RADIUS
Systems

Natural Gas Pipelines

Polyethylene pipe systems for pressure classes up to 10 bar

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1.INTRODUCTION

Gas distribution was among the first applications for medium density polyethylene when it was introduced in the early 1960's. As a material, it offers a number of advantages including resistance to corrosion, flexibility and simple welding technologies for leak tight joints. With adoption of the material by the USA and the UK in the 1960's, polyethylene gas distribution systems have become established and are now the preferred solution for new and replacement networks, worldwide, for operating pressures up to 10 bar. Continuous development of the materials will continue to push this boundary to higher pressures in the future.

Both naturally occurring methane gas, and suitable manufactured gases can be transported under pressure through polyethylene pipes. As a hazardous substance, the design of installations involving the transportation of flammable gases is subject to national and international regulations, and as such, only competent persons should undertake the design and supervision of installations. This guide has been prepared as an aid for suitably qualified persons involved in the process of laying polyethylene gas distribution pipes.

This manual is seen as a living document and Radius Systems intend to develop the content over time to reflect introduction of new technology, or to respond to common requests for information. If you have any suggestions for content you believe would be of general industry to the gas industry, connected with polyethylene pipe systems then please email us at marketing@radius-systems.co.uk and we will review and develop a section based on the information we hold.

PROPERTIES OF POLYETHYLENE

1.1 Colour

The colour of polyethylene pipes for gas distribution in the United Kingdom is normally either a bright yellow or orange colour. Whilst originally the colour was used to differentiate the grade of polyethylene, it is now more accurately a reflection of the pressure class of the pipe.

The colour of polyethylene pipes in the United Kingdom conforms to guidance from the National Joint Utilities Group (NJUG), contained in their document "Utility guidelines on positioning & colour coding of apparatus", reflected also in national and European standards.

The following products are found in the gas distribution systems of the United Kingdom and Ireland;

- Tan coloured pipe; Laid in the 1960's and early 1970's, this will typically be imperial dimensioned pipe and will be found working at pressures up to 2 bar

- Yellow coloured pipe; Laid since the 1970's to the present. At one time the standard for all dimensions to 630mm and all pressure classes up to 5.5bar.

- Yellow coloured pipe with brown stripes; Laid since 2000, a peelable skin multilayer pipe which has become the industry standard for all dimensions above 180mm, all pressure classes up to 2 bar. Currently being introduced in the size range 90 to 180mm.

- Orange colour pipe; Available in selected sizes from 63 to 500mm diameters, this pipe is used for all pressure classes above 2 bar, and up to 7 bar in the United Kingdom and Ireland.

1.2 Strength

The strength of polyethylene pipe is normally classified at a point in time known as the 50-year design point. This should not be confused with lifetime of the installation; it is simply an accepted point in time at which the material strength should be classified for the purpose of designing a system.

Classification is based on the hoop strength of the material, which is the measure of the material in a pipe form to contain the stresses imposed by the pressurised gas without rupture occurring. Using a process embodied in the internationally recognised standard ISO TR 9080, materials are classified according to their minimum required strength (MRS) at the 50-year design point, at a nominal operating temperature of 20°C and receive the following designation:

- PE80; a material with MRS 8MPa

- PE100; a material with MRS 10MPa

- PE125; a material with MRS 12.5MPa

Note; there are no commercially available PE125 pipes currently available for gas distribution systems.

To determine the potential pressure rating of the pipe, the classical Barlow's formula is used;

$$P = (20\sigma)/c(SDR-1)$$

$$SDR = D_o/t$$

Where

P = Maximum operating pressure (bar)
σ = Minimum remaining strength at 50 year design point (MPa)
c = Minimum safety factor (UK national requirement is minimum 2.9)
SDR = Standard dimension ratio
D_o = Minimum outside diameter
t = Minimum wall thickness

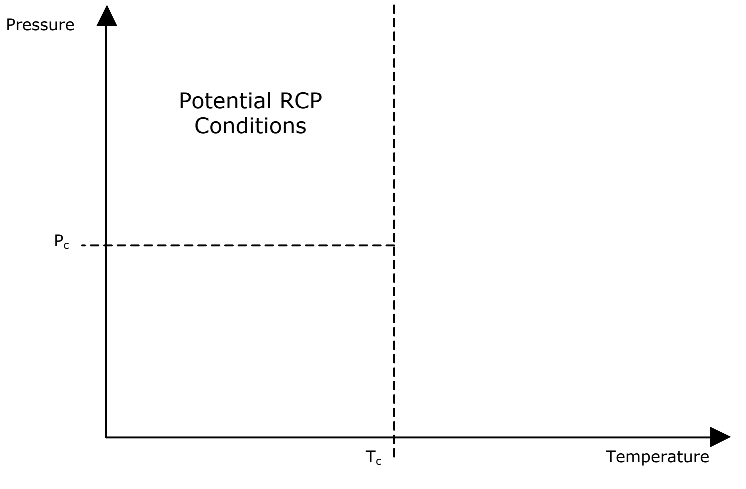
Where pipelines are operating at temperatures above 20°C, then an additional derating factor should be applied, reducing the potential maximum operating pressure in line with the reducing strength of the material.

1.3 Fracture Resistance

The inherent flexibility of polyethylene pipes provides a very high level of fracture (resistance) toughness. As a simple measure, the flexibility of the pipe allows it to absorb high levels of impact loads associated with the construction phase, and vibration and stress caused by soil or ground movement post installation (fatigue resistance). Their flexibility and ability to deform significantly without failure through either ring or beam bending, enable PE pipes to be laid in difficult ground conditions (potentially unstable ground normally associated with mining subsidence or earthquakes), or to be cold bent on site to accommodate difficult road layouts and varying terrains.

When designing a system containing a pressurised gas, irrespective of the material, the designer should have some knowledge of events that can lead to fracture of the material, and the consequences that this might have. In terms of consequential effects, the main failure mode which is designed out of the system is known as rapid crack propagation, an event where a crack is forced into the material and a combination of material quality, temperature and internal pressure then determine whether the crack will be driven further along the pipe and if so, how far before the crack tip is blunted and the fracture event arrested. A simplied explanation of the phenomenon is given below.

The graph shown above provides a conceptual view of the conditions necessary for RCP to occur. Normally a critical temperature (Tc) must first be achieved, this being the mean temperature of the pipe material. For PE80 materials Tc is generally >0ºC, whilst for PE100 materials it is generally <0ºC. A critical internal operating pressure (Pc) must then be exceeded and finally there must be a fracture initiation point to enable the RCP event to commence.



