frequently requested specifications we can also produce SDR 9 (20 bar), SDR 21 (6 bar) and SDR 26 (5bar). Black and blue colours are available for water applications whilst yellow is commonly used for gas. Pipes can also be produced with colour coded stripes to suit various applications. For pipes of other SDR's, diameters and colours, please contact our Technical Department. Pipes can be supplied as cut lengths or, for diameters up to 110, in coiled form.

The raw material used in the manufacture of pipes is of the highest quality and it is important to note that we use only 100% virgin material in our production. Each raw material batch undergo comprehensive testing program to ensure full compliance with respective standard requirements.

A wide range of both standard and bespoke fabricated fittings with diameters of up to 1200mm are produced in our factory. Our design team can offer solutions for specific piping applications in situations where the use of a standard fitting is not practical or possible. We have a wealth of experience in designing bespoke fittings which can overcome many on-site application problems. Please contact our Technical Department for further information or assistance.

**Standars Dimensional Ratio *(SDR) is defined as Outside Diameter/Wall Thickness*

Polyethylene Pipe Systems

Hepworth PME (Qatar) WLL manufactures a full range of PE80 and PE100 Polyethylene pipes at its factory in Qatar that meet the requirements of international standards

This Manual contains details of the following polyethylene pipes for potable water supply and industrial uses;

Application	Medium Nominal	Size Range	Specifications
PE80 Pipes for below ground use	potable water gas	16mm - 800mm	ISO 4427-2 ISO 4437-2 BS 1555-2
Pe80 Pipes for above and below ground use (i.e. industrial uses and other applications below ground, e.g. sewerage and pumping mains)	various	16mm - 800mm	ISO 4427-2
PE100 Pipes for below ground use	potable water gas	16mm - 800mm	ISO 4427-2 ISO 4437-2 BS 1555-2
Pe100 Pipes for above and below ground use, (i.e. industrial uses and other applications below ground, e.g. sewerage and pumping mains)	various	16mm - 800mm	ISO 4427-2

Technical & Design Services

A comprehensive advice and consultancy service is available from Hepworth PME (Qatar) WLL. Our team of qualified water services and sewerage engineers provide comprehensive advice on all Hepworth PME polyethylene and PVC-U water supply and sewerage systems.

Polyethylene Pipes

Fabrication Division

In our fabrication factory in Qatar, we are able to produce an extensive range of standard and bespoke butt-welded fitting to suit almost any situation. Our strength is in our ability to design bespoke according to client's requirements for situation where a standard fitting is simply not suitable. Using a wide range of Georg Fischer butt-fusion workshop machines our trained technicians can produce the necessary fitting – fast. Each butt-welded joint is supplied with a certificate of traceability confirming that the joint has been processed according to specification. Traceability extends as far back as the batch number of virgin material used in the production of the original pipe extrusion. This ensures that the client can be confident about the integrity of the joints and ability of the fitting to perform.

Manufacturing Standards

Polyethylene pipes for the water supply are manufactured according to ISO 4427 and also covered by two British Standard Kitemarks Licenses for all sizes and SDR's our production capability. For gas applications we produce BS kitemarked pipes according to ISO 4437 / BS EN 1555 and if required.

A Note to Specifiers

When specifying polyethylene pipe for water supply it is important that the correct standards are recommended to ensure that the pipe supplied is suitable for the intended use.

PE pipes from manufacturers bearing the BSI Kitemark have been type tested by the British Standards Institution and this is therefore an assurance that the product complies with the relevant standard ISO 4427 and EN 12201 are for PE pipe intended to be used for the conveyance of water under pressure for general purpose, as well as for the supply of drinking water. Fittings should also have internationally recognized approval. If PE pipes are to be used above ground they should be protected against UV light in accordance with recommended practice.

Polyethylene Fusion Equipment

Machine Hire

In certain cases it not always viable for a clients to purchase Butt-fusion or electro-fusion welding machines. Hepworth PME (Qatar) WLL offers one of the region's rental PE welding machines, the expertise to maintain and calibrate such and the ability to provide certified training to client's Engineers on site. Where necessary Hepworth PME (Qatar) WLL can also supervision to ensure that all jointing is executed according to specification avoiding costly remedial work as a result of poor welding techniques.

	Pipe Series																					
	SDR 6 S 2,5		SDR 7.4 S 3,2		SDR 9 S 4		SDR 11 S 5		SDR 13,6 S 6,3		SDR 17 S 8		SDR 17,6 S 8,3		SDR 21 S 10		SDR 26 S 12,5		SDR 33 S 16		SDR 41 S 20	
	Nominal Pressure, PN [a] in bar																					
PE 40	–		PN 10		PN 8		–		PN 5		PN 4		–		PN 3,2		PN 2,5		–		–	
PE 63	–		–		–		PN 10		PN 8		–		PN 6		PN 5		PN 4		PN 3,2		PN 2,5	
PE 80	PN 25		PN 20		PN 16		PN 12,5		PN 10		PN 8		–		PN 6 [c]		PN 5		PN 4		PN 3,2	
PE 100	–		PN 25		PN 20		PN 16		PN 12,5		PN 10		–		PN 8		PN 6 [c]		PN 5		PN 4	
Nom. Size	Wall thicknesses [b]																					
	emin	emax	emin	emax	emin	emax	emin	emax	emin	emax	emin	emax	emin	emax	emin	emax	emin	emax	emin	emax	emin	emax
16	3,0 [c]	3,4	2,3 [c]	2,7	2,0 [c]	2,3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20	3,4	3,9	3,0	3,4	2,3	2,7	2,0 [c]	2,3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25	4,2	4,8	2,5	4,0	3,0	3,4	2,3	2,7	2,0 [c]	2,3	–	–	–	–	–	–	–	–	–	–	–	–
32	5,4	6,1	4,4	5,0	3,6	4,1	3,0 [c]	3,4	2,4	2,8	2,0 [c]	2,3	2,0 [d]	2,3	–	–	–	–	–	–	–	–
40	6,7	7,5	5,5	6,2	4,5	5,1	3,7	4,2	3,0	3,5	2,4	2,8	2,3	2,7	2,0 [d]	2,3	–	–	–	–	–	–
50	8,3	9,3	6,9	7,7	5,6	6,3	4,6	5,2	3,7	4,2	3,0	3,4	2,9	3,3	2,4	2,8	2,0	2,3	–	–	–	–
63	10,5	11,7	8,6	9,6	7,1	8,0	5,8	6,5	4,7	5,3	3,8	4,3	3,6	4,1	3,0	3,4	2,5	2,9	–	–	–	–
75	12,5	13,9	10,3	11,5	8,4	9,4	6,8	7,6	5,6	6,3	4,5	5,1	4,3	4,9	3,6	4,1	2,9	3,3	–	–	–	–
90	15,0	16,7	12,3	13,7	10,1	11,3	8,2	9,2	6,7	7,5	5,4	6,1	5,1	5,8	4,3	4,9	3,5	4,0	–	–	–	–
110	18,3	20,3	15,1	16,8	12,3	13,7	10,0	11,1	8,1	9,1	6,6	7,4	6,3	7,1	5,3	6,0	4,2	4,8	–	–	–	–
125	20,8	23,0	17,1	19,0	14,0	15,6	11,4	12,7	9,2	10,3	7,4	8,3	7,1	8,0	6,0	6,7	4,8	5,4	–	–	–	–
140	23,3	25,8	19,2	21,3	15,7	17,4	12,7	14,1	10,3	11,5	8,3	9,3	8,0	9,0	6,7	7,5	5,4	6,1	–	–	–	–
160	26,6	29,4	21,9	24,2	17,9	19,8	14,6	16,2	11,8	13,1	9,5	10,6	9,1	10,2	7,7	8,6	6,2	7,0	–	–	–	–
180	29,9	33,0	24,6	27,2	20,1	22,3	16,4	18,2	13,3	14,8	10,7	11,9	10,2	11,4	8,6	9,6	6,9	7,7	–	–	–	–
200	33,2	36,7	27,4	30,3	22,4	24,8	18,2	20,2	14,7	16,3	11,9	13,2	11,4	12,7	9,6	10,7	7,7	8,6	–	–	–	–
225	37,4	41,3	30,8	34,0	25,2	27,9	20,5	22,7	16,6	18,4	13,4	14,9	12,8	14,2	10,8	12,0	8,6	9,6	–	–	–	–
250	41,5	45,8	34,2	37,8	27,9	30,8	22,7	25,1	18,4	20,4	14,8	16,4	14,2	15,8	11,9	13,2	9,6	10,7	–	–	–	–
280	46,5	51,3	38,3	42,3	31,3	34,6	25,4	28,1	20,6	22,8	16,6	18,4	15,9	17,6	13,4	14,9	10,7	11,9	–	–	–	–
315	52,3	57,7	43,1	47,6	35,2	38,9	28,6	31,6	23,2	25,7	18,7	20,7	17,9	19,8	15,0	16,6	12,1	13,5	9,7	10,8	7,7	8,6
355	59,0	65,0	48,5	53,5	39,7	43,8	32,2	35,6	26,1	28,9	21,1	23,4	20,1	22,3	16,9	18,7	13,6	15,1	10,9	12,1	8,7	9,7
400	–	–	54,7	60,3	44,7	49,3	36,3	40,1	29,4	32,5	23,7	26,2	22,7	25,1	19,1	21,2	15,3	17,0	12,3	13,7	9,8	10,9
450	–	–	61,5	67,8	50,3	55,5	40,9	45,1	33,1	36,6	26,7	29,5	25,5	28,2	21,5	23,8	17,2	19,1	13,8	15,3	11,0	12,2
500	–	–	–	–	55,8	61,5	45,4	50,1	36,8	40,6	29,7	32,8	28,3	31,3	23,9	26,4	19,1	21,2	15,3	17,0	12,3	13,7
560	–	–	–	–	–	–	50,8	56,0	41,2	45,5	33,2	36,7	31,7	35,0	26,7	29,5	21,4	23,7	17,2	19,1	13,7	15,2
630	–	–	–	–	–	–	57,2	63,1	46,3	51,1	37,4	41,3	35,7	39,4	30,0	33,1	24,1	26,7	19,3	21,4	15,4	17,1
710	–	–	–	–	–	–	64,5	71,1	52,2	57,6	42,1	46,5	40,2	44,4	33,9	37,4	27,2	30,1	21,8	24,1	17,4	19,3
800	–	–	–	–	–	–	72,6	80,0	58,8	64,8	47,4	52,3	45,3	50,0	38,1	42,1	30,6	33,8	24,5	27,1	19,6	21,7
900	–	–	–	–	–	–	–	–	–	–	53,3	58,8	51,0	56,2	42,9	47,3	34,4	38,3	27,6	30,5	22,0	24,3
1000	–	–	–	–	–	–	–	–	–	–	59,3	65,4	56,6	62,4	47,7	52,6	38,2	42,2	30,6	33,5	24,5	27,1
1200	–	–	–	–	–	–	–	–	–	–	–	–	–	–	57,2	63,1	45,9	50,6	36,7	40,5	29,4	32,5
1400	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	53,5	59,0	42,9	47,3	34,3	37,9
1600	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	61,2	67,5	49,0	54,0	39,2	43,3

a) PN values are based on C = 1,25.
b) Tolerances in accordance with grade V of ISO 11922-1:1997 [1].
c) Actual calculated values are 6,4 bar for PE 100 and 6,3 bar for PE 80.
d) The calculated value of emin (ISO 4065 [2]) is rounded up to the nearest value of either 2,0 2,3 or 3,0. This is to satisfy certain national requirements

BS EN 1555
ISO 4437

Table 2 - Minimum wall thickness for pipes SDR 17.6, SDR 17 and SDR 11

Dimensions : Millimeters

Nominal size DN/OD	Minimum wall thickness e_{min} [a]		
	SDR 17.6 [b]	SDR 17	SDR 11
16	2,3 c	2,3 c	3,0 c
20	2,3 c	2,3 c	3,0 c
25	2,3 c	2,3 c	3,0 c
32	2,3 c	2,3 c	3,0
40	2,3	2,4	3,7
50	2,9	3,0	4,6
60	3,6	3,8	5,8
75	5,2	4,5	6,8
90	6,3	5,4	8,2
110	6,3	6,6	10,0
125	7,1	7,4	11,4
140	8,0	8,3	12,7
160	9,1	9,5	14,6
180	10,3	10,7	16,4
200	11,4	11,9	18,2
225	12,8	13,4	20,5
250	14,2	14,8	22,7
280	15,9	16,6	25,4
315	17,9	18,7	28,6
355	20,2	21,1	32,2
400	22,8	23,7	36,3
450	25,6	26,7	40,9
500	28,4	29,7	45,4
560	31,9	33,2	50,8
630	35,8	37,4	57,2

a $e_{min} = e_n$.
b The SDR 17,6 series will be removed at the next revision of this standard.
c The calculated values of e_{min} have been rounded up to 2,3, mm for SDR 17,6 and SDR 17 and 3,0 mm for SDR 11, respectively.

6.3.2 Tolerance on the wall thickness

The tolerance on the wall thickness at any point shall conform to Table 3 footnote a, which is derived from ISO 11922-1

Specifications

Minimum Required Strength (MRS)

Polyethylene pipes and fittings materials are evaluated by their Minimum Required Strength (MRS).

When PE80 pipes are hydrostatically tested at 20°C, ISO 1167 specify a Minimum Required Strength at 50 years of 8MPa (80 daN/cm2) – MRS80

When PE100 pipes are hydrostatically tested at 20°C, ISO 1167 specifies a Minimum Required Strength at 50 years of 10MPa (100 daN/cm2) – MRS100.

Design Stress

The design stress for PE80 pipes is 6.3MPa. The design stress for PE100 pipes is 8 MPa.

PE80 Pipe Systems

Introduced in the early 1980's, to replace low density materials, PE80 polyethylene pipe is today used in the water industry for underground potable water supply, above ground water supply and industrial uses.

Its many benefits include:

Fully end-load bearing pipe system
Hydraulically smooth bore
Surge attenuating characteristics
Corrosion-free and resistant to most chemicals
Extremely tough and durable
Comparatively light in weight and easy to handle
Jointing by butt welding, electrofusion or mechanical joints
Inherently flexible in long lengths
Available in straight pipe lengths or in long, continuous lengths in coils.

Standard Dimension Ratio (SDR)

In polyethylene pipes of 25mm nominal size and above, the pipe wall thickness bears a constant ratio to the outside diameter, for a given pressure rating. This is known as the Standard Dimension Ratio (SDR), which is calculated as follows: -

$$\frac{\text{Nominal outside diameter}}{\text{Minimum wall thickness}} = \text{SDR}$$

E.g. The SDR of a 90mm, 12.5 bar rated PE80 pipe is:-

$$\frac{90}{8.2} = \text{SDR } 11$$

The SDR of a 90mm, 10 bar rated, PE100 pipe is:-

$$\frac{90}{5.3} = \text{SDR } 17$$

Pressure Rating

The pressure rating of polyethylene pipes is generally referred to in 'bar', where 1 bar equals 10.2 head (approx.) Table 1 gives the pressure rating and SDR of both PE80 and PE100 pipes.

PE100 Pipe Systems

A high performance PE100 polyethylene pipe material for use in underground potable water and gas mains. The new material's higher permissible design strength (PE100 – 8MPa: PE80 – 5MPa), together with its superior toughness, allows the design engineer to use PE100 pipes at substantially higher operating pressures than PE80 pipes with equivalent SDR rating.

In addition to their superior qualities, PE100 also has greater resistance to rapid crack propagation. PE100 pipes are supplied for working pressures up to 16 bar for underground potable water and 10 bar for gas mains.

C	Material	SDR17	SDR11	SDR9
		pressure bar	pressure bar	pressure bar
Water	PE80	8	12.5	16
1.25	PE100	10	16	20
Gas	PE80	5	8	10
2	PE100	6	10	12.5

All pressures based on 50 year design life at 20°C Average Temperature

Table 1 -SDR and Maximum Rated Working Pressures

Characteristics and Properties

Typical Physical Properties

Table 3 shows typical properties of both PE80 and PE100 polyethylene raw materials.

PE80 – Physical Properties

The physical properties of pipe produced from these compounds combine the flexibility and toughness of low density polyethylene and the strength and rigidity of high density to give a highly durable pipe eminently suited for the distribution of potable water and gas under pressure.

PE100 – Physical Properties

In addition to the quoted properties of PE80, PE100 pipe has enhanced toughness, higher permissible design strength and improved resistance to rapid crack propagation. PE100 pipe offers the water engineer substantial benefits in efficiency and economy.

PE properties (reference values)

	PE 80	PE100		
Characteristics	**Value**	**Value**	**Units**	**Test Standard**
Density	0..93	0.95	g/cm^3	EN ISO 1183 - 1
Yield stress at 23°C	18	25	N/mm^2	EN ISO 527 - 1
Tensil e-modulus at 23°C	700	900	N/mm^2	EN ISO 527 - 1
Charpy notched impact strength at 23°C	110	83	kl/mm^2	EN ISO 179 - 1/1eA
Charpy notched impact strength at -40°C	7	18	kl/mm^2	EN ISO 179 - 1/1eA
Ball indentation hardness (132N)	37		Mpa	EN ISO 2039 - 1
Crystalline melting point	131	130	°C	DIN 51007
Thermal expansion coefficient	0.15 ... 0.20		mm/m K	DIN 53752
Heat conductivity at 23°C	0.43	0.38	W/m K	EN 12664
Water absorption at 23°C	0.01 - 0.04		%	EN ISO 62
Colour	9005		-	RAL
Limiting oxygen index (LOI)	17.4		%	ISO 4589

Table 3 - Physical Properties

*PE80 – Melt Characteristic

Melt characteristics of commercially available PE80 can vary. Pipes of different manufacture produced to the requirements of ISO 4427/4437, BS 6572 and kite marked or produced to WRC specifications 4.32.03 & 4.32.09 and stamped accordingly can be fusion jointed. In all other cases, please seek further advice from the Hepworth PME (Qatar) Technical Services Department.

*PE100 – Melt Characteristic

Melt characteristics of commercially available PE100 can vary. Pipes of different manufacture produced to the requirements of ISO 4427/4437 and WRC specification 4.32.13 and stamped accordingly can be fusion jointed. In all other cases, please seek further advice from the Hepworth PME (Qatar) Technical Services Department.

Characteristics and Properties

This section briefly describes the characteristics and properties of polyethylene as a guidance to the selection, design and use of the material for installation. Reference is also made to relevant research and testing procedures.

General Properties

The properties of polyethylene have been described as:

- Light and easy to handle
- Conveniently flexible
- Good fusibility
- Tough
- Strong
- Systems can be fully end-load bearing
- Resists cracking
- Non corrodible
- Resistant to chemical attack by aqueous media
- Low frictional resistance

Strength

The "strength" of a pipeline may be considered as the ability to withstand (hoop) stress in the pipe material under internal pressure over a prolonged period of time. The design stress considered is taken to be a life expectancy in **excess** of 50 years.

The stress/life characteristics are obtained by a standard universally accepted test procedure, **regression curve predictions**. The regression curve shows the performance ability of the material under a specified load for a design life in excess of 50 years.

The strength of polyethylene is known to be **time/temperature dependent**. This characteristic is used to assess the future available strength of the pipe material by generating regression curves from varying **stress/life to failure tests** at higher temperatures than that normally experienced in distribution mains. These prolonged tests, in excess of 10,000 hours, are accelerated for quality control purposes by using elevated temperatures (typically 80°C).

The method therefore identifies **a Minimum Required Strength (MRS)** value derived from the 50 year extrapolated **97.5% Lower confidence limit (LCL) failure stress**.

A safety factor is applied to the MRS to determine the **Hydrostatic Design Stress (HDS)**. Recent European practice has been to specify the ISO minimum safety factor for PE of 1.25 for buried water applications 2.0 for buried gas applications and 1.6 for above ground non gas applications. PE pipes are not recommended for above ground gas applications.

Using these analyses, the predicted minimum failure stress of **PE80** material is **8.0 MPa** – (based on the extrapolated 50 year 97.5% LCL stress value at 20°C). Figure 1 gives a regression curve (or series of data points) for a material at 20°C.

The predicted minimum failure stress of **PE 100** material is **10.0** MPa. With a design co-efficient of 1.25, the design stress of this material is 8.0.

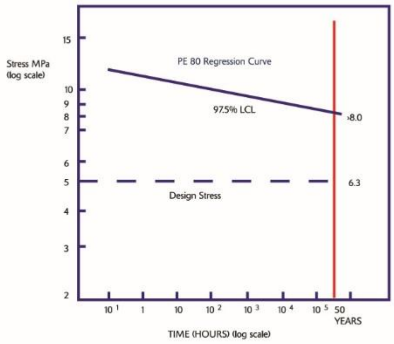


Figure 1-Regression Curves for PE80 Materials at 20°C

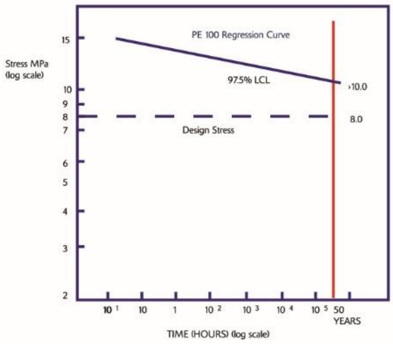


Figure 2-Regression Curves for PE100 Materials at 20°C

Characteristics and Properties

Toughness

In practice it is recognized that PE is a tough, resilient material capable of withstanding the normal rigours of pipelaying conditions. The many years of successful installation of polyethylene pipe in the gas and water industry adds confidence to this recognition. However, the definition and description of this characteristic is difficult and complex. There is no single test or measure one can apply, as it is a combination of many characteristics and properties.

Abrasion

Although the material has high resistance to abrasion by suspended particles being carried in the water, the external surface can be scratched and gouged by sharp objects. Careful handling is therefore required but provided the depth of the notch is no greater than 10% of the wall thickness there is no significant loss in the performance of the pipe.

Flexibility, Recovery and Creep

The inherent flexibility and recovery of PE enables the pipeline to absorb impact loads, vibration and stress caused by soil or ground movement. This also implies that PE pipes may have useful fatigue characteristics where cyclic loadings are present, (pumping mains, heavy traffic loading conditions, etc). Its absorption of ground movement is advantageous in potentially unstable areas such as recently filled ground or mining areas.

The property of flexibility and the ability to deform without permanent damage (creep/relaxation property) enables pipelines to be contoured to difficult road layouts or rapid changes of direction. Polyethylene is subject to creep under stress but those stresses developed will relax with time. This characteristic requires a different approach from the traditional pressure testing procedures.

Crack Resistance

PE is tough with brittle type failure difficult to achieve even in laboratory tests unless it is at very low temperature. Failure cracks are usually of a ductile nature and, so far, tests indicate that rapid crack propagation (RCP) in water filled SDR11 pipe is slow. Catastrophic failure, rapid crack propagation, appears unlikely under normal distribution conditions. The difference between brittle and ductile failure is illustrated in Specification ISO 1167.

Chemical Resistance and Stability

Corrosion Resistance

For all practical purposes PE is chemically inert within its normal temperature range of use. It does not rot, rust, pit, corrode or lose wall thickness through chemical or electrical reaction with the surrounding soil. It does not normally support the growth of, nor is affected by algae, bacteria or fungi.

Chemical Effects

PE has a good resistance to a wide range of chemicals. In the water supply context the main concern is the effect of certain chemicals existing in contaminated ground, some of which can have harmful effect upon the pipe material or may cause minor taste problems in extreme cases. In broad terms the most common harmful chemicals can be grouped into Oxidisers, Cracking Agents and certain solvents as follows:

Group	Generalised Examples	Effect on PE
Oxidisers	Very strong acids	Degradation
Cracking Agents	Detergents	No degradation but under high temperatures, accelerates cracking under stress in brittle manner
Solvents	Hydrocarbons, such as petrols and oils	No degradation but may be absorbed into pipe wall causing reduction in hoop strength and possible taste problems

Table 1 – Harmful Chemicals

Where pipelines are to be laid in environments where concentrations of such chemicals may prevail (e.g. garage forecourts, within certain processing works, etc) the use of PE is NOT recommended unless suitably protected. For further information, Hepworth PME (Qatar) Technical Services Department should be consulted. The effect of specific chemicals on polyethylene pipe can be requested from Sales Department.

Permeability

All grades of polyethylene can be shown to be permeable to certain gases and liquids under extreme conditions, the rate of permeation being mainly dependent upon the media involved and the wall thickness of the pipe concerned.

Weatherability and Temperature Changes

Generally PE material has good weatherability properties and can readily withstand the variations of weather without degradation but certain properties require consideration.

Coefficient of Expansion

PE has a coefficient of linear expansion of approximately between 0.16-0.20mm per meter per °C which is an order of magnitude greater than exists in metal pipelines and this characteristic must be considered carefully in the design of the pipeline and during installation. The coefficient of circumferential expansion is approximately one half the linear value and seldom presents problems in system design except where large diameter compression fittings are proposed.

Characteristics and Properties

Temperature Range

From the time of manufacture to the time that a PE pipeline is commissioned, the pipe will normally be subject to a range of temperatures and some exposure to UV light (sunlight). Both require attention during this period. Once installed underground, the effects are usually insignificant as the viscoelastic properties of the material make it quite adaptable to relaxing or adjusting with time to stresses imposed by thermal changes due to weather and soil temperature.

Temperature Stability

The exposure of PE to normal changes in temperature does not cause degradation of the material. During manufacture and fusion jointing the material is subjected to temperatures in the range of 200°C - 240°C and to safeguard against degradation at these high melt temperatures special stabilisers are used. PE pipe should not be used under pressure at constant temperatures in excess of 20°C without an appropriate reduction in its design pressure rating if the minimum design life of 50 years is to be achieved.

Low Temperature

The mechanical properties of polyethylene allow the pipe to be successfully operated in low temperature environments. Laboratory based tests indicate that PE will retain its flexibility until temperatures as low as -60°C are reached. At the moderately cold temperatures the low thermal conductivity of PE will delay the freezing of the water contained within the pipe. In addition, should the water become frozen, the inherent flexibility of the material will accommodate the expansion due to the formation of ice without leading to rupture of the pipe wall.

UV Degradation

PE pipe is subject to a degree of degradation when exposed to excessive ultra violet light (sunlight). UV stabilisers (anti-oxidants) are used in the manufacture to counteract this effect and such material has withstood practical exposures for periods in excess of a year without apparent deleterious effects. This surface degradation has a particular impact when using fusion jointing techniques and leads to recommendations for the peeling of the surface of the material prior to jointing.

PE is basically intended for use in buried conditions unless protected from prolonged sunlight exposure. This is reflected in the current recommendation to provide protection when used in above-ground situations or when stored outside for periods greater than one year.

Thermal and Electrical Conduction

PE is a poor conductor of heat but is flammable, therefore a naked flame should not be used for the thawing of frozen pipework. At all times pipes should be protected against radiant heat that could raise its surface temperature above 60°C. PE is also a poor conductor of electricity and no attempt should, therefore, be made to use pipework constructed of the material as a means of earthing electrical equipment; similarly the contents of such pipes cannot be thawed by electrical techniques using the pipe as the conductor. Because of its high electrical resistivity, caution is required in the use of PE pipes where high levels of static electricity may be present.

Hydraulic Properties

The smooth bore of PE pipes enables them to be treated as "hydraulically smooth" when used for the conveyance of potable water. The smooth surface discourages the formation of scale in hard water areas but particular waters may, at certain times, give rise to slime and silt deposits associated mainly at joints or fittings which may increase frictional losses.

For the purpose of calculation of flow rates in NEW pipelines the Colebrook-White formula may be used in which the value of the hydraulic roughness factor Ks is 0.003mm for clean water.

Other Applications

Although principally developed for conveying water and gas, polyethylene pipes have many other applications, some of which are:-

(1) Sewage pumping mains, where the materials resilience provides excellent resistance to the surge pressures generated by continuous pump starting and stopping.

(2) Slurry conveyance in quarries, mines, etc. In this application, PE pipes provide superb resistance to abrasion. When comparing PE pipes with conventional pipes used for slurry applications, considerable increase in lifetimes can be achieved.

(3) Fire mains FM Approved piping systems offer safe, secure and correction free solutions for underground fire fighting mains.

(4) Chilled Water

(5) Demineralised Water

(6) Industrial/Chemical applications

(7) Submarine pipelines

(8) Rehabilitation of existing pipelines by relining

(9) Compressed Air Lines

(10) Vaccum Sewage

(11) Telecom Applications

(12) Ship Building

(13) Irrigation

(14) Sea Water Intakes

(15) Aqua and Marine Parks

(16) Potable Water

(17) Cable Duct

(18) Gas Application

(19) Surface Water (Perforated/Non-perforated)

(20) Foul Sewer

(21) Gravity Drainage

Design Considerations

When considering the design of polyethylene pipe systems, the appropriate international specifications should be taken into consideration. For example extracts from the WRc Manual are published here with acknowledgment to the Foundation for Water Research.

Review of Current Position

PE80 and PE100 pressure gas and water mains are inert flexible, lightweight and have the required structural strength without being brittle. They are suitable for use where ground movement is expected, where corrosive soils are present and where long ducts and flexibility in bending are required. They appear to withstand surge pressures better than PVC-U pipe and to be even more resistant to freezing because of the improved thermal insulation properties.

Fusion welded PE piping systems resist axial stresses arising from thermal or pressurisation effects, except at the transition points to non end load bearing pipe systems. Thrust blocks and anchorages need only to be considered in these cases.

Both PE80 and PE100 pipes allow the use of many modern no dig techniques.

Environment

PE pipes are normally joined using fusion techniques. Butt fusion jointing is usually carried out above ground and after cooling; long lengths of pipe are snaked into the trench.

Fusion jointing using the electrofusion jointing technique may be carried out at the trench bottom, but care must be taken to keep jointing surfaces clean and dry.