Normally a designer need not be concerned with RCP performance when designing gas distribution pipelines against the established codes of practice in the United Kingdom (i.e. the GBE/PL2 pipe materials specifications and the IGEM construction codes of practice). Manufacturers are required to test their pipes at twice the rated maximum operating pressure, at a temperature below Tc, to ensure that they are resistant to RCP within this performance envelope. This ensures that a safety factor of at least 1.25 exists when the pipe is under pressure test conditions, the time when the pipe is at the greatest pressure it will see in service (commissioning pressure tests are normally conducted at 1.5 times the rated maximum operating pressure of the pipeline).

1.4 Corrosion resistance

Polyethylene is chemically inert at the temperatures of operation normally associated with below ground gas distribution infrastructure. As such, it will not form a chemical or electrical reaction with the surrounding soil leading to corrosion of the pipe material.

1.5 Chemical resistance

Polyethylene has good resistance to a wide range of chemicals. The main area to be concerned with is the effect of certain chemicals likely to be found within contaminated land, or inside old metallic gas mains (where for example a new polyethylene pipe might be inserted). In general terms, the most common harmful chemicals can be grouped into 3 categories, oxidisers, cracking agents and certain solvents (see the table below).

Group	Generalised examples	Effects on PE
Oxidisers	Very strong & concentrated acids	Degradation
Cracking agents	Detergents	Can accelerate cracking of defects when combined with high temperatures
Solvents	Hydrocarbons such as benzene (petrol)	May be absorbed into the pipe wall causing reduction in the hoop strength of the pipe

The effect of specific chemicals (i.e. combination of polyethylene and a single chemical type) is considered in the specification ISO/TR 10358(1993) "Plastics pipes & fittings – combined chemical resistance classification table". The specification defines three classifications; satisfactory resistance, limited resistance and resistance not satisfactory. Resistance data is provided for 427 chemicals of varying concentrations at differing temperatures of installation.

For specific cocktails of chemicals that may be found in contaminated land areas, it may be necessary to perform specialist accelerated life tests to assess the suitability of polyethylene materials. Significant studies have already been undertaken of sites previously used for the manufacture of gas (i.e. old gas works for towns gas manufacture), and the residues likely to be found in both the site grounds and the pipes used to convey the gases. It is recommended that specialist consultants such as Advantica Technologies Ltd, or Ewan Associates, be consulted in the first instance for guidance on this subject, (they were responsible for researching and producing the Contaminated Land Investigation for Pipe Selection CLIPS database).

1.6 Weathering

Polyethylene pipes supplied by Radius Systems are intended for installation below ground, except in special cases where they might be installed inside a duct, for example in a tunnel or a suspending bridge crossing. In service, they would not expect to be visible to solar radiation (sunlight), other than during the storage period prior to installation, or for short durations where excavations are made to expose the pipe during maintenance operations.

Coloured polyethylene pipes are manufactured using a built in UV radiation stabiliser package, hence they can be stored outdoors and exposed to sunlight for a period of up to 12 months. This advice is based upon a level of sunlight equivalent to a radiation energy level of 3.5 GJ (i.e. 12 months average sunlight in the United Kingdom).

Where it is necessary to store the pipe outside for a period beyond 12 months, then it is recommended that the pipe be covered with black polythene sheeting of a gauge sufficient to resist damage while pipe is in storage, or the pipe be brought into a warehouse so that sunlight cannot directly shine on the material. The sheeting should be arranged so that air can still pass through the storage area to prevent the growth of organic matter which would otherwise need to be cleaned off the pipe prior to use.

1.7 Thermal effects

Polyethylene is affected in two main modes by thermal forces, and these must be allowed for in the design of the gas distribution system.

In the UK the normal ground temperature is not expected to exceed 10ºC year round, and with the material design temperature being 20ºC, no consideration of the effect of temperature on hoop strength (i.e. operating pressure) is required. It is only where the pipe is installed in ducts, tunnels or warmer climates where a treatment of the thermal effects is required.

The method of calculating the maximum operating pressure of a polyethylene pipe at elevated temperature is detailed in the following 2 reference standards:

- EN1555-5:2002; "Plastics piping systems for the supply of gaseous fuels – Polyethylene (PE) – Part 5; Fitness for purpose of the system"

- ISO 12007-2:2000; "Gas supply systems – Pipelines for maximum operating pressure up to and including 16 bar – Part 2; Specific functional recommendations for polyethylene (MOP up to and including 10 bar)"

As a guide, the above specifications recommend that where the operating temperature of the pipeline exceeds 20ºC up to a maximum operating temperature of 40ºC, then the maximum operating pressure of the pipeline must be reduced by 1.3% per degree Celsius for every 1ºC above 20ºC. . As a simplified calculation, use the formulae below and the table to estimate the maximum operating pressure of a polyethylene pipe conveying natural gas, assuming the UK minimum safety factor of 2.9, for temperatures in the range 20 to 40ºC, for PE80 and PE100 pipes.

- MOP (ProFuse PE100 pipe, SDR 21) = 2 bar*Df

- MOP (Yellow PE80 pipe, SDR 17.6) = 4 bar*Df

Temperature	Derating Coefficient (D_f)
20ºC	1.00
22ºC	0.974
24ºC	0.948
26ºC	0.922
28ºC	0.896
30ºC	0.87
32ºC	0.844
34ºC	0.818
36ºC	0.792
38ºC	0.766
40ºC	0.74

For temperatures between each step in the table, it is permissible to use linear interpolation.

In the same way that the operating pressure is affected by temperature, so to is the tensile strength of the material, since the two properties are closely related. This may be a consideration when laying PE pipelines when using "No-Dig" or "Trenchless" construction techniques that involve pulling the pipe into the ground. Section 5 deals with tensile forces but as a first approximation, it is worth applying the above 1.3%/ºC reduction factor to the tensile strength when calculating the maximum permissible tensile loading for the pipeline during installation.

The final consideration of thermal effects in the design of a pipeline is to consider the effect of thermal expansion and contraction. Polyethylene materials have a coefficient of thermal expansion of $1.5x10^{-4}$ (m/m) per °C, roughly 10 times the amount for iron or steel. For gas distribution pipelines laid below ground, with full end load bearing joints, this does not present a major problem as the visco-elastic nature of polyethylene generally means that the stresses imposed creep to low values over time.

Where the polyethylene pipe is to be connected to pipelines with non end load bearing joints, for example cast iron spigot and socket jointed pipes, then anchorage blocks must be used to ensure that thermal contraction forces do not cause the joints to disengage by pull out. Guidance on the use of concrete anchorage blocks and their design for differing ground conditions and thrust forces is contained in BS6700(1997); "Design, installation, testing & maintenance of services supplying water for domestic use within buildings and their curtilage". Anchorage blocks are generally cast in-situ at site and it is recommended that a membrane of polyethylene, (nominally) at least 3mm thick, should be wrapped around the polyethylene pipe (approximately 150mm either side of the termination point through the concrete anchorage block), to minimise shear and bending stresses from differential settlement between the concrete block and the pipeline and to prevent damage to the pipe from chafing on the concrete. Additionally, the general principle should be applied that concrete should not be cast over any jointed elements in the system.

Where polyethylene pipe is to be used in ducts above ground, full end load bearing joints must be used throughout the installation. Where a polyethylene pipe is installed unconstrained within a larger diameter duct then to prevent movement of the pipe within the duct and chafing (abrasion) of the surface of the pipe then consideration should be given to the use of pipe supports or spacers.

1.8 Electrical

Polyethylene is a poor conductor of electricity and should never be used for the earthing of electrical equipment.

Within the gas distribution application, caution should be exercised in the use of polyethylene materials as they are capable of holding a static electricity charge. It is the normal practice before performing a live gas operation on a polyethylene main to ensure that the pipe has been earthed using wet rags prior to commencing the operation to mitigate the hazard.

2. STANDARDS

The basic set of recommended standards and codes of practice when working with polyethylene pipe and fittings for gas distribution applications is listed below. The list is by no means exhaustive and designers should maintain an awareness of the most up to date current practice and legislation within the industry through their professional bodies.

Institution of Gas Engineers & Managers
Charnwood Wing
Ashby Road
Loughborough
Leicestershire
LE11 3GH
www.igem.org.uk

IGE/GL/1; edition 2; 2005 “Planning of gas distribution systems of MOP not exceeding 16 bar”

IGE/GL/5; edition 2; 2005 “Procedures for managing new works, modifications and repairs”

IGE/TD/3; edition 4; 2001 “Steel and PE pipelines for gas distribution”

GBE/PL2; Suite of specifications for polyethylene pipe and fittings

GBE/PL3; Specification for end load bearing mechanical fittings

British Standards Institute
www.bsonline.bsi-global.com

BS EN 1555; Suite of European specifications for polyethylene pipe and fittings

BS EN 1295-1; Structural design of buried pipelines under various conditions of loading

3. PIPE SELECTION

3.1 Sizing of the pipe's internal bore based on demand flow rate

The basis of sizing any pipeline is to begin with an assessment of the peak demand (maximum volumetric flow rate), the length of the pipe, the inlet pressure and the minimum terminal pressure required. With these key pieces of information, the minimum bore size of the pipeline can be calculated.

For anything other than a single length of pipe, or a very simple "tree" network, it is recommended that a computer based analysis programme is used that permits the steady state conditions of the network to be established and the pipes sized accordingly.

For simple analysis of a length of pipe, one of two approaches is favoured, either calculated using the formulae for the sizing of gas pipelines as published in document IGE/TD/3, sections 5.3 and 5.4, or a manual calculation using a disc calculator, such as the Mear's (metric gas flow calculator for plastic pipes) calculator.

3.2 Sizing wall thickness based on pressure class

The following pipes are considered to require no structural design considerations when laid in accordance with NJUG recommendations (i.e. to a nominal depth of cover of around 600mm), in a footpath or road. In such cases, the selection of pipe SDR is based only on the pressure class required. Note; for sizes 75mm and below, pipes are currently only available as PE80 SDR 11 pipes and are rated for pressures up to 5.5bar.

- PE100 SDR 21.0, diameters 90 to 630mm, maximum operating pressure 2 bar
- PE100 SDR 17.6, diameters 250 to 500mm, maximum operating pressure 4 bar
- PE100 SDR 11.0, diameters 63 to 500mm, maximum operating pressure 7 bar

PE100 SDR 21.0 pipes are supplied as peelable skin pipes, with a yellow colour, often referred to by their product name "ProFuse". Pipes of SDR 17.6 & 11 are supplied as a solid wall orange pipe and may be referred to by their product name "PerformOR".

The table overleaf lists the common sizes of pipe and their dimensions, enabling the preferred bore size to be calculated (i.e. minimum, mean or maximum).

Table of common pipe dimensions 25 to 630mm

Outside diameter Minimum	Outside diameter Maximum	SDR 11.0 Wall thk. Minimum	SDR 11.0 Wall thk. Maximum	SDR 17.6 Wall thk. Minimum	SDR 17.6 Wall thk. Maximum	SDR 21.0 Wall thk. Minimum	SDR 21.0 Wall thk. Maximum
25	25.3	2.3	2.7				
32	32.3	3.0	3.4				
40	40.4	3.7	4.2				
55	55.4	5.0	5.8				
63	63.4	5.8	6.5				
75	75.5	6.9	7.6				
90	90.6	8.2	9.2	5.2	5.9	4.3	4.8
110	110.7	-	-	6.3	7.1	5.2	5.9
125	125.8	11.4	12.7	7.1	8.0	6.0	6.6
140	140.9	-	-	8.0	8.9	6.7	7.4
160	161.0	-	-	9.1	10.1	7.6	8.5
180	181.1	16.4	18.2	10.3	11.5	8.6	9.5
250	251.5	22.8	25.1	14.2	15.8	11.9	13.2
280	281.7	-	-	-	-	13.3	14.8
315	316.9	28.7	31.6	17.9	19.8	15.0	16.6
355	357.2	32.3	35.7	20.2	22.4	16.9	18.7
400	402.4	36.4	40.2	22.8	25.2	19.0	21.0
450	452.7	41.0	45.1	25.6	28.3	21.4	23.7
500	503.0	45.5	50.2	28.4	31.4	23.8	26.3
630	633.8	-	-	-	-	30.0	33.1

3.3 Sizing wall thickness based on ground loading

As with all pipeline materials, consideration needs to be given to structural design of below ground infrastructure if large static and dynamic loads can be expected within the soil structure surrounding and covering the buried pipe. Consideration might be necessary for construction phases where the final surfaces are not built up and very heavy earth moving equipment is being used over the pipeline, for unique applications such as beneath major structures such as runways or civil engineering works (i.e. heavy concrete caps and structures), and beneath railway lines. In these situations the designer is required to demonstrate that the pipe is sufficiently strong to resist the loadings without excessive deformation, collapse or fracture (failure mode dependent on material type, for a visco-elastic material such as polyethylene, the failure mode is likely to be collapse resulting in reduced capacity).