The sub surface material to be excavated should be assessed for its suitability as selected backfill material, i.e., free from large sharp stones, heavy clay, etc. If the material is unsuitable for bedding and surround to the pipe then imported material should be utilised and the surplus spoil removed from site.

The properties of PE make such pipelines particularly suitable for areas subject to ground movement due to seismic forces, mining subsidence, compaction of filled sites or the disturbance caused by the activities of other utilities in the vicinity.

Where PE is to be used in environments with temperatures greater than 20°C the allowable operating pressures should be reduced in accordance with the manufacturer's recommendations.

Corrosive ground (e.g. ground with low pH or high sulphate characteristics) has little or no effect upon PE but all metal fittings, ancillary equipment, bolts, etc., should be carefully protected in the normal way.

Contaminated ground, however, must be considered carefully. PE is resistant to many chemicals, but is vulnerable to petroleum products and certain solvents; where concentrations of such contaminants exist PE should **NOT** be used unless suitably protected. Where any doubt exists soil sampling should be undertaken and specialists advice sought.

Where the natural ground water table is high, or the construction trench is liable to flooding, special consideration should be given to the possible flotation of the pipe. This particularly applies to the large diameters where special anchoring or weighting may be necessary prior to the backfill being installed.

Operating Conditions

Both the static and dynamic loads to which the pipe system is likely to be subjected should be considered with care. However variations of pressure due to demand seldom warrant special design consideration with regard to the pipe material. Pipe systems designed with the relevant safety factor take account of occasional deviations from the maximum rated pressure. These occasional pressure excursions within conditions reflected by the safety factor are therefore acceptable. Further advice should be sought from Hepworth P.M.E Technical Services.

The DYNAMIC loads normally considered during operation are the:

- internal cyclic loading e.g., surge associated with pumping regimes or the rapid closure of valves; external cyclic loadings due to traffic conditions.

Design for Surge and Fatigue

When considering applications where surge transient pressures may occur, polyethylene pipes exhibit significant advantages. The relatively low material modulus for polyethylene means that, for a given change in fluid velocity, the surge transient pressure induced will be approximately one third of that induced in ductile iron pipes. In addition, quality pipe grade polyethylene resins are almost immune to fatigue damage for typical fatigue loadings in water and effluent pipelines, hence no de-rating is required for the pipe. However, this is a complex area and a full analysis should always be undertaken.

Surge Design

A critical factor when assessing surge transient pressures generated in Polyethylene pipes, is the RATE at which the pressure rises in the pipe subsequent to a surge transient pressure being generated by for instance, the rapid operation of a pump or valve. Detailed study of the UK water network over a period of time has shown that this 'Pressure Rise Rate' has rarely exceeded 8 bar/ second and in 'normal' operating conditions, rarely reaches this figure.

Fatigue

There is no necessity to de-rate Polyethylene pipes where fatigue conditions are encountered, providing the pipes meet the stress crack resistance requirements of ISO 1167.

Resistance to Vacuum

Polyethylene pipes can safely withstand negative pressure, for instance when subjected to vacuum subsequent to sudden power failure to the pumps in a pumping main.

When large diameter Polyethylene pipelines are to be laid in ground conditions which raise doubts regarding the suitability of the backfill/native soil stiffness, the designer should carry out a detailed analysis of both ground conditions as well as projected soil loadings.

The complete analysis of pressure transients, particularly in complex water distribution mains, requires specialist advice, knowledge and experience. For computer analysis of the likely pressure transients many specialist consultants are available. By utilising these sources of guidance and expertise, the very good response of polyethylene pipes to surge and fatigue loading can be used by water engineers to the advantage of their company.

External Dynamic Loading

For external dynamic loading conditions the use of PE pressure mains under MAJOR CARRIAGEWAYS is dependent on the type of trench bedding conditions.

Experience has shown that if the PE80 and PE100 pipes are laid with the correct installation techniques, PE pressure mains can be laid under major roads.

A comprehensive testing programme has been undertaken which commenced prior to the publication of the original PE80 manual on the potential risk of the failure of butt welded PE80 pipes by rapid crack propagation.

The result of these tests showed that it was not possible to generate a fast fracture in PE80 completely full of water even under arduous conditions of low temperature and high pressure.

Full scale fast fracture tests were also carried out on PE100 material. The tests were carried out on 500mm pipe tested at 1.5 times the maximum rated pressure of the pipes (16 bar and 10 bar for SDR11 and SDR 17.6 respectively). Nitrogen (as air substitute) was used as pressuring medium to simulate the worst case situation. It was not possible to generate fast fracture in fully gas filled PE100 pipes.

Therefore the significant advantage of PE100 pipe is that it can be used at its respective full rated pressure without the risk of failure by fast fracture.

Design Considerations

Hydraulic Flow - Pipes

The hydraulically smooth bore of a PE pipe gives excellent flow characteristics which are usually retained through its operational life. Tile hydraulic frictional coefficients normally used in the design of continuous straight PE pipes working under pressure are:

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

The metric Colebrook-White formula for the velocity of water in a smooth bore pipe under laminar conditions takes the form:

$$V = 2\sqrt{2gDi}. \quad \text{Log.} \left\{ \frac{Ks}{3.7D} \quad \frac{2.15v}{D\sqrt{2gDi}} \right\}$$

Where

V = velocity in metres per second

g = gravitational acceleration (a value of 9.807 ms^{-2} may be assumed)

i = hydraulic gradient

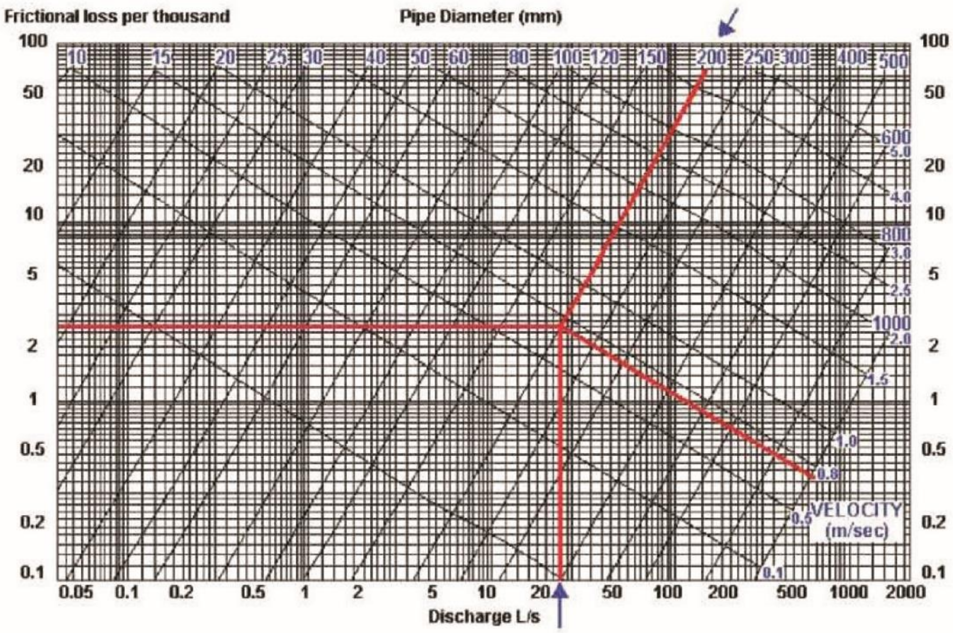
v =kinematic viscosity (a value of /sm101.14126-x may be assumed for water at 15°C)

Ks = linear measure of roughness in mm = 0.003

D = mean internal diameter of pipe in metres .

For ease of reference, a typical Design Flow Chart based upon these coefficients is reproduced as

Figure 1 for Pipes up to 1000mm



Example: PE pipe PN 6 225 x 12.8mm (Dia. = 200mm). discharge 25l/s. Follow the Dia. line = 200mm until this line cuts the discharge line = 25 l/s. This gives the value for friction = 2.8 per thousand and the velocity = 0.75 m/s

Friction diagram for PE and PVC pipes calculated according to Colebrook. For diameters up to 200mm, k = 0.01mm, and for diameters exceeding this k = 0.05mm. Water temperature + 10°C.

Flow Chart -Pipes up to 1000mm

Design Considerations

Frictional Loss - Values and Fittings

The frictional losses occasioned by flow through valves and fittings are approximately proportional to the square of the liquid velocity.

$$H = \frac{K.V2}{2g}$$

H = loss of head

V = liquid velocity

g = acceleration due to gravity

K = coefficient dependent on type of fitting.

Table 1 gives commonly used values for K.

Fitting Type	K Values
90 Elbow	K = 1.00
45 Elbow	K = 0.4
22 ½ Elbow	K = 0.2
90 Bend	K = 0.2
45 Bend	K = 0.1
22 ½ Bend	K = 0.05
90 Tee flow in line	K = 0.35
90 tee flow into branch	K = 1.20
Gate valve: open	K = 0.12
¼ Closed	K = 1.0
½ Closed	K = 6.0
¾ Closed	K = 24.0
Butterfly valve: open	K = 0.3

Table 1-Commonly used values for K.

Perhaps a more convenient way of allowing for the frictional resistance of valves, fittings, obstruction, etc., is to consider an equivalent straight length of pipe which would create the same frictional resistance.

Actual headloss characteristics for a range of service pipe sizes and appropriate fittings were researched by WRc during 1991 - 1992 to determine overall headloss for PE80 pipes in specific service pipe installations.

For a typical service pipe length of 25m, the pipework contributes up to 35% of the total headloss. The average results are given here as Table 2 for quick and easy reference.

The effect of the frictional resistance created by the internal beads in butt welded joints is hardly significant in normal distribution installations but in the smaller diameters or where the joints are frequent (say every 2 metres for some continuous lengths) an increase in the frictional resistance of about 2% should be allowed.

Pipeline Selection

The selection of both material and size of a particular pipeline will be influenced by any particular design policy or "standards" employed by the developing body. Within the normal distribution range (up to 630mm) the use of "standard" sizes and designs may well prove cost effective in terms of simplication of design, operation, repair or renewal, stores levels, etc.

Table*	Fitting/ Componant	Size mm/"	Headloss (m) at Flow Rate of:				
			L/m 10	25	35	100	160
			L/s 0.16	0.42	0.58	1.66	2.66
1	Ferrule connection	20	0.1	0.9	20		
		25	0.1	0.7	1.5		
		32		0.2	0.4		
		63				0.5	1.5
2	Stop valves	½	0.6	3.7	9.5		
		¾	0.2	1.2	1.9		
		1		0.4	0.7		
		1½		0.1	0.2	0.9	2.2
		2			0.1	0.4	0.8
3	Boundary boxes (with meter)	20	0.8^	4.5^	10.0^		
		25	0.7^	3.2^	6.1^		
	Boundary boxes (without meter)	25	0.5^	1.9^	3.4^		
4	Double check valves	20	1.8	4.0	6.0		
		25	1.2	2.0	2.7		
		32		1.3	1.8		
		50				2.5	
		63				0.4	0.9
5	Adaptors	20	0.4	0.5			
		25		0.1	0.1		
		32			0.1		
6	Elbows	20	0.3	1.3	2.4		
		25	0.1	0.2	0.4		
		32		0.1	0.2		
		50				0.2	
		63					0.1
7	Tees (on Branch)	20	0.2	1.0			
		25		0.3	0.6		
		32		0.1	0.2		
		50				0.3	
		63					0.2

* These table numbers refer to tables 1 - 7 in report FR 0255

^ These figures refer to results generated from various sources

Table 2-Average Headloss in fittings and Components

These design procedures are readily applied to individual mains or simple layouts. The charts are also invaluable for establishing an initial selection for pipelines forming an integral part of more complex layouts. As pipe networks become more extensive and hence more hydraulically complex, use must be made of computer-aided design for which a variety of programs are available. The selection of program will depend upon both the complexity and format of output required,

- The jointing method
- The trench width (standard, or narrow)

PE pipe is available either in coils or straight lengths depending upon pipe size.

Straight pipes are usually produced in 12m lengths but other lengths are available by upon request.

Coils are available in sizes up to 125mm and usually up to 100m length.

Design Considerations

Narrow trenching has the considerable advantages of reduced reinstatement costs and less spoil to handle but not all subsoils are conducive to such a technique and proper laying, bedding and compaction is not always possible at the required depths of cover. Trenchless techniques such as micro-tunneling and impact moling can be used particularly well with PE systems, as alternatives to conventional trenching techniques. The flexibility of PE allows the accurate alignment of the pipeline to awkwardly contoured curve lines on housing sites. This is particularly valuable in Cul de sacs where turning circles and hammer heads are prevalent. In such layouts it can prove quite economic to provide a looped service main and consideration may also be given to installing the service connections prior to the pressure test. Apart from the avoidance of high stress environments and unsuitable ground situation as mentioned previously, the selection of layouts and routes for PE pipelines needs no other special consideration than that which would be given to other pipeline materials:-

Figure 2-Typical Open Trench

- Wherever practical, a looped or ring main should be formed.
- Where dead legs cannot be avoided they should have a washout facility and air bleed facility (preferably a hydrant) adjacent to the last service connection.
- Mains should follow and be located on the side of the public highway serving the most properties to minimise the length of service pipes.
- The possibility of incorporating leakage detection or control devices should be considered, thus benefiting a planned zonal approach to leakage control.
- Consideration should be given to possible future extension of the site and of fire service requirements.

The provision and siting of ancillary equipment for PE pipelines is also similar to other pipeline layout except for one aspect; The ease with which PE can accommodate gradual changes of direction in the vertical plane requires special attention to the provision of adequate and properly sited air valves at high points.

Bends and Cold Bending

The bending of PE80 and PE100 is permissible and the properties of fusion jointed systems enable changes of direction without recourse to the provision of special bends. However, pipes should not normally be COLD bent to a radius less than 25 times the outside diameter of the pipe at 20˚C (Ref. Table 3). In special circumstances and in the smaller service diameters this requirement may be relaxed to 15 x OD for SDR 11 pipe, provided no joints or tappings occur on the bend and care is taken not to kink the pipe.

At 0˚C pipes should not normally be cold bent to radii less than 50x the outside diameter of the pipe (Ref. Table 3).

A full range of moulded or mitred elbows are available. In addition preformed pipe bends and configurations are available upon request.

Nominal diameter	Minimum Cold Bending Radii In Meters	
	at 20°	**at 0°**
20	0.5	1.0
25	0.625	1.25
32	0.8	1.6
50	1.25	2.5
63	1.58	3.15
90	2.25	4.5
125	3.125	6.25
180	4.5	9.0
250	6.25	12.5
315	7.88	15.75

Table 3-Recommended Minimum Cold Bending Radii

Design Considerations

Anchorage and Thrust Blocks

One of the fundamental features of fully integrated fusion welded PE pipe systems is that they are end load resistant and anchorage is not normally required at the junctions or bends.

However, an exception to this is at transition points to non end load bearing pipe systems where thrust anchoring will be required.

The designer should consider all aspects of the system, including the imbalanced loads imposed by testing procedures, unusual configurations, large temperature variations, etc., and where excessive stress on the pipe system is envisaged, additional anchorage should be considered.