The basis of the accepted method of calculating the strength of pipe required for a UK application is EN1295-1. When working with these calculations, the following polyethylene material properties are required:

- Short term modulus; PE80=800MPa, PE100=1100MPa
- Long term modulus; PE80=130MPa, PE100=160Mpa
- Design deflection should be limited to <12.5%

If the calculated SDR required to limit deflection is greater than that required to contain the internal pressure, then clearly this criteria should take precedence when selecting the most appropriate pipe and vice versa.

3.4 Derating for elevated temperature operation

Where pipe is to be installed such that the temperature of the material is likely to be raised to the range 20 to 40°C, then the advice contained in section 1.7 should be followed to reduce the maximum operating pressure capability of the pipe.

4. PIPE INSTALLATION

4.1 Surface Damage

The safety factors applied to polyethylene pipes allow for some surface damage occurring on the outer surface of the pipe. However, as a pipe system destined for the distribution of a flammable fuel gas and the safety considerations that this entails, a system of work should be implemented whose basic philosophy is to avoid surface damage occurring in the first instance.

Most surface damage occurs as a result of storage, lifting and handling operations between the point of manufacture and the point of installation, and with the advent of trenchless techniques during the actual installation process itself.

To avoid damage during storage simple precautions should be taken to ensure pipe is stored on firm level ground, it should be supported off the ground to prevent any sharps or stones being impressed into the pipes. When pipe is lifted at site, it should be lifted using man made fibrous slings around the pipe, and for sticks of 12m length or more, using a lifting beam to spread the loading to prevent sagging or slippage of the pipe during the lifting operation. Similarly, when moving butt fusion jointed strings of pipe around a worksite, pipe rollers or pipe bogies should be used to support the pipe off the ground whilst it is pulled to the area where it is to be installed.

The allowance for unavoidable surface damage is taken as 10% of the minimum wall thickness of a pipe. Pipes normally state their diameter and SDR on the printline and thus it is possible to calculate the wall thickness at the worksite prior to making the inspection. The thickness is calculated according to the formula:

- Minimum wall thickness = Outside diameter / SDR

Standard tools are available from industry tooling providers for measuring the depth of scoring damage in pipes (quote: depth damage measurement indicator for polyethylene pipes). Such tools normally work on the principle of taking a datum measurement on the pipe immediately adjacent to the damaged area, then measuring the damaged area itself. The difference between the two measurements is the actual depth of the score in the surface of the pipe and this can be judged against the 10% wall thickness criteria.

The only variation to this principle is the use of peelable skin multilayer pipes such as ProFuse. In the case of these pipes, the skin layer is considered to be sacrificial and as such scoring damage contained within the skin does not require measurement. The only requirement for checks is where the skin is pierced and in this case the normal 10% criteria applies, the wall thickness being that of the core pipe beneath the skin.

4.2 Tensile loading

During pipe installation using trenchless techniques such as insertion (by pulling/winching), or horizontal directional drilling, tensile forces are applied to the pipe and in some cases these can be considerable. It is important that these tensile forces do not exceed the pipe manufacturers recommendations, as a rule of thumb they should be calculated by using a maximum of half the minimum yield strength of the pipe material. By limiting these tensile forces, the pipe will not be subjected to significant elongation (stretching) under load and equally will not be taken to a point where plastic damage (yielding) of the pipe will occur. Suitable equipment shall be selected and used at the worksite to limit the loads applied to the pipe to the maximum values in the table below. Note; for HDD applications where the pipe is subjected to a tensile force for over 1 hour, a derating factor of 0.8 should be applied to the values in the table below.

Outside diameter (min)	SDR 21.0 ProFuse Maximum load (tonnes)	SDR 17.6 PerformOR Maximum load (tonnes)	(SDR 11.0 PE80) or SDR 11.0 PerformOR Maximum load (tonnes)
25			(0.12)
32			(0.20)
40			(0.32)
55			(0.60)
63		0.68	(0.79)1.05
75			(1.12)
90	1.18	1.39	(1.61)2.15
110	1.76		(2.40)
125	2.27	2.68	(3.10)4.14
140	2.85		(3.89)
160	3.72		(5.08)
180	4.71	5.56	(6.44)8.58
250	9.08	10.73	16.55
280	11.39		
315	14.42	17.04	26.28
355	18.31	21.64	33.38
400	23.25	27.48	42.37
450	29.43	34.77	53.63
500	36.33	42.93	66.21
630	57.68		

4.3 Trench design & reinstatement

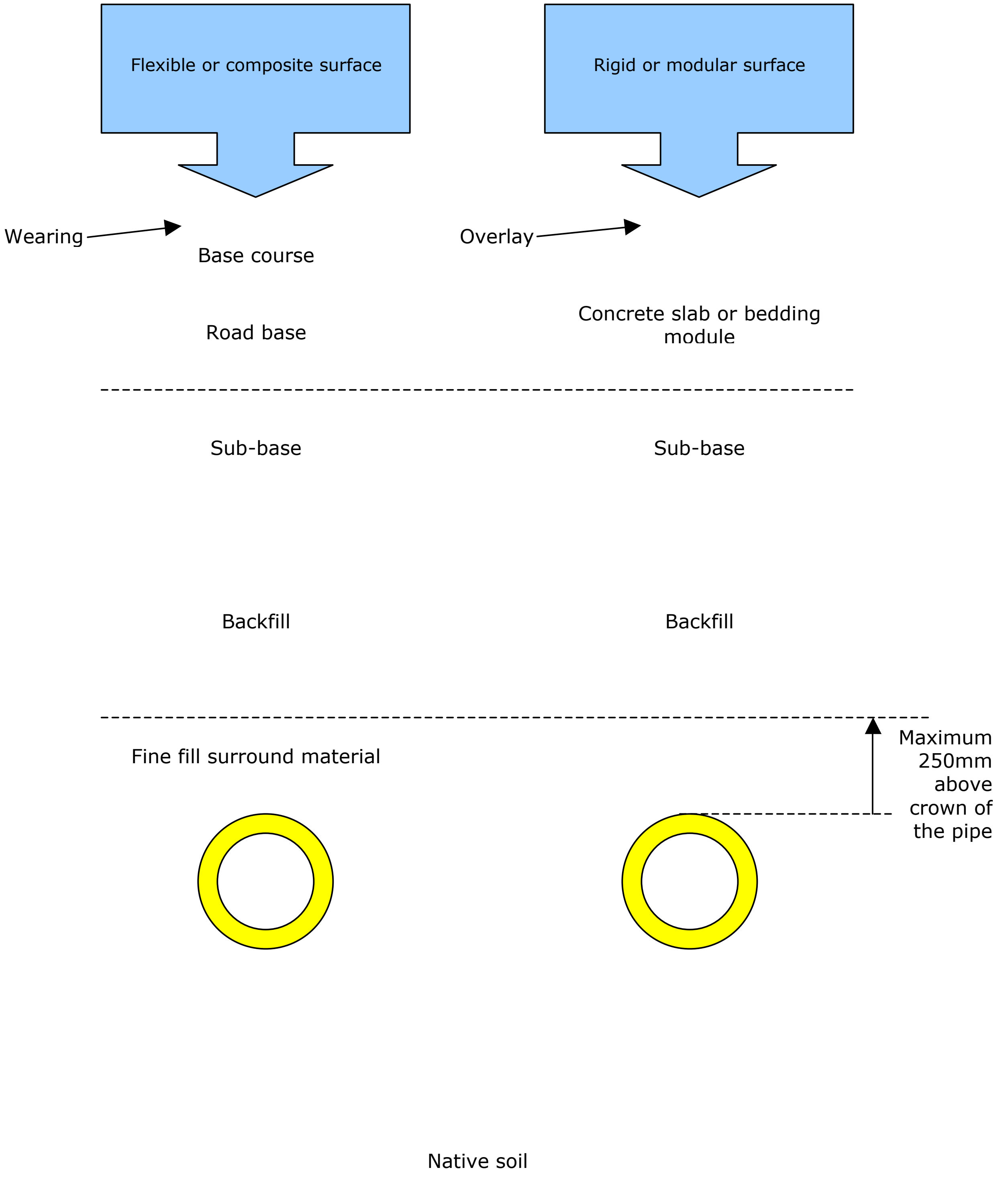
All excavations in the United Kingdom must be made in accordance with the New Road and Streetworks Act (NRSWA) 1991, designers, site supervisors and operatives must be familiar with the practical application of its requirements.

Generally the width of the excavation should be the minimum dimensions compatible with safe working practices and sufficient to enable a quality installation of pipe and fittings. For pipes, the minimum trench width is generally taken to be equal to the pipe outside diameter plus an additional 300mm, although where jointing operations are to be performed this may be increased to enable tooling to be used within the trench. The depth of trench must allow for compliance with depth of cover requirements, the recommended depth of cover for gas mains being 600mm measured from the crown of the pipe.

Where excavations are opened in isolated sections to facilitate a pipe insertion operation (i.e. the new pipe is being inserted inside the old metallic pipe which is being abandoned), then the length of the excavation must be sufficient to enable the pipe to bend as it enters the trench and into the abandoned metallic pipe, and must be sufficient to subsequently allow pipe to be levelled and jointed to the existing system. As a guide to the cold bending of polyethylene pipes, the minimum-bending radius for polyethylene pipes is taken to be 45 times the outside diameter of the PE pipe.

In uniform, relatively soft grained soils free from large flints, stones or other hard objects, where the trench can be readily brought to an even finish to provide uniform support for the pipe over its full length, it is permissible to lay the pipes directly onto the trimmed bottom of the excavation. Clearly some localised additional trimming will be required for any socket fittings to ensure the pipe is correctly supported over its full length. If the trench native soil is other than this, then additional material must be removed to a depth of 100mm and an imported selected bedding material brought in to form the pipe bedding layer.

The surround to the pipe effectively forms the foundation element of the reinstatement and offers adequate support to the pipe for the transmission of static and dynamic loadings from the soil structure above the pipe. Suitable materials for the bedding and surround include free draining sand, pea gravels, soils of a friable nature and suitable man-made or graded recycled materials which when compacted in layers meet the requirements of both the pipe asset owner and the relevant highways authorities. Surround should be laid around the pipe, manually compacted, to a layer thickness no more than 250mm above the crown of the pipe. Above this the ground should be reinstated in accordance with the NRSWA, illustrated in the diagrams overleaf.


Flexible or composite surface
Rigid or modular surface
Wearing
Base course
Overlay
Road base
Concrete slab or bedding module
Sub-base
Sub-base
Backfill
Backfill
Fine fill surround material
Maximum 250mm above crown of the pipe
Native soil

5. PIPE JOINTING

Jointing of polyethylene gas distribution pipes should only be undertaken by suitably qualified operatives who have attended a competency based training course and have been assessed as suitably competent to undertake the activity. Presently the main route to competency is through the completion of an NVQ vocational qualification leading to the award of a gas network operative (GNO) qualification. Specialist courses are also available specifically in the techniques of welding and jointing of polyethylene pipes and these would be expected to lead to a City & Guilds qualification as a minimum.

5.1 Electrofusion practice, socket fittings

Electrofusion socket welding systems allow pipes of the same or differing materials, diameters and/or wall thickness to be successfully jointed. Some of the advantages of the electrofusion technique include:

- Suited to working within the confines of excavations for jointing of pipe, or pipes and spigot end fittings

- Suited to inserting repair sections or branching tees into existing pipelines and welding the new section in-situ

- Suited to installations requiring minimal head loss as there are no internal obstructions to flow from, for example, pipe inserts or internal weld beads

The electrofusion procedure detailed in this section of the manual provides a simple guide to the use of electrofusion socket fittings and is suited to installations of up to 355mm in diameter. It should be seen as a reinforcement of the practices developed during operative and supervisor training. For installations 400mm and above, operatives and managers should attend specialist training in the correct use and installation of electrofusion fittings and this can be organised by contacting the Radius Systems Training Coordinator (tel. 01773 811112).