The PE pipe itself may be partially or completely surrounded by concrete but should be protected by a heavy duty polyethylene membrane to a minimum thickness of 3mm. The membrane should extend outside of the concrete to avoid possible damage during pouring or compaction and minimise local stresses.

Where concrete surround to the pipe barrel is to be provided as anchorage, the forces may be transmitted to the concrete by the introduction of a stub flange or similar fitting to form a puddle flange.

Concrete Support Consideration should be given to the provision of concrete support to all heavy fittings or ancillary equipment installed on PE mains. The support design should take into account both the dead weight and any excessive turning movements which may be created under operating conditions (hydrants, air valves, etc.).

Pipe Entry into Structures Wherever the PE pipework meets or passes through rigid structures careful consideration should be given to at least:

- the need to affect a watertight joint at the interface;
- the extent to which the structure itself is required to with stand forces transmitted from the pipe;
- where there is RIGID connection between pipe and structure the adaption of standard fittings or the introduction of special fittings is necessary. Such fittings influence the degree to which compressive, tensile, bending and shear forces are generated;
- where DIFFERENTIAL settlement may occur, the pipe flexibility can normally be relied upon to withstand the bending and shear stresses set up.
- Where pipe is to be connected by a flange to a large rigid structure, localised movement and bending can be prevented by a reinforced support pad as shown in Figure 4. This pad should extend one pipe diameter or a minimum of 300mm from the flanged joint. The strapping should be provided with a compressible protection to the pipe.

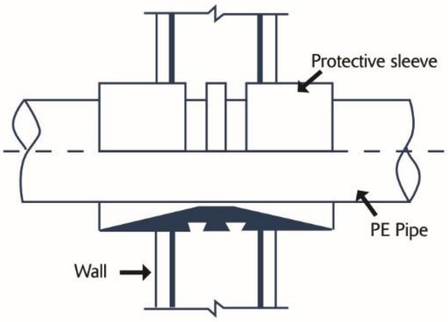


Figure 3

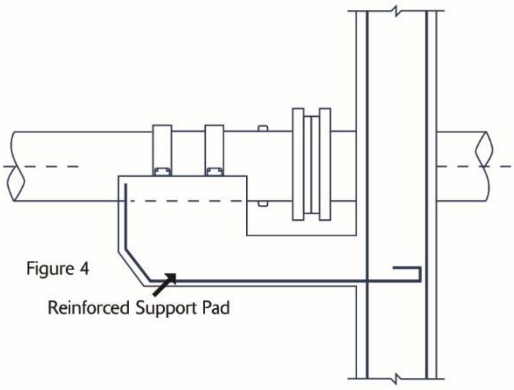


Figure 4

Figure 3 and Figure 4 show typical details of

- Pipe passing through a structure
- Rigid connection to a structure

Design Considerations

Effect on Temperature Variation

Expansion and Contraction

The coefficient of linear expansion for PE pipe is between 0.16mm -0.20mm per degree celcius.

Due allowance must be made for movement created by temperature variation when designing pipe systems. The position of rigid fixings or anchor points must be carefully considered, particularly in above ground installations. By utilising the inherent flexibility of the pipe and by judicious siting of supports, anchors, etc., expansion and contraction can be conveniently accommodated at changes in direction. For further details contact Hepworth P.M.E Technical Department.

Table 4 gives expansion/contraction in mm for a range of temperature variations and pipe lengths. The effect of expansion/ contraction requires particular attention if the pipe system includes one or more push fit, non end load bearing joint. In these circumstances pipes installed at relatively high ambient temperatures may contract to such an extent when operating at service temperatures that movement in the joint may result in leakage.

Movement caused by thermal variation in pipe systems jointed by one of the fusion welding techniques (full end load bearing joints) will generate tensile or compression stresses within the pipe material. In buried pipelines which have been allowed to stabilise to trench bottom ambient temperatures the elastic properties of the material will normally adequately accommodate these forces which are rarely of sufficient magnitude to adversely affect the performance of the system. A more critical consequence of this movement could be its effect at pipe supports, or branch connections to plant/equipment and other pipelines. Such points should be analysed for shear and bending stresses.

Length in metres	Temperature Variation in °C					
	5	10	15	20	30	40
1	0.8	1.6	2.4	3.2	4.8	6.4
2	1.6	3.2	4.8	6.4	9.6	12.8
4	3.2	6.4	9.6	12.8	19.2	25.6
6	4.8	9.6	14.4	19.2	28.8	38.4
8	6.4	12.8	19.2	25.6	38.4	51.2
10	8	16	24	32	48	64
12	9.6	19.2	28.8	38.4	57.6	76.8
20	16	32	48	64	96	128
50	40	80	120	160	240	320
100	80	160	240	320	480	640

Table 4

Above date based on coefficient of expansion 0.16mm/ metre/°C
all dimensions in mm

For pipe systems above or below ground and intended to carry water it is advisable to make final connections during the coolest time of the day.

Effect of Temperature Variation on Mechanical Properties

The tensile strength of thermoplastics materials is temperature dependent. As a consequence the recommended maximum sustained operating pressures of PE pipes must be reduced for operating temperatures over 20°C if a 50-year minimum life is to be maintained.

Where operating Figure 5 plots pressure reduction factors against temperature for polyethylene pipe, temperatures are in excess of 20°C the designer must ensure that adequate pipe support is provided in above ground situations and that the medium being conveyed will not degrade or attack the pipe material.

Polyethylene can be use for pressure applications in the temperative range of -50°C to +60°C subject to pressure de-rating due to operating temperatures.

Pipe bracket spacing for PE for liquids with a density of 1 g/cm

Pipe bracket intervals L for pipes SDR 11 in mm at pipe wall temperature:-

Size mm	d20°C	30°C	40°C	50°C	60°C
16	500	450	450	400	350
20	575	550	500	450	400
25	650	600	550	550	500
32	750	750	650	650	550
40	900	850	750	750	650
50	1050	1000	900	850	750
63	1200	1150	1050	1000	900
75	1350	1300	1200	1100	1000
90	1500	1450	1350	1250	1150
110	1650	1600	1500	1450	1300
125	1750	1700	1600	1550	1400
140	1900	1850	1750	1650	1500
160	2050	1950	1850	1750	1600
180	2150	2050	1950	1850	1750
200	2300	2200	2100	2000	1900
225	2450	2350	2250	2150	2050
250	2600	2500	2400	2300	2100
280	2750	2650	2550	2400	2200
315	2900	2800	2700	2550	2350
355	3100	3000	2900	2750	2550
400	3300	3150	3050	2900	2700
450	3450	3330	3200	3050	2850
500	3700	3500	3400	3250	3030

For other SDR ratings multiply the values given in the table with the following factors:-

SDR 17 and SDR 17.6 with 0.91
SDR 7.4 with 1.07

The pipe bracket spacing given in the table may be increased by 30% in the case of vertical pipe runs, i.e. multiply the values given by 1.3.

Pipe bracket spacing for PE for fluids of a density other than 1 g/cm^3

if the liquid to be transported has a density not equal 1 g/cm^3, then the bracket spacing in the table above should be multiplied by the factor of the following table:-

Density of the fluid in g/cm³	Factor for pipe bracket spacing
1.25	0.96
1.50	0.92
<0.01	1.30 for SDR11 1.21 for SDR 7.4

Handling & Storage

The importance of good handling and storage of polyethylene pipes and fittings applies equally to all forms of installation. The procedures and recommendations should be followed at all times giving particular attention to handling and storage at site.

General Principles. The recommendations for handling and storage are the same for both PE80 and PE100 pipes although, due to the increased stiffness, PE100 pipes may require even greater care in handling pipe coils than PE80 pipes of similar wall thickness. Polyethylene is a tough resilient material which irrelatively light and easy to handle although it is prone to damage through scoring by sharp objects. Therefore, careful handling is always required and the dragging of straight pipe and coils should be avoided whenever possible. The maximum allowable depth of scoring of the external surface of the pipe is 10% of the wall thickness. Pipes and fittings showing obvious defects or excessive scoring should be withdrawn and clearly identified as unsuitable. The general properties of polyethylene are unaffected by low ambient temperatures but having very smooth surfaces, the pipes and fittings become slippery in wet or frosty weather. Particular attention should be given to the effective securing and storage under such conditions. Extra care should also be taken when handling large diameter prefabricated fittings during very cold weather. As far as practicable the protective packaging (pallets, strapping, bags etc.) should be kept intact until the material is required for use. The temporary capping or plugging of pipe ends is recommended. Pipes and fittings likely to be stored outside for periods longer than 12 months, should be covered by tarpaulin or black polythene sheeting to prevent ultra violet degradation from sunlight. Electrofusion fittings should be stored under cover and in their protective packaging. For hygiene purposes, the pipe ends must be protected from the ingress of dirt/water etc. This protection should be carefully disposed of following use.

Transport and Delivery.

For transporting bulk loads the vehicles should be provided with a clean flat bed, free from nails or other projections which may cause damage. If high sided lorries are used, special care must be taken to prevent slippage or excessive bowing of the pipes and extra protection given at all sharp edges. Care should be taken to avoid positioning pipes and fittings near or adjacent to exhaust systems or other heat sources and to avoid possible contamination from materials such as diesel oil. Metal chains or slings should not be brought into direct contact with the material. Webbed slings of polypropylene or nylon are recommended. Straight pipes should be fully supported and bound together. Pipes must not rest on the integral socket if one is incorporated. When transporting 'pupped' fittings, these should not be loaded in a way that could distort the pup end. Both vertical and horizontal deliveries of coiled pipes are permissible, although in the case of horizontal transportation special arrangements may be required. Off Loading – Frame Packed Pipes when lifting by crane, non metallic wide band slings or ropes should be used, and for pipe lengths greater than 6m, load spreading beams of a length at least equivalent to one quarter of the length of the pipe or bundle pack should be employed.

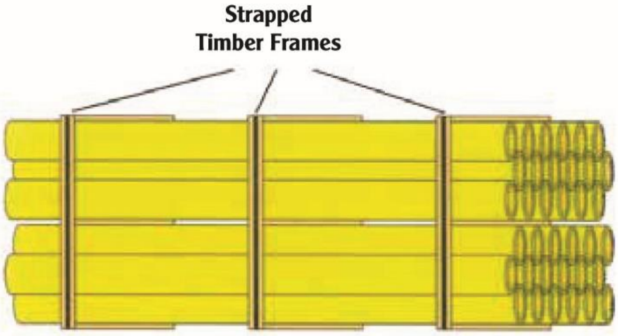


Figure 1 Typical Framed Pack of PE Pipes

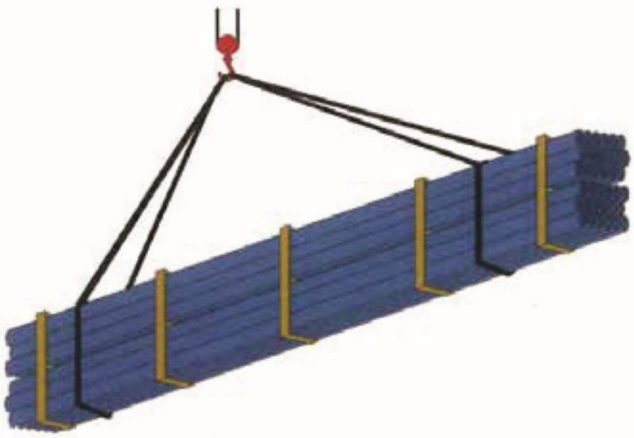


Figure 2 Lifting Framed packs by Crane

Chains or end hooks should not be used. Care should be taken to avoid damage to pipes and pipe ends during lifting. Some bending should be allowed for in the middle of the lift when loading and unloading pipe and because of this lifting points should always be well spread and evenly spaced (see Figure 2). Standard bundlepacks, 6m long, may be handled by fork lift trucks and due allowance made for the flexible nature of the pipes in the positioning of the forks and the raising of the load.

Bundlepacks greater than 6m long should be handled either by a side loader with a minimum of four supporting forks, or by a crane using a spreader beam and suitable slings. Individual pipes may be handled in the same way. Off-loading on site may be made easier by using skid timbers and rope slings (Figure 3).

Figure 3- Off Loading using Skid Timbers"

Pipes must never be thrown from delivery vehicles or slid from the tailboard of a moving flat-bed wagon

Coiled Pipes

SAFETY CONSIDERATIONS

It is now well understood that coiled pipe contains a considerable amount of stored energy which has the potential to cause injury if handled in an incorrect way. To ensure a safe working environment during the installation of large diameter pipe in coil form it is intended that coils should only be dispensed from an approved coil dispenser. Always ensure that the tail ends of coils are released in a restrained and controlled manner and never cut all the retaining straps at one time or in one operation. The work area should be restricted to essential personnel only who should always wear hard hat, gloves, safety shoes and eye protection when carrying-out this type of operation. After completion of the dispensing operation it is important to ensure that the free tail-end of any part-used coil is 'secured' before transporting it from the site. Reinforced adhesive tape at least 2" wide is used for banding. Complete coils are secured by outer and intermediate bands and individual layers are also independently secured as shown in Figure 4. These should not be removed until the pipe is required for actual use and the method or release detailed in Figure 5 MUST ALWAYS be followed.

There should be facilities to restrain securely each coil individually throughout individually transit and the unloading process.

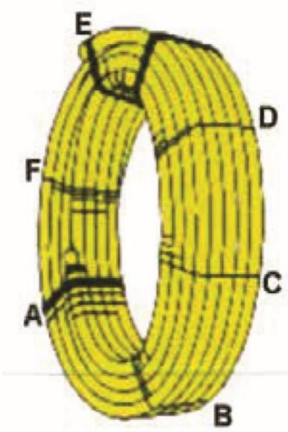


Figure 4 – Banding of individual Layers of Coils

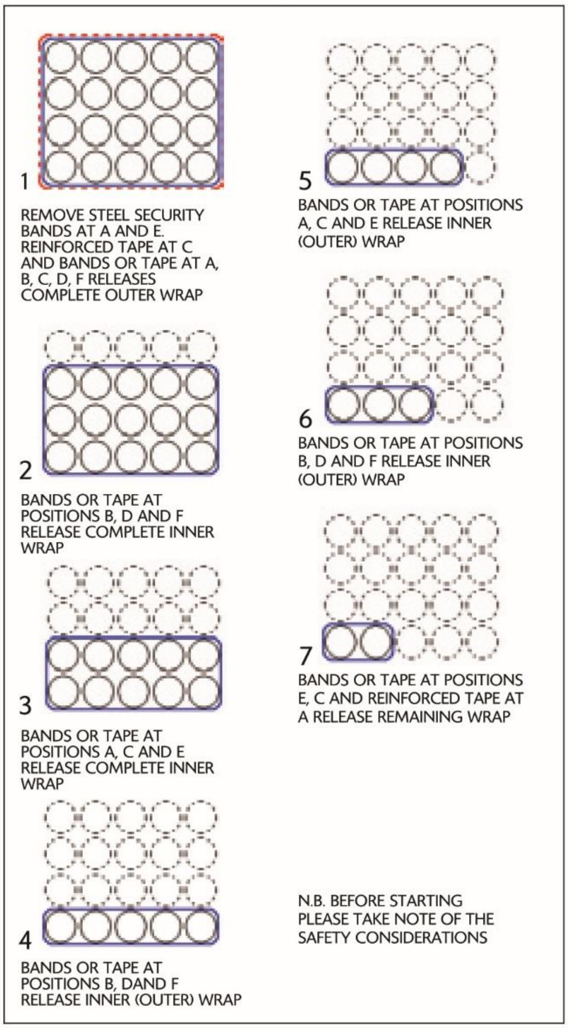


Figure 5-Releasing Instruction for coiled Pipe Retaining Straps

Handling & Storage

Fittings. Hooks should not be used to lift fittings, which are supplied in cardboard boxes or polythene bags.

Storage at Depot

All materials should be carefully inspected at the time of delivery and any defective material set aside before accepting the delivery into stores. Any such defects should be notified to the supply source immediately.

Pipes and fittings should be used in the order of delivery to ensure the correct rotation of stock. Polyethylene pipes are date stamped at the time of manufacture and checks should be made to ensure the stock is being rotated on an "oldest out first" basis.

Blue polyethylene pipe should preferably be stored under cover and protected from direct sunlight until required for use. Where storage facilities necessitate the material to be exposed externally for more than twelve months, suitable opaque protective sheeting should be used.

All pipe stacks should be made on sufficiently firm, flat ground to support the weight of the pipes and any necessary lifting equipment. Stacking heights should be kept to a minimum and adequate space allocated for lifting machinery to manoeuvre without accidental damage occurring.

For safety and convenience of handling the stacking height for manufacturers bundles should not be more than 1 metre. To prevent possible deformation of the pipes, bundles must be stored timber to timber as shown in Figure 6.

For similar reasons, pipe coils should be stored flat, See Fig. 7, and the number of coils per stack should be limited to;

- 1 coil for 110mm diameter pipe
- 1 coil for 125mm diameter pipe
- 1 coil for 180mm diameter pipe

Where individual pipe lengths are stacked in pyramidal fashion, deformation may occur in the lower layers, particularly in warm weather. Such stacks should therefore be not greater than 1 metre high. Socket or coupled pipes should be stacked with the sockets at alternate ends and with the sockets protruding to avoid uneven stacking which may permanently distort the pipes, as shown in Figure 8.

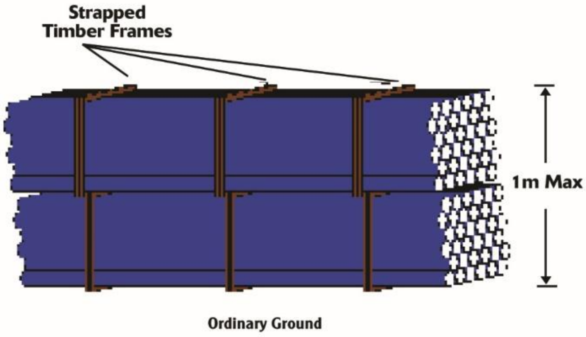
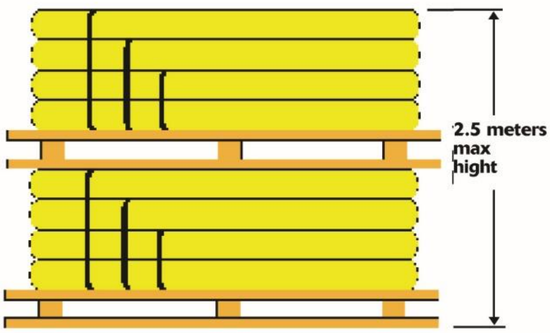


Figure 6-Storage of Famed Packs



Horizontal Storage: Each coil must be protected from surface contact by using wooden battens of pallets

Figure 7-Storage of Coils

Polyethylene fittings should be stored under cover, preferably on racking and the manufacturer's protective wrapping or cartons kept intact for as long as possible.

At all times pipes and fittings should be stored away from exhaust outlets and all other high temperature sources. Care should also be taken to avoid contact with lubricating or hydraulic oils, gasolines, solvents and other aggressive chemicals.

All special tools and equipment associated with the jointing of PE pipes and fittings should be stored separately and securely until they are required for use. The heating faces of fusion tools should be kept in a position where the surfaces are protected from scratching or other damage. Tools incorporating cutting edges should likewise be protected from damage which could cause poor joint preparation.

Storage On Site

On major projects the establishments of a sub depot which is manned or securely compounded may have the features and requirements as set out above. On medium sized projects, or work within a congested area, it is often necessary to store pipes and materials at selected points close to the laying operations whilst on the smaller works, or laying in rural or less congested areas, pipe stringing may be acceptable. In all cases careful consideration should be given to the following aspects:

- Security of all materials and equipment from theft, vandalism, accidental damage or contamination.
- Safety of pedestrians, especially children and blind persons.
- The movement of traffic, construction equipment, farming machinery and animals

All pipe store locations should be on suitably firm, level ground, free from damaging material with adequate access for construction vehicles and/or lifting equipment.

For safety at site locations, stacking of large diameter pipes should be strictly limited to two units high and the store adequately fenced and protected.

Where stringing is adopted, pipes should be placed well clear of the digger tracks and away from the excavated material area. They should be wedged to prevent accidental movement. Where necessary protective barriers should be erected with adequate warning signs and lamps.

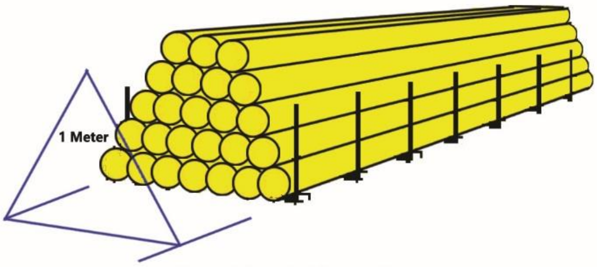


Figure 8- Individual Pipe Stacks

Jointing Methods

Butt Fusion

This technique is used in situations where the pipes to be joined are of the same material (PE 80 or PE 100) and having the same nominal wall thickness and outside diameter (SDR). Pipes sizes greater than 90mm can be jointed using this technique. Hepworth PME (Qatar) WLL offers a range of butt fusion machines for both site and workshop use. Dramatic increases in productivity in jointing long pipe systems can be cooling whilst a second joint is prepared. Certain machines within our range also offer full traceability for each welded joint identifying not only the operator responsible for the joint but also technical data relating to that joint.

Electrofusion

Electrofusion is suitable for materials and/or SDR's being the same or dissimilar providing that the appropriate couplers are used. This method is particularly suitable in situations where access is restricted or when jointing direct from a coil. Hepworth PME (Qatar) WLL offers a comprehensive range of couplers from Georg Fischer covering pipe sizes of 20mm to 630mm. All electrofusion fittings conform to EN12201 and EN1555 and are manufactured from PE100 material. As with butt fusion we offer the option of producing traceability reports for each joint. Additionally many of the electrofusion joints supplied by Hepworth PME (Qatar) offer bar coded settings for the jointing parameters eliminating the chance of operator error when inputting such data into the electrofusion machine.

Mechanical Fittings

Hepworth PME (Qatar) WLL stocks a wide range of mechanical fittings suitable for jointing PE pipe.

Jointing Methods

Range of Joints Butt Fusion and Electrofusion

The advantages of a PE integrated end load resistant system is usually achieved most economically by fusion welded jointing. Butt fusion is perhaps more commonly applied although electrofusion may be preferred where butt fusion is impractical due to lack of space for example.

Mechanical Fittings

Plastic mechanical fittings for sizes up to and including 110mm should be manufactured to ISO 14236:2000. Wide tolerance couplings and flange adaptors for use with pipes of different materials: ductile iron, steel, PVC-U, PE, fiber-cement should be manufactured to EN 14525:2004.

Training in Fusion Jointing

Although the principles of fusion jointing are relatively simple, in practice care is needed to maintain the integrity of the PE system through appropriate instruction and on site monitoring.

It is strongly recommended that such training is given at both operator and supervisor levels. In-house schooling followed by some on-site experience under supervision is recommended.

Fusion Machines and Equipment

Fusion machines and equipment may be bought or hired through Hepworth PME (Qatar). Owners usually arrange for periodic maintenance contracts and the available servicing facilities should be taken into account before purchase. Georg Fischer issue comprehensive and detailed literature on their products and their use, which should be studied prior to use of the equipment.

The mating surface of all heater plates must be kept clean to ensure good heat transfer and to prevent contamination at the weld interface. Any deposit on the surface should be carefully removed when the plate is cold using a soft wooden spatula and/or a rag soaked in a suitable solvent such as Iso-propanol. Protective and refurbishing techniques are available.

Trimming tools are required to prepare the fusion faces of the pipe prior to heating and are usually an integral part of the machine. The cutting edges should be maintained in clean and sharp condition.

Most fusion tools are made from aluminium because of its good heat conduction properties but this is a relatively soft material and easily suffers impact damage. Heater plates should be protected when not in use. Recent development of automatic butt fusion machines and fully retractable heater plates may reduce the risk of contaminating heater plate surfaces.

Fusion machines must be capable of applying a controlled fusion pressure at the joint interface but at the same time be capable of developing high pull-up forces to cope with the work of drawing long pipe strings. Power driven, centerline action thrust cylinders provide smoothness and help to prevent misalignment.. Frequent roller support to the pipe string lessens the required pulling forces and prevents unnecessary drag and scratching of the pipeline. This is particularly essential when dual pressure welding machines are used.

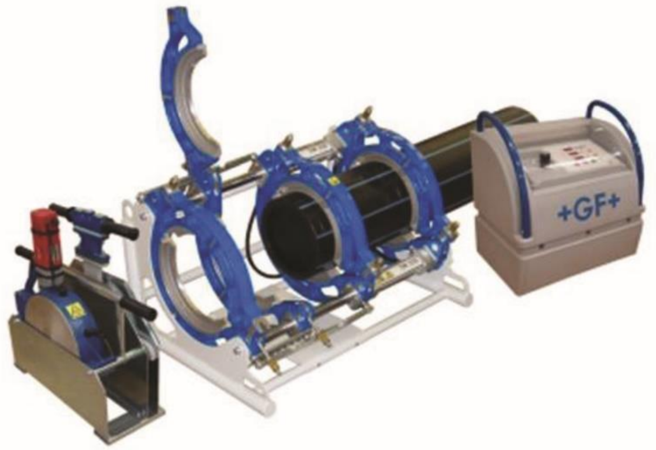


Figure 1- Typical Butt Fusion Equipment

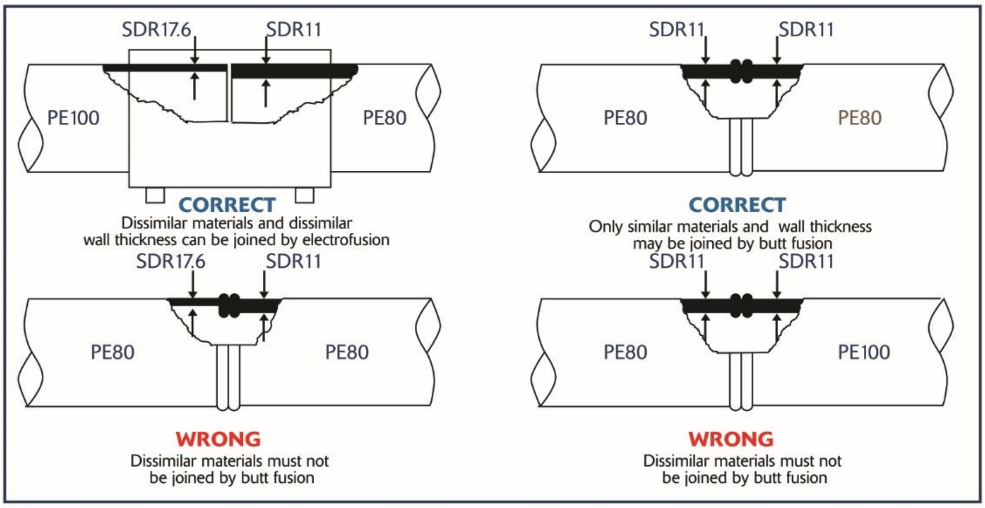
Figure 2- Typical Electrofusion Equipment

Jointing Methods

Fusion Jointing

The recommended procedures for fusion jointing are specified in ISO 12176 parts 1/2/3:1998-2001. Materials suitable for the manufacture of pipes and fittings to the above specification may not be compatible for fusion jointing under certain circumstances and guidance should be sought before attempting to join materials with different pressure ratings or with different diameters.

The correct procedures for jointing dissimilar materials and wall thickness are outlined below. Only similar materials and similar wall thickness should be joined by butt fusion.



Butt Fusion Jointing

Pipes and fittings can be jointed by butt fusion using an electrically heated plate. The facility to independently check the face temperature in the field is essential. Butt fusion is suitable for jointing pipes and fittings in the same size range. However, only pipes and fittings with same SDR ratings and material may be jointed together using this technique.

Electrofusion Jointing

Electrofusion fittings have sockets that contain electrical wires which, when connected to the appropriate power source, fuse the socket onto the pipe without the need for additional heating equipment.

It is essential that jointers take special care to ensure that jointing procedures are rigorously respected and, in particular, that:

- The oxidised surface of the pipe over the socket depth is removed using a mechanical peeling tool.
- The peeled area is cleaned with Isopropyl Alcohol (minimum 70%) prior to insertion of pipe into fitting. Clamps are used to ensure that no movement of the joint can take place during the heating and cooling cycle.
- Welding shelters are used to ensure that dust and rain do not contaminate the joint and to protect it against draughts.

It is possible to join dissimilar polyethylene pipe material and wall thickness. For example, PE80 pipe can be joined to a PE100 pipe of the same pressure rating using electrofusion couplers with the appropriate pressure rating. Electrofusion couplers are available up to size 630mm but larger sizes are being developed.

NOTE: Some coiled pipes may be too oval to fit into couplers, or the bend of the pipe may make alignment of the ends impossible. A number of approaches have been proposed, including:

(i) use a mechanical pipe straightener or rerounding tool;

(ii) fusion joint a straight length of pipe onto the end of the coil before jointing.

Jointing Methods

Mechanical Joints and Fittings

There is a wide range of proprietary metal and plastic mechanical joints and fittings available. All such fittings should be assembled in accordance with the manufacturer's instructions and all metal fittings should be supplied with suitable protection from possible corrosion.

The most common group of metal fittings associated with polyethylene are:

- flanged and other adaptors;
- mechanical type couplers;
- compression fittings;
- gun metal ferrules

Mechanical fittings are classified into three distinct endload performance levels. These are defined as follows:

Type 1 fitting: The end-load resistance of the joint shall be greater than the longitudinal strength of the pipe;

Note 1: Type 1 fittings are applicable to polyethylene pipe only. Such fittings could be used on PE pipelines, for example, in areas of mining subsidence and for pull-through applications. Pipelines installed using this type of fitting would not require anchoring except where connected to non end load bearing pipe systems.