Tools required to successfully weld socket fittings should be available and in good serviceable condition. Essential tools include:

- Electrofusion fitting alignment clamp (available for couplers, reducers, elbows, etc)
- Cleaning rags/water to remove the bulk dirt off the pipe surface to be jointed
- Scraper tool, preferably a mechanical rotary pipe preparation tool although hand scrapers can be used under managed site conditions
- Electrofusion control unit, preferably conforming to technical specification ECE1, 40V or 80V depending on the socket fitting to be welded
- Suitably sized generator, preferably conforming to technical specification ECE3, and TIN12 output control
- Welding shelter
- Permanent marker pens

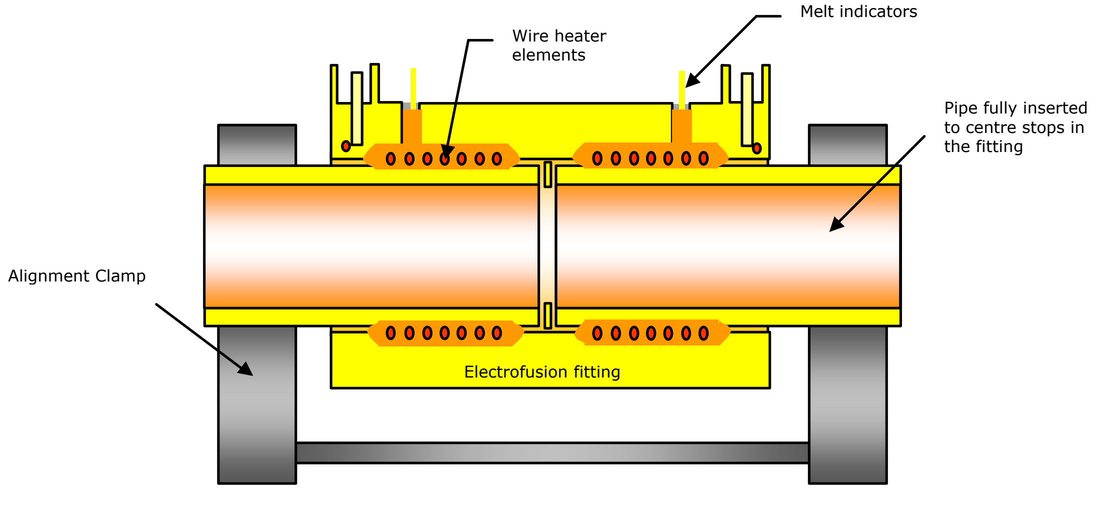
Details on control box and generator pairings are detailed later in the description.

The process of electrofusion requires a high level of cleanliness to be achieved at the worksite in order to achieve a good quality welded surface that is capable of lasting as long as the pipe components of the installation. This requirement is no different to welding any type of material, to achieve good weld quality the physical dirt deposits, precipitation and oxide residues must be removed.

When undertaking an electrofusion welding operation, the process should be viewed as a continuous process, once started it should be seen through to completion without stopping to carry out other works.

During the welding process, the body of the electrofusion fitting and the surface of the pipe (within the fitting) will become partially molten, within internal temperatures in the range 100-200°C. It is important that the pipe is adequately restrained to ensure that the optimum pressure and temperature conditions can be achieved without molten PE being displaced from within the joint. For this reason it is important to restrain pipes in excavations so that they do not apply bending stresses on the joint during the welding process, alignment clamps and additional local restraint of the pipe against the trench wall are the preferred route to achieve this.

Finally, it is important to ensure that the pipe is inserted sufficiently into the socket fitting for the welding process to work. Sufficient penetration should be taken to mean that all the coils of wire within the fitting are completely covered by the pipe. The diagram below shows a sectional view of the correct arrangement for welding.



Basic procedure for electrofusion welding of solid wall polyethylene pipes

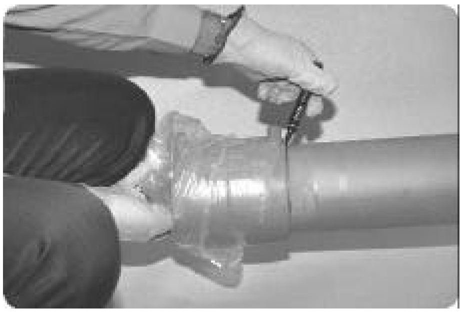
a. Prepare the immediate environment around the pipes to be jointed. The environment needs to be clean, dry and all tools necessary to complete the task should be brought together. If trench conditions are muddy then attempts should be made to drain excess water to a sump from which it can be pumped dry. It is desirable to place a section of clean plastic sheet beneath and around the area where the weld is to be made to prevent dirt being drawn up from the ground onto the pipe surface during the assembly preparation. Welding shelters assist in preventing airborne dust or rain from contaminating the pipe surface once prepared, there use is strongly recommended.

b. The following checks should now be made:
   1) Check that the generator has sufficient fuel in its tank to complete the weld once started.
   2) Check that the pipe ends to be joined are square cut so as to minimise the gap between the two pipe ends being joined.
   3) Check that the pipe ends can be brought together and supported so that they will not generate bending forces on the coupler assembly during the welding process.
   4) Check that the gap between the pipe ends is sufficiently small that when centred over the gap, the pipe ends will completely cover the wire elements within the fitting.

c. Using cleaning cloths (rags and water if required), clean the pipe ends to be jointed ensuring that encrusted dirt is removed. Use a dry rag to dry the pipe ends. Without removing the fitting from its bag (if it is not protected in a bag when delivered to site, it should not be used), mark the length of the fitting socket onto each pipe end and extend this mark a further 15-20mm further from the pipe end. This is the length of pipe that will need to be scraped prior to insertion into the fitting. Use the permanent marker pen to mark the pipe with a hatched pattern over the entire surface area to be scraped, such that when scraped it will provide a very visible indication if an area has been scraped. Mark the second pipe end in the same way.

d. Using a suitable pipe surface scraping tool, remove a layer of material from the surface of the pipe to a nominal depth of 0.2 to 0.4mm, ensuring that there are no gouges or scores left with dirt once this is complete (if the scoring is excessively deep, the preferred practice if more than 0.4 to 0.8mm of material is to be removed by double scraping, is to cut the pipe back to a position which is free from such large defects and perform the joint at this position). Where possible, the preferred practice is to use a rotary mechanical pipe end scraping tool, capable of removing a continuous and even layer of material from the entire circumference of the pipe's surface. Once scraped, do not touch the pipe surface, as this transfers dirt and grease back onto the freshly prepared surface.

e. Open one side of the bag containing the electrofusion fitting, so that the fitting can slide onto the prepared pipe surface with the opposite end of the fitting still protected by the bag.