Note 2: All fittings for use with polyethylene pipe with outside diameters including 63 mm are required to be manufactured to the requirements of Type 1

Branch Connections

Normally, branch connections on the main as opposed to service connections are achieved by introducing fusion tees during installation of the main. A subsequent branch connection into an existing polyethylene main can be achieved by using:

Note: Pipelines installed using Type 2 fittings would not normally require anchoring. Type 3 fitting, the end-load resistance of the joint is less than that required by the Type 2 definition.

Note: Pipelines installed using Type 3 fittings will normally require anchoring as for an unrestrained pipeline and the advice of the manufacturer should be sought.

- standard fusion tee with electrofusion couplers;
- standard electrofusion branch connections;
- branch or saddle fusion fittings (requiring special fusion equipment).

For transition from polyethylene pipe to flanged metal fittings, either polyethylene stub faced flanges with metal backing rings or mechanical flanged adaptors complying to ISO14236 and EN 14525:2004 can be used. The gasket and bolt length used should be appropriate to the particular adaptor. A jointing compound should NOT be used.

When tightening polyethylene flanges, care should be taken to produce an even torque load to the limits given by the manufacturer. The use of a torque wrench is strongly recommended.

Typical bolt torques are shown in Table below:

Nominal diameter DN	Screw tightening torque [Nm]	
	Flat gasket up to max. pressure of 10 bar	Profile Oring up to max. pressure of 16 bar
15	15	15
20	15	15
25	15	15
32	20	15
40	30	15
50	35	20
65	40	25
80	40	25
100	40	30
125	50	35
150	60	40
200	70 1)	50
250	80 1)	55
300	100 1)	60
350	100 1)	70
400	120 1)	80

1) up to a maximum working pressure of 6 bar

Installation

Buried Installations

Polyethylene is a thermoplastic material that when extruded produces a pipe of flexible nature and to which the principles of flexible pipeline design must be applied not only at the design stage but throughout installation as well. In particular the quality of materials and workmanship employed in trench preparation, bedding, backfilling and compaction must be of a high standard if the full strength potential of the pipeline is to be achieved and pipe deformation limited to that calculated by the design engineer. The following sub-sections deal with trench preparation, bedding, backfill and compaction.

Site Conditions

For each pipeline development, consideration must first be given to the nature of the site in terms of configuration, existing surface material and the likely subsoil component materials.

- the machinery and equipment necessary to carry out the work,
- the method of installation (i.e. by trenching or guided drilling),
- the need or otherwise of imported material for bedding and surround,
- the requirements in respect of the surface restoration

Figure 1 – The versatility of PE pipes

Traditional Open Trenching

Generally the width of the trench should be the minimum dimension compatible with safe working and the satisfactory laying, jointing and bedding of the pipe. The depth of the trench must allow for compliance with the cover depth requirements (i.e., minimum 750mm for service pipes and 900mm for mains from the crown of the pipe, dependent upon local regulation / soil conditions) together with any allowance for the base of the excavation to be prepared in such a way as to ensure the firm even support of the pipeline along its entire length.

Any exposed pipes and cables belonging to other utilities must be supported and protected throughout the work to the satisfaction of the owners. Any damage must be reported immediately to the appropriate utility or authority. As excavation proceeds, all unstable trench walls need to be supported and this requirement is mandatory for trenches of 1.2 metres or deeper.

Long lengths of fusion jointed pipeline, having joints made above ground can be rolled or snaked into narrow trenches. Such trenches may be excavated by narrow bucket or vacuum methods where subsoil conditions permit.

In uniform, relatively soft, fine-grained soils free from large flints, stones, or other hard objects, and where the bottom can readily be brought to an even finish, providing a uniform support for the pipes over their length, it may be permissible to lay PE pipes directly on the trimmed bottom of the trench. In other cases the trench should be excavated to a depth below the bottom of the pipe sufficient to allow for the necessary thickness of selected bedding material.

Narrow Trenching

This technique involves the use of a trench with a **width of pipe outside diameter plus 100mm minimum,** with all the laying and jointing operations carried out at ground level. A whole range of specially adapted compactors, hand tools and narrow trenching machines have been developed. Since any length of PE pipe string can be pre-welded on the surface, the trench can be narrow along its entire length and will have minimal associated embedment and reinstatement costs.

Microtunnelling using PE pipes

Trenchless Systems

PE is a versatile material and particularly through its toughness and flexibility, it is able to be used with a range of cost effective "no dig" methods of installation.

Systems of thrust boring and microtunnelling techniques have become more readily available within the last decade or so.

Guided drilling or "no dig" systems can be classified into several broad groups according to the way in which the actual excavation of the pilot bore takes place.

These are:

- Fluid jet cutting. High pressure jet nozzles use relatively low flows of water or bentonite-based mud to cut the hole. Mechanical blade, fluid assisted. A chisel blade cuts the soil and fluid jets directed onto the blade help in cooling and lubrication .
- Impact moles. Percussive moles with slant faces cut through the soil under thrust and rotation. Down-the-hole air motors can also be used for cutting harder grounds. The new PE pipe is then inserted through the bore hole, often directly below the mole .
- Rod pushing. An angled tool is forced through the ground, compacting the soil and forming a pilot bore .
- Pipe bursting. Size for size replacement (or upsizing) of many existing pipelines is achieved by winching a percussive or hydraulic mole through the deficient pipeline, thereby splitting it and displacing the fragments outwards. A new PE pipe, with or without an outer sleeve, is then pulled through the enlarged borehole.

Narrow Trenching using PE pipes

Conventional and Close-Fit Lining

Slip lining a smaller diameter PE pipe through an old mains is probably the earliest form of no-dig technology. This has been developed to various "closefit" systems. A polyethylene pipe having an outside diameter at least as great as the inside diameter of the pipeline to be lined, is temporarily reduced in diameter by passing it through a die or rollers, and this enables it to be pulled through the existing pipeline just as in the sliplining process.

The polyetllylene pipe is then re-expanded to be close fit in the host pipe either by the use of internal pressure, or by allowing it to revert naturally.

Pipe Bedding and Surround

It is essential that pipelines are laid on a bed of material which will provide even and continuous support. In suitable soils this can be provided by the hand trimming of the base of the trench with any predominantly hard or soft spots being removed and replaced by compacted fine material.

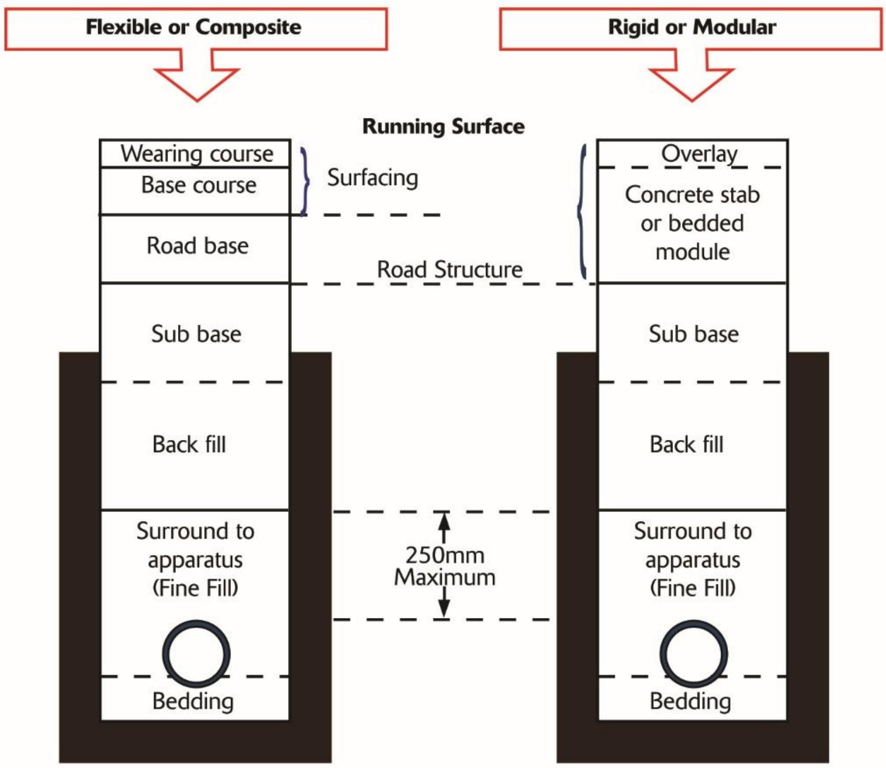
Where such trimming cannot be easily achieved (e.g. in narrow trenching) small irregularities can be overcome by the placing and compaction of selected site material or imported fine granular material to depth of at least 50mm.

The surround to the pipe effectively forms the foundation element of the reinstatement and therefore must offer adequate support for the remainder of the restoration and be capable of transmitting the imposed loading to the subgrade below the pipe or apparatus.

Suitable materials for bedding and surround include free draining sand, gravels and soils of a friable nature which are then compacted in layers according to the specified requirements. This "finefill" material is acceptable up to a maximum of 250mm above the pipeline after which the fill is to be backfill material as defined by local regulations.

The highway surfaces can be grouped as;

- flexible and composite roads.
- rigid and modular roads.
- footways, footpaths and cycle tracks.
- verges.



Trench Reinstatement-Zone Technology

Other considerations when selecting a surround should include the potential for the migration of "finefill" from the adjacent ground (and the backfill) into open-textured surround. Such action normally results in settlement of the adjacent ground (and/or the backfill). Migration of "finefill" can be prevented by using a close textured surround or, if this is undesirable, by enclosing the surround within a suitable filter membrane.

Bricks or other hard material should not be placed under the PE pipe as temporary support.

Installation

Backfill and Sub-Base

There are four classes of acceptable material (dependent on local regulations) which may be used in the backfill zone between the top of the surround and the sub-base zone in highway reinstatement.

These are:

Class A : Graded granular materials

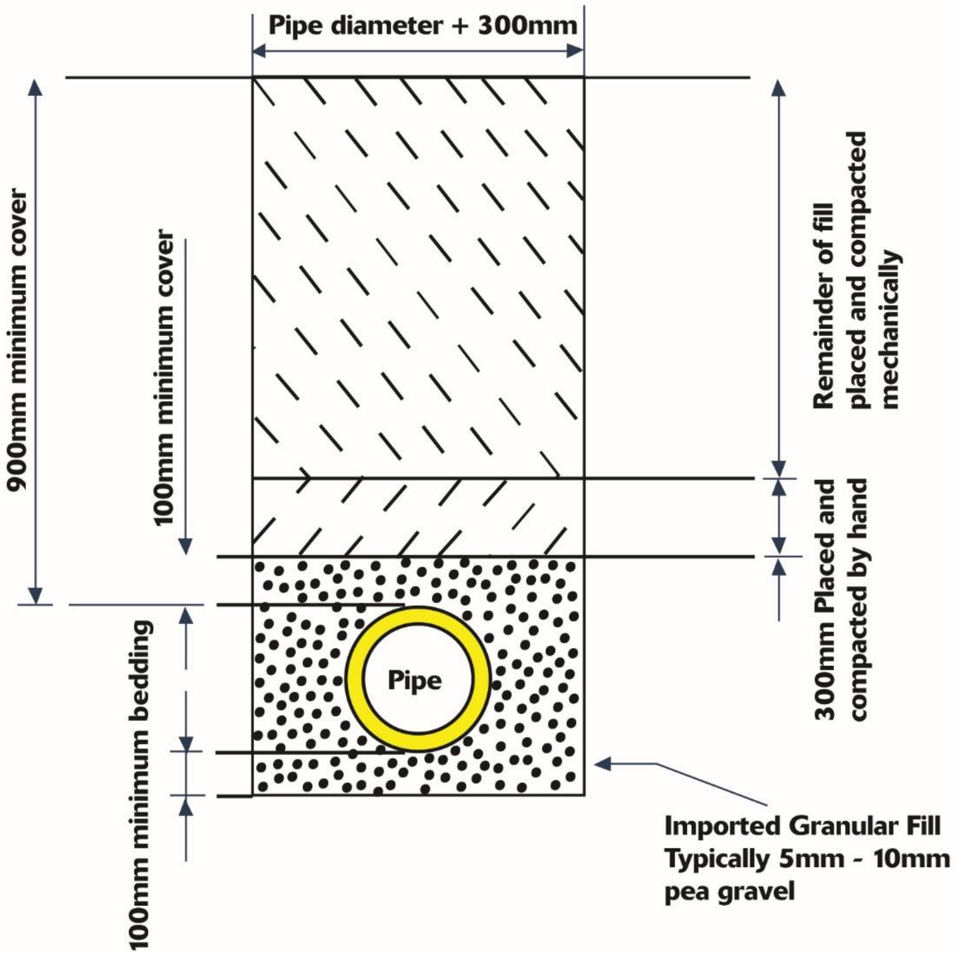
Class B : Granular materials

Class C : Cohesive/Granular materials

Class D : Cohesive materials

Unsuitable material for any part of the permanent backfill would include large stones, flints, lumps of clay, frozen earth, organic matter or chemically contaminated soil.

Heavy mechanical compaction machinery should not be used until the fill has reached a depth of at least 300mm above the top of the pipe.



Recommended Bedding, Side Fill and Back Fill

Installation

Typical Tests for Suitability of Soil Material (imported or local) for Surrounding Buried Plastic Pipes

Particle Size

This maximum particle size should generally not exceed 20mm. The presence of an occasional particle between 20mm and 40mm is acceptable provided the total quantity of such particles is only a very small fraction of the whole. If particles over 40mm are present the material should be rejected.

In cases of doubt a representative sample of material (about 2kg) should be sieved, using test sieves of 19mm and 38mm nominal mesh size.

NOTE 1 -To obtain a representative sample, about 50kg of the proposed material should be heaped on a clean surface and divided with the spade down the middle. One of these halves should then be similarly divided, and so on until the required mass of sample is left.

NOTE 2 -In the sieving, clumps of material that break up under light finger pressure may be helped through the sieve, but considerable force shall not be used to squeeze oversize clumps through the mesh.

If (i) any particles are retained on the 38mm sieve, or (ii) more than 5% by mass of the sample is retained on the 19mm sieve the material is not recommended.

Procedure - Obtain a representative sample (see Particle Size, Not e 1) more than sufficient to fill the cylinder (about 11 kg). It is important that the moisture content of the sample should not differ materially from that of the main body of material at the time of its use in the trench. Place the cylinder on a firm flat surface and gently pour the sample material into it, loosely and without tamping.

Strike off the top surface level with the top of the cylinder and remove all surplus spilled material. Lift the cylinder up clear of its contents and place on a fresh area of flat surface. Place about one-quarter of the contents back in the cylinder and tamp vigorously with the metal rammer until no further compaction can be obtained. Repeat with the second quarter, tamping as before, and so on for the third and fourth quarters, tamping the final surface as level as possible.

Measure down from the top of the cylinder to the surface of the compacted material. This distance in centimetres divided by the height of the cylinder (25cm) is referred to as the 'Compaction fraction'.

Test

Apparatus

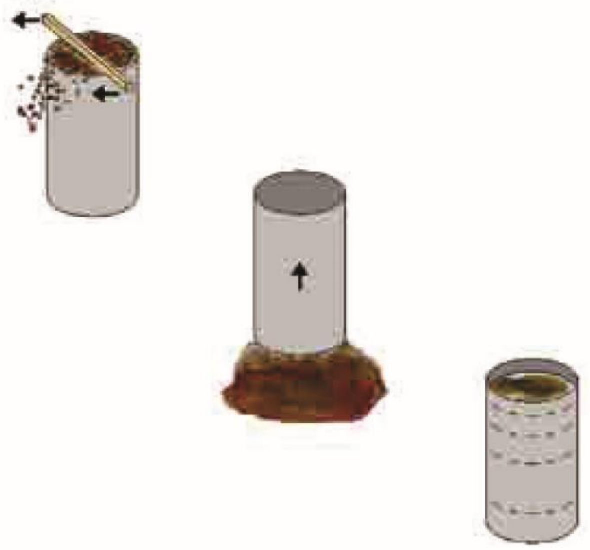
1. Open-ended cylinder 25cm long and 1 5±0.6cm internal diameter (15cm diameter PVC pipe is suitable).
2. Metal rammer with striking face 40mm diameter and weighing 1.0±0.1kg.
3. Rule.

Interpretation of results

Compaction fraction	**Suitability for use**
0.1 or less	Material suitable.
0.1 to 0.3	Material suitable but requires extra care in compaction. Not suitable if the pipe is subject to waterlogged conditions after laying.
Over 0.3	Material unsuitable.

Procedure

(a) Place cylinder on a firm flat surface and fill to overflowing with a typical sample of soil excavated from pipe trench.
(b) Skim off overfill and remove spillage
(c) Lift cylinder so that contents are left behind.
(d) Place now empty cylinder onto another firm flat surface.
(e) Place one-quarter of material back into cylinder and tamp down until completely compacted.
(f) Repeat with 2nd, 3rd and 4th quarters.
(g) Measure in mm from top of cylinder to surface of material to obtain figure "X".
(h) Divide figure "X" by 250 to obtain a compaction figure.
0.1 or less - suitable
0.1 to 0.3 - suitable with care, except in ground conditions generally waterlogged.
over 0.3 - unsuitable.



Installation

Mainlaying

This Section covers mainlaying including the lowering, laying and preparation for testing of the pipeline and summary of installation methods.

Preparation

Generally polyethylene pipes are joined to form a string above ground prior to snaking into the trench. To prevent scoring pre-made pipe systems, pipe rollers should be used.

Before commencing of pipelaying, the person responsible should ensure that the trench is safe in accordance with the health and safety procedures.

Before lowering polyethylene pipelines into the trench, a check should be made for cuts, deep scratches or other pipe damage and in fusion jointed systems that the system has cooled sufficiently before stress is imposed upon any pre-made joints. When lowering pipe into trenches, care should again be taken to avoid scoring of the pipe by contact with the sides and bottom of the trench. Special care is needed when passing under/around obstructions or other utility services. Use may be made of planks and ropes where appropriate but wire ropes or chains should not be used.

During lowering no-one should be allowed to stand underneath the suspended pipe.

Figure 6-Jointed PE pipes prior to laying

Pipelaying

Gradual changes in direction of polyethylene can be accommodated by pipe deflection but every effort should be made to keep the pipe as central as possible within the trench to enable correct side-fill compaction. Similar care should be taken when any distortion of coiled pipe has occurred.

During the pipelaying of continuous fusion jointed systems, due care and allowance should be made for the movements likely to occur due to the thermal expansion /contraction of the material. This effect is most pronounced at end connections to fixed positions and at branch connections.

For summer time installations with two fixed connection points, a slightly longer length of polyethylene may be required to compensate for contraction of the pipe in the cooler trench bottom. The snaking in the trench which naturally occurs with pipe 90mm and below is normally sufficient to compensate for this anticipated thermal contraction.

During a winter installation, the exact length of pipe should be used. Pipe which is too short or not aligned must not be drawn up by the bolts of a flanged connection because of overstressing the stub end, flanged adaptor and ultimately the valve or fixture to which it is connected.

It is advisable to defer the final tie-in connections until thermal stability of the pipeline has occurred. Once a pipeline is installed and in service, the temperature variation is usually small, occurring over an extended period of time and is not likely to induce any significant stress or movement in the pipe system.

Whenever possible, a minimum distance of 300mm from obstructions and other services should be maintained. This distance is often possible when laying parallel to other services but not always practicable when crossing other services. A separation distance of 75mm may be allowed for a square crossing but suitable protection should be provided from possible point loading, interference, damage or contamination.

Polyethylene is not a conductor of electricity and no attempt should be made to use PE pipework as a means of earthing electrical equipment. Similarly, because of its high electrical resistivity, caution is required in the use of the material where static electricity may be an important consideration.

The bending of polyethylene is permissible and the properties of fusion jointed systems enable changes of direction without recourse to the provision of special bends or anchor blocks. However, the pipe should not normally be cold bent to a radius smaller than the limits prescribed (see Design Considerations). For mechanical non end load resistant jointing systems, anchor blocks to withstand the resultant thrusts must be provided in the traditional manner, (See Design Considerations).

The hot bending of polyethylene pipe is possible under carefully controlled conditions but under no circumstances should hot bending be attempted under site conditions.

Polyethylene is a poor conductor of heat but is flammable and should not be exposed to naked flame.

Installation

The installation of flanged fittings such as sluice valves, hydrant tees, end caps etc., usually requires the use of polyethylene stub flanges complete with backing rings and gaskets. Care should be taken when tightening these flanges to provide even and balanced torque. Provision should be made at all heavy fitting installation points for concrete support both for the weight and to resist the turning moments associated with valves and hydrants.

Where flange connections are included in the pipeline these must be properly aligned and care taken when tightening to provide even and balanced torque. Bolts should be tightened in a North/ South, East/West, NE/SE, etc., pattern. On no account must flanged connections be used as a means to overcome poor alignment.

Recommended torque for flanged connections is given in Jointing Methods.

It should be noted that at three way fusion jointed fabricated tee installations, additional equipment and care in handling is necessary if the risk of damage is to be avoided. Consideration should be given to introducing a flanged connection on the branch outlet of the tee so that the branch main joint can be made in a separate operation.

Polyethylene pipes and fittings may be partially or completely surrounded by concrete but the pipe should be protected by a heavy duty polyethylene membrane to avoid possible damage during pouring or compaction and to prevent high localised stresses.

After completion of an installation, pipework and fittings should be inspected and made ready for testing to ensure the safety and efficiency of the system. If the system is a large one it should be tested in sections of convenient length up to a maximum length of 800m.

The degree to which the trenchline is backfilled prior to testing will be influenced by:

- the prevailing site and/or traffic conditions .
- the potential risk of floatation.
- the imbalanced forces due to configuration and imposed test pressure.

Where practical it is advisable to leave joints exposed throughout the test.

As part of the preparation for the hydrostatic pressure test all anchorages and struts should be checked to ensure they are adequate to withstand the excess pressures and it is advisable to retighten all bolted flanged joints and to check that all intermediate control valves are open.

Complete and accurate records should be taken of the installation. It is useful for records to be taken before the pipes are buried whilst memories are fresh and key elements are still visible.

Photographic records of important or complex features should be considered.

Marker tape should be laid along the line of main and connected at each end to either a sluice valve or hydrant. The recommended position of the tape is 350mm below the surface directly above the crown of the pipe.

On-Site Jointing

The various heat fusion techniques available for jointing PE pipe allow the installer a greater degree of freedom when considering the most cost effective/practical installation method suitable to a particular construction site. The main element of choice is that jointing a number of straight pipe lengths can be carried out at a fixed jointing station outside the trench area or conventionally at each joint position along the pipeline either outside the trench area or in the trench bottom. Generally and providing site conditions permit, the greatest advantage is obtained from jointing at a fixed position outside the trench area. In this circumstance pipes are transported by hand or mechanical means depending on size and class from the site storage area to the jointing station. During this phase all recommendations given in the 'Handling & Storage' section apply. The jointing station should consist of a covered shelter heated in winter months adequately lit to give the jointing operative clear vision around the pipe joint and of all pressure and temperature gauges, etc. Even in summer months it is good site practice to include for a shelter at the jointing station to provide protection against wind, rain, dampness, sands etc. These recommendations apply equally to projects where Electrofusion or Butt fusion jointing techniques are used but are most common for Butt fusion. Normally on land installations pipes are pulled through the jointing station by hand, winch, tractor, etc., depending on pipeline length, size and class. It is strongly recommended that the jointed pipeline is supported on sufficient free-running rollers as will prevent the jointed pipes from coming into contact with the ground. This will not only make pipe handling and the jointing operation easier but will prevent the pipe from being scratched and scored. In cases where jointing equipment is continuously moved to joint positions along the length of the pipeline, protection from the elements should still be provided and if joints are to be made in the trench then sufficient ground material must be excavated to provide adequate space for the operative and jointing equipment. In wet trench conditions precautions must be taken to ensure that the area around the jointing station remains dry.

On-Site Jointing Station Cover

Other Applications

Installing Coiled Pipes - Sizes 125mm and below

Coiled Polyethylene Pipes in 125mm and below should be moved and uncoiled using an approved dispensing trailer. There should be facilities available on site to restrain securely each coil individually throughout the transit and unloading process. Pipes should be uncoiled strictly in accordance with the releasing instructions for coiled pipe retaining straps detailed in Handling & Storage. After sufficient pipe has been cut from the coil, the protective end cap must be replaced on the remainder of the coil.

Coiled PE Pipe

Pipeline Rehabilitation / Re-Lining

The use of PE pipes for water main rehabilitation by slip lining techniques is now well established across the globe.

It is recognised that the properties of the material, particularly its flexibility, toughness and smooth bore are ideally suited for this application.

Pipeline rehabilitation is, of itself, an extensive subject and many professional contractors specialising in these techniques have emerged over the last decade.

This section, therefore, is not exhaustive but is intended to draw attention to some common aspects of this application for PE pipes which should not be overlooked.

Pipe Selection

The outside diameter and pressure class of the pipe required will probably be selected by considering:

- Flow requirements
- Size and condition of pipe to be relined
- The anulus to be grouted
- Is the system pressure or non-pressure
- Medium being conveyed e.g., potable water, sewage, industrial effluent, etc.

PE pipes to be used for re-lining applications are normally Butt fusion jointed.

It is normal practice to remove the external weld bead in order to provide a smooth continuous pipe surface when using pipe insertion technique.

Typical Slip Lining Installation

Installation

Sub-Aqueous Installations

Polyethylene pipes have been used extensively for many years in subaqueous installations. Here, in addition to effluent disposal projects, polyethylene potable water distribution mains link communities and Public Utility pumping stations over several kilometres. There are numerous examples where one continuous butt-welded polyethylene pipeline, traverses land and water over many kilometres.

Above Ground Installations

Where PE pipes are to be used in above ground installations, they must be protected against exposure to direct sunlight. It is good design practice to insulate thermoplastic pipes above ground. This will help to reduce the amount of movement caused by temperature variation.

Support for Horizontally and Vertically Suspended Pipes

There are two main factors to be considered when specifying support details for suspended PE pipe systems.

- Technical requirements
- Aesthetics

Technical Requirements:

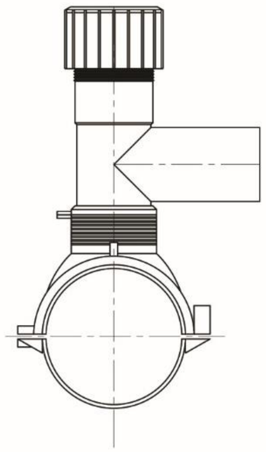
Polyethylene pipes installed in above ground systems will generally be black. Where PE pipe is specified this must be protected from direct exposure to ultra violet light (sunlight).

The correct specification of restraints and supports is an essential part of suspended PE pipe system design, and must take account of expansion and contraction at the extreme maximum and minimum service.

Installation

Connection to Polyethylene Mains

The preferred method of connecting polyethylene service pipes from polyethylene mains is my means of electrofusion self-tapping tees .



Electrofusion Self Tapping Tee

Laying Polyethylene Services

Service pipes are available in coils and thus offer an opportunity to limit the number of joints required in a particular situation. This, together with the facility to joint above ground enables narrow trenches to be adopted where conditions are suitable.

The ideal bed and surround requirements normally applied to mainlaying may not always be achievable. Care should be taken to ensure the pipe is not bedded on uneven or sharp projecting material. Every effort should be made to adequately compact suitable fine material around the pipe to at least 100mm above the pipe before normal back-filling takes place.

- electrofusion couplers
- push fit couplers
- compression fittings (metal or plastic)

Testing and Commissioning

This Section deals with the standard procedures for testing installed pipelines prior to commissioning. These standards will normally require, as a minimum, the adequate flushing of the service and the testing of all pipes and joints to the maximum head to which the system is to be subjected.

After being tested, all service pipes must be subjected to a final disinfection process before being introduced into the supply system.

Special attention should be paid to the proper sterilisation of those services laid to hospitals and renal-dialysis machines.

Hydrostatic Pressure Testing

The normal testing procedure used for most pipeline materials requires the application or a nominated hydraulic pressure to the pipeline, then isolating the pressure pump for a period of 1 hour. The success of the test is then judged by the quantity of water required to restore the original test pressure measured against a given formula.

However, when applying this regime to PE pipelines it is found that, due to the characteristic stress relaxation of the material, confusing and occasionally meaningless results are obtained. The relevant procedure that should be adopted for PE is outlined below.

HDPE Pressure Pipelines

1) Upon substantial completion of the pipeline or major sections, the line shall be cleaned and hydrostatically tested to prove integrity of the pipeline section and to detect any leakage prior to commissioning. Testing shall be performed in accordance with the Finnish Standard SFS 3115:E and the procedure described below. The Contractor shall supply all necessary fittings, equipment and facilities required to undertake the testing.

2) The Contractor shall prepare a detailed Method Statement for the pressure test that shall follow the outline test procedure described below and be subject to the approval of the Engineer.

(a) Seal the pipeline. Fix all blank flanges. Remove air valves. Remove all on line equipment that may be damaged by high pressure.

(b) Only test against blank flanges, do not attempt to test against closed valves.

(c) Cover the pipe with sufficient backfill to protect it from direct sunlight, leaving joints exposed where practical.

(d) If backfilling is not practicable schedule the tests for early morning or evening.

(e) Fill the pipeline from the lowest point. Bleed the air from all high points and flange points where it is possible and tighten once water begins to spill.

(f) When the line is full, close off the filling valve and check all flanges and the small diameter test pipework for leaks.

(g) **Phase1**

Commence raising the pressure at the filling point to the operating pressure or a pressure of 5 bar, whichever is higher. Hold this pressure for a period of 2 hours and add water whenever the pressure drops by 0.2 bar in order to maintain a steady pressure

(h) Visually inspect the pipe length for leakage.

(i) **Phase2**

After two hours raise the pressure to 1.3 times the operating pressure or 6.5 bar, whichever is higher, as quickly as is practical. Again maintain this pressure for two hours by adding water whenever the pressure drops by 0.2 bar.