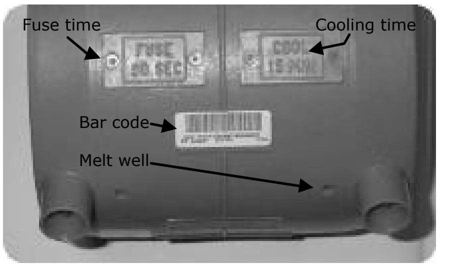
f. The electrofusion fitting is fitted with a centre stop. Slide the fitting along the pipe until the centre stop butts up against the end of the pipe. Mark the pipe around the edge of the coupler to note the insertion depth using the permanent marker pen.

g. Prior to scraping the second pipe end, take a tape measure and make a mark at some distance outside of the area to be scraped and measure the distance from this mark to the end of the pipe, noting this value on the pipe with a marker pen. Now scrape the second pipe end using the same process described in step (d). On completion, remove the bag from the coupler and insert the pipe fully into the coupler until it feels as if it is butting against the centre stops in the fitting. Use a tape measure to measure from the centre of the fitting to the mark previously made outside the scraped area to confirm that the pipe is fully inserted and then mark the pipe around the edge of the coupler as in step (f).

h. Fit the alignment clamp around the socket fitting ensuring that the insertion depth marks are correctly positioned in relation to the coupler and that the coupler is sited centrally within the alignment clamps.

i. Having ensured that the generator fuel level is adequate, the generator should be started and allowed to warm through and stabilise its output. The generator should then be connected to the control box and in turn connected to the fitting to be fused using the correct leads suited to the terminal pin size on the fitting, (Note: A check should be made to ensure that the correct voltage is being applied to the fitting). The correct parameters should be entered in response to the requested data entries. Monitor the control box through the complete weld cycle to ensure that the weld is completed and no error messages have been generated. Note; control box types vary; the two most common types are bar code data entry or manual data entry.

j. Once the coupler has completed the fusion cycle, check that the melt indicators/melt wells show that a successful fusion cycle has taken place. Melt wells are essentially a hole in the body of the fitting which will fill with molten polyethylene during the welding phase coming flush or slightly proud of the outside surface of the fitting after a successful fusion. Melt indicators, fitted predominantly to smaller fittings push the indicator out of the body of the fitting when successfully fused. The coupler must be left in the alignment clamps for the duration of the cooling time marked on the fitting so that the cooling material inside the joint can fully solidify without defects occurring.



k. Note; if the fitting has not been satisfactorily welded, no attempt should be made to weld the fitting a second time. As the nature of the original fault is not known, fusing the fitting a second time will produce a joint of unknown long-term integrity. For a gas distribution system this is not acceptable and the only accepted course of action is to cut the fitting from the system and weld using a new fittings.

Variation to the procedure for electrofusion welding of peelable skin polyethylene pipes

The ProFuse peelable skin polyethylene pipe system has an outer skin layer that can be peeled from the pipe prior to electrofusion jointing, thus overcoming the requirement for manual or mechanical scraping. The purpose of the skin is to protect the surface of the core pipe from collecting dirt that would otherwise interfere with the welding quality. Where however, the pipe skin has been pierced or where the core pipe has been inadvertently contaminated prior to the electrofusion jointing process then the pipe should be manually or mechanically scraped.

Note: Only approved tools should be used to remove the ProFuse skin, **it is not acceptable under any circumstances to use sharp open-bladed knives to cut through the skin**. The procedure below illustrates the main variation to the procedure just described (i.e. step d in the procedure).

a. Remove any surface debris from the skin layer using rags (and water if necessary), cleaning the area where the skin is to be peeled and over which the skin cutting tool will operate (the skin cutting tool should be centred over the mark made 15-20mm beyond the socket depth of the coupler). Position the peel tool on the mark, ensuring all four wheels remain in contact with the pipe, push forward firmly in the direction of the arrow marked on the side of the tool, whilst pressing down on the cutting shaft. This should cause the cutter to penetrate the pipe skin and cut beneath the skin layer. . Only light pressure is required to keep the cutting blade in contact with the pipe wall and the four wheels in contact with the pipe, push the tool around the pipe circumference to make one complete revolution and a continuous cut through the skin layer.

b. Turn the tool through 90 degrees so that it sits on the top of the pipe and hook the blade under the skin, which has just been lifted by the circumferential cut. Again, keeping all four wheels in contact with the pipe and light pressure on the cutting blade, push the tool forward and carefully cut the skin to the end of the pipe.

c. Lift a section of the skin, preferably starting from the junction of the circumferential and longitudinal cuts (i.e. outside the fusion zone) and once the corner has been sufficiently raised to obtain a grip, carefully and slowly peel the skin off the pipe taking care not to get dirt on the core pipe which is revealed underneath. Check that the skin has been completely removed and that there is no evidence of, or pieces of, the skin still adhering to the pipe surface in the area to be welded.

d. Open the bag containing the electrofusion fitting, on one side of the socket fitting only and slide it fully onto the end of the pipe until the pipe butts up against the centre stops in the fitting. Now continue with the final steps already described in the original procedure.

Finally, a word on contamination and some of the myths that prevail. Firstly; it doesn’t matter whether we are talking about conventional solid wall pipe, or peelable skin pipes, if the surface to be welded to is contaminated with dirt and/or water prior to being inserted into the electrofusion socket fitting, the only accepted means of removing this contamination is to use a manual scraper tool; it is not acceptable to wipe dirt off the surface of the pipe using wet wipes or other cleaning cloths/rags. Secondly; the other myth, how long can we leave the surface of the pipe after preparation before inserting into the coupler? Answer, you can’t; electrofusion should be viewed as a continuous process from start to finish, once pipe ends are prepared they should be inserted into the body of the fitting and welded without undue delay (i.e. the time required to prepare and insert the second pipe end, fit the clamps and set up the control box).

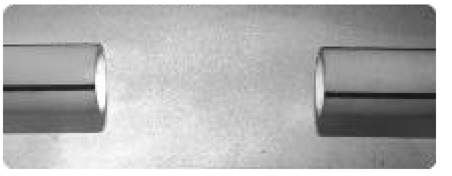
The procedure described so far is suited to jointing of pipes where at least one of the pipes is free to move so that it can be inserted into the socket. Where two pipes are to be joined, for example the insertion of a repair piece, where the pipes cannot be moved or bent to insert into the socket, then the fitting must be adapted to work in “slip mode”. Here the centre stops in the fitting are removed which enables the pipe to be fully inserted through the entire fitting, allowing the pipe ends to be brought together and then the coupler is slipped back over the pipe ends and centred for clamping and welding.

It should be noted that only coupler fittings have removable centre stops. Where reducers or tees are fitted they should be fitted according to the standard procedure above and then the final connections made using couplers in the slip mode.

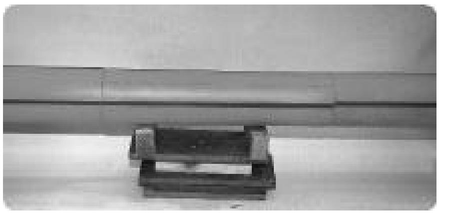
Using electrofusion couplers in the "slip mode"

The centre stops fitted into the coupler are removable and should be cut out of the fitting using a pair of hand snips (i.e. wire cutter snips), taking care not to touch the wires on the inside surface of the fitting, or the inside of the fitting itself.

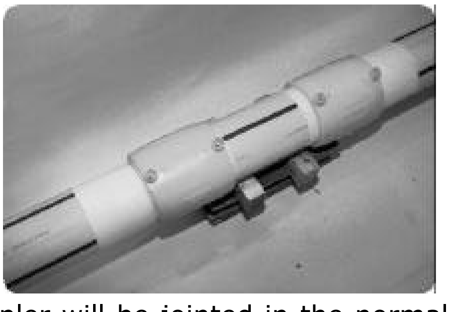
a. As with any electrofusion joint the welding environment must first be prepared to a standard which enables the pipes and joints to be assembled without contamination of the surfaces occurring from either dirt and/or water. The two pipe ends to be joined must be cut squarely so that when inserted into the fitting they will completely cover the wire elements and butt up against each other in the centre of the fitting.



b. A repair situation is illustrated. The next step is to cut a length of pipe with square cut ends and then check that when placed in-situ and supported, that the pipe ends line up and minimum gap is present.



c. Depending on the pipe type either mark up and scrape, or peel the skin, from the end of the pipe to a length at least equal to the full length of the coupler. Using a marker pen, carefully measure from the end of the pipe the depth of the electrofusion socket and make a mark. Allow any pen mark to fully dry and then with the coupler removed from its bag and the stops cut out, fully insert the coupler so that it slips fully onto the end of the pipe. Prepare the other pipe end to which the coupler will be jointed in the normal manner, i.e. a single socket length plus 15-20mm, and again make a mark on the pipe to show the correct socket depth. Place the pipe containing the couplers and support so that the pipe ends are aligned.



d. Slide the couplers across the pipe ends so that they are centred between the measurement marks made on each pipe for the correct insertion depth. Repeat for the second end in the case of the repair piece and then clamp both joints in place with an alignment clamp. Weld each fitting in turn.

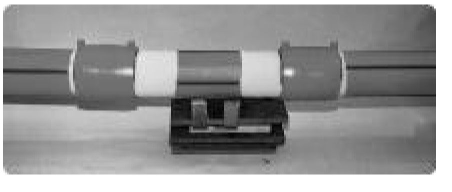


Table of coupler fittings, recommended control box and generator pairings

Socket diameter	Fitting Voltage	Single/Multi Cycle	Fitting Power	Recommended generator size
< 250mm	40V	Single	< 2.5 kW	3.5 KVA
250mm	40V	Single	< 2.5 kW	3.5 KVA
268mm	40V	Single	< 4.0 kW	6.5 KVA
280mm	40V	Single	< 4.0 kW	6.5 KVA
315mm	40V & 80V version	Single	< 4.0 kW	6.5 KVA
355mm	80V	Single	< 4.0 kW	6.5 KVA
400mm	80V	Single	< 4.0 kW	6.5 KVA
450mm	80V	2 stage weld	< 4.8 kW	7.5 KVA
500mm	80V	2 stage weld	< 4.8 kW	7.5 KVA
630mm	80V	2 stage weld	< 4.8 kW	7.5 KVA

Single cycle electrofusion control boxes are available as either 40V or 80V systems conforming to the ECE1 specification. Some newer generation boxes use systems that can be manually configured to output the required voltage that can be a benefit at site but it is important that the correct voltage setting is selected. If in doubt as to the required voltage, then check the fitting, it will say on the fitting what the voltage required for welding is.

Electrofusion control boxes for the 450, 500 and 630mm couplers are specialist adaptations of standard boxes, so that the timings for a preheat, soak and weld cycle can be entered. These are currently available via Caldervale Technology, or through their official hire agents.

Generators are the most common cause of problems associated with the electrofusion process. As a minimum a quality generator must be used with a TIN12 regulator system capable of holding the output voltage in the range required for the electrofusion boxes. Also, the generator will need to have an output power greater than the power to be consumed by the fitting, as the electrofusion control units are not 100% efficient. As with all tools the generator should be rated for the task, so for example the output rating must be sustainable over the duty cycle expected in the field (both the box and the generator heat up when fittings are welded consecutively, in the case of the generator this may cause the output voltage to drop as the efficiency reduces as the copper windings in the generator heat up, in the box it may cause the thermal protection circuit to cut in to protect the box). Check that the generator duty cycle is suited to the task in the field and include within the maintenance schedule a check to ensure the generator is capable of producing its rated output by testing on a dummy load.

5.2 Electrofusion practice, saddle fittings

Electrofusion "tapping tee" or "saddle fittings", provide a means of making an offtake connection to a polyethylene pipe. Offtake diameters of either 32 or 63mm can be used to form a branch in the pipe network. Such branches are normally, although not exclusively, used to provide service pipe connections between a property and the supplying main, and the fitting allows the connection to be made whether the parent main be pressurised with gas or decommissioned.

Tools required to successfully weld tapping tees should be available and in good serviceable condition. Essential tools include:

- Tapping tee top loading clamp capable of clamping the tapping tee to the pipe with a compressive force of between 1kN and 1.5kN
- Tapping tee 12mm A/F hex drive to wind cutter up and down the tapping tee stack
- Cleaning rags/water to remove the bulk dirt off the pipe surface to be jointed
- Manual hand scraping tool
- 40V Electrofusion control unit, conforming to technical specification ECE1
- 3.5 kVA generator, conforming to technical specification ECE3, and TIN12 output control
- Welding shelter
- Permanent marker pens

The process of electrofusion requires a high level of cleanliness to be achieved