(j) Visually inspect the pipe length for leakage.

(k) **Phase3**

At the end of the second two hours release the pressure back down to the phase I level i.e. the operating pressure or 5 bar, within a period of no more than 30 minutes and as quickly as is practical, in a controlled manner.

(l) **Phase3-Case1**

If after one hour the pressure in the pipelines remains at or above the operational pressure, the test is considered to be completed with the pipeline passing the hydrostatic test.

(m) **Phase3-Case2**

If after one hour the pressure in the pipeline has fallen below the operational pressure, water shall be added to raise the pressure back to the operating pressure level, having first noted the low pressure before adding any water.

(n) **Phase3-Case2**

Measure the added water by draining it off into a measuring cylinder. (i.e. reduce pressure to the previously recorded low value and save the water bled off). The measured quantity is then compared against the allowable quantity to determine if the pipeline passes the hydrostatic pressure test.

Figure 1 Graphical Representation of the Hydrostatic Test Process
Case 1 - Pipeline passes test without adding any make up water

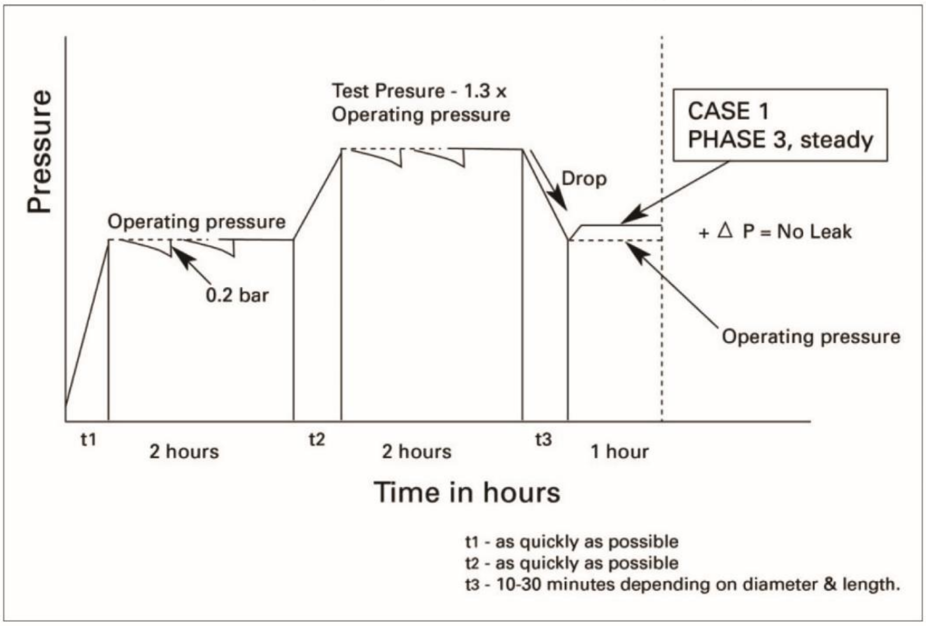
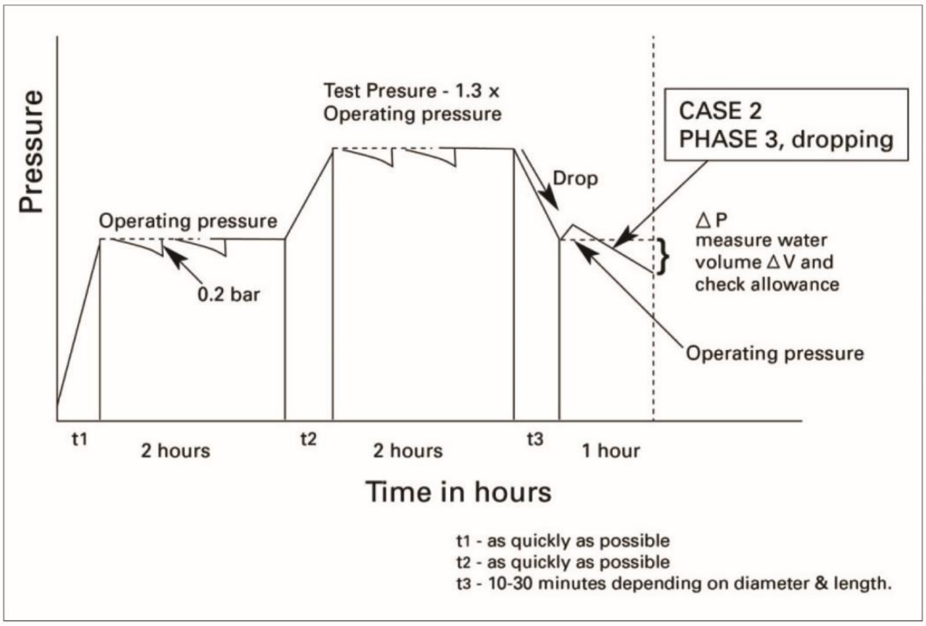


Figure 2 Graphical Representation of the Hydrostatic Test Process
Case 2 - Water to be added to determine if the pipeline passes or fails



3) If during Phase 3 the pressure within the pipeline remains at or above the operational pressure of the pipeline for a period of at least one hour, the pipeline is considered to have passed the hydrostatic test.

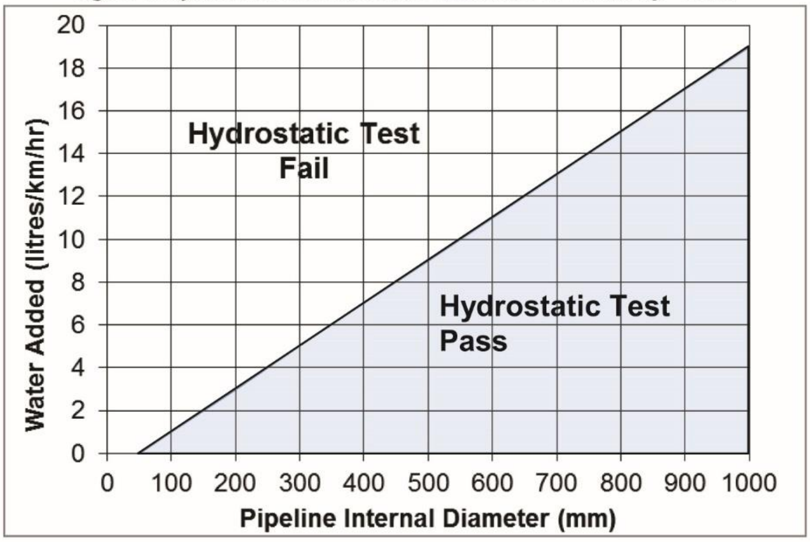
4) If water needs to be added the pipeline is considered to have passed the hydrostatic test if the quantity of water added in terms of litres of water per km of pipeline length per hour of the phase 3 period is less than that given in the following expression and in Figure 3.

Q≤ Di/50- 1 (litres/ km/ hour)

Q = added water in litres.

Di =internal diameter for the pipeline in mm.

Figure 3. Hydrostatic Test-Allowable Quantities of "Make Up" Water



5) The pressure gauge shall be calibrated, certified and to accurate to 0.1 bar. It shall be connected to the feed pipework.

6) The small diameter test pipework shall include a bleed valve at upper end of the pipeline and at all high points together with feed pipework and valve at the lower end of the pipeline. The feed pipework shall include a means of draining off the water in to a measuring cylinder that shall have a capacity of at least 2 litres capacity, graduated to 100 mls.

7) The Contractor shall also have a thermometer for air and water temperature measurement.

8) Care should be taken not to over pressure the lower end of the system during testing. Gauges should always be placed at the lower end of the length under test. As far as possible the difference between the lower and upper end should be kept to one bar. It is recognized that this may not always be possible when longer lengths are being tested, or where the slope of the pipeline makes it impractical.

9) Where the phase II pressure is within the pressure rating of the pipe and test temperatures are 30°C or less no adjustment of test pressure is necessary.

10) When ambient temperatures at the time of test are over 30°C and test pressures are over the pressure rating of the pipe then it may be necessary to modify the test pressure according to the table below or as agreed with the pipe manufacturer.

Test Temp. (°C)	32	38	43	49	54	60
Multiplier	0.9	0.8	0.75	0.65	0.6	0.5

11) When undertaking the testing the Contractor shall also take in to account the following points.

(a) Care should be taken that any mechanical elements on the system are protected from elevated pressure or completely removed from the pipeline.

(b) Do not subject the line to prolonged over-pressure. Always aim to complete the procedure within one working day.

(c) During the summer make sure that the pipe is not subject to direct sunlight during testing.

(d) During pressure testing pay full attention to the HSE aspects of the procedure. In particular keep the general public away from high pressure test areas.

(e) The test equipment must be capable of pressurizing the test length within a reasonable time. If the procedure becomes protracted (beyond one working day) the test length may be modified or reviewed. Extremely long test lengths may be subject to special procedures.

Health and Safety

Polyethylene pipes and fittings have been used safely and effectively throughout the world, in a wide variety of installation conditions, for almost 40 years. At all times, the health and safety of operatives, and other people, involved in the processing, handling, jointing, installation, testing and use of polyethylene pipe systems has been of paramount importance to Hepworth PME (Qatar) WLL to achieve and maintain these objectives, good working practice is essential.

The Material

Polyethylene is chemically unreactive and generally regarded as biologically inert. It is not classified as a dangerous product (EEC).

Ingestion

Ingestion of polyethylene in any form should be avoided.

Inhalation

Inhalation of PE dust can irritate the respiratory system. Wherever possible, when cutting or scraping PE pipes, operatives should work in the open air or in well-ventilated areas.

Physical Contact

Polyethylene is not regarded to be a skin irritant. When cutting or scraping PE pipes or fittings, PE dust particles may cause eye irritation and it is recommended that protective eyewear be used.

Fire Hazards

Polyethylene burns but is not classified as flammable. It has a flash point of 360°C approximately.
Above 300°C, PE will degrade to produce carbon monoxide, water and small amounts of various hydrocarbons and aldehydes.
Avoid the accummulation of PE dust particles as they could give a potential risk of dust explosion.
All electrical equipment in the area should be carefully sited and earthed.
In the event of fire involving PE materials, apply water in a spread jet. Dry chemical, foam and carbon dioxide can also be used.

Handling

PE pipes and fittings should be handled and moved in accordance with the instructions detailed in the Handling & Storage section of this publication.
Particular care should be taken when handling large diameter PE pipes.
Safety clothing and equipment should be used at all times when handling and moving PE pipes and fittings.
When transporting, handling and releasing coils of PE pipes, extreme caution should be taken, instructions detailed in the Handling & Storage section MUST be strictly adhered to.

Jointing

Butt fusion or electrofusion jointing of PE pipes and fittings should always be carried out in well-ventilated areas. The fusion process is a high temperature operation and fumes are produced around the jointing area. Inhalation of the fumes should be avoided or kept to a minimum.

During the butt fusion operation, molten PE is formed. This should not be allowed to come into contact with the skin as it will adhere strongly and cause severe burns. Protective gloves should be worn during the jointing process and when cleaning the heater plates of the welding machinery.

During the electrofusion process, care should be taken to prevent the ejection of molten material from the joint area. Protective clothing, including gloves and safety eyewear, should always be worn during the jointing process.

Disposal of Waste Material

Surplus or waste polyethylene material can be reprocessed into new pipes or other products. Alternatively, it can be used as landfill or incinerated, dependant on local regulations. Recycle where it is practical to do so.

The Environment

Polyethylene is not considered dangerous for the environment.

First Aid

The following are recommendations for immediate first aid to be applied in the event of an accident involving polyethylene products. However, **qualified medical attention should be obtained as soon as practically possible**.

Ingestion: Wash mouth out with water

Inhalation: Move affected person into fresh air situation. If in distress, apply oxygen or artificial respiration.

Eye Injury: If PE particles enter the eye, immediately flood with water, repeating as necessary.

Burns: If molten PE material comes into contact with the skin, cool the affected area immediately by flooding with cold water. DO NOT remove the PE material from the skin - seek medical attention as quickly as possible even for the smallest burn. For more information, request Hepworth pipes Safety Data Sheet (SDS) from Technical Service Department.

FM Approval

The increasing acceptance of polyethylene as an approved material for safe transportation and distribution of both gas and water has led to the fire fighting industry introducing the material for fire-fighting applications.

Hepworth PME (Qatar) WLL and our principal Georg Fischer Piping Systems (Switzerland) have successfully undertaken FM Approval Testing and Auditing which means that we are now able to offer fully Factory Mutual (FM) approved Fire Fighting Pipe Systems for buried applications with operating pressures of 185 PSi 12.76 for SDR11 and 250 PSi 17.24 for SDR9.

Main pipeline sizes from 63 – 500mm for SDR11 and 63 - 400mm for SDR9 are approved for firefighting applications together with a wide range of fittings.

Stringent FM Testing and Auditing guarantees customers complete confidence for the use of polyethylene as a material for buried firefighting applications. Fusion welded joints ensure that the subsequent pipe system is secure and safe and is able to give an operational lifetime of more than 50 years, leak and corrosion free with minimal maintenance.

FM APPROVED

Certificate of Compliance

This certificate is issued for the following:

Polyethylene (PE) Pipe for Underground Fire Protection Service
(see attached product table)

Prepared for:
Hepworth PME (Qatar) WLL
PO Box 50207
Mesaieed
Qatar

Manufactured by:
Hepworth PME (Qatar) WLL
PO Box 50207
Mesaieed
Qatar

FM Approvals Class: 1613

Approval Identification: 0003046077 Date Approved: September 27, 2012
Superseded by: RR210876 Date Approved: August 31, 2017

To verify the availability of the Approved product, please refer to www.approvalguide.com

Said Approval is subject to satisfactory field performance, continuing Surveillance Audits, and strict conformity to the constructions as shown in the Approval Guide, an online resource of FM Approvals.

David B. Fuller
VP, Manager of Fire Protection
FM Approvals
1151 Boston-Providence Turnpike
Norwood, MA 02062 USA

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FM APPROVED

Certificate of Compliance

Polyethylene Pipe and Fittings

Product Designation	*Nominal Pipe Size, mm*	*Pressure Rating, psi (kPa)*	*Remarks*
HDPE PE100 SDR11 Pipe	63, 75, 90, 110, 125, 160, 180, 200, 225, 250, 280, 315, 355, 400, 450, 500	185 (1275)	a, b, c, d
HDPE PE100 SDR9 Pipe	63, 75, 90, 110, 125, 160, 180, 200, 225, 250, 280, 315, 355, 400	250 (1725)	a, b, c, d

Remarks:
a. Dimensions refer to the pipe outside diameter.
b. Pipes and fittings may be directly connected together by the butt fusion process or through the use of electrofusion fittings and couplings. Manufacturer's fusion instructions must be strictly followed to ensure a proper fusion joint.
c. The color of the pipes is black or black with colored identification stripes.
d. Pipes are manufactured in accordance with ISO4427.

FM Approvals
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Page 2 of 2

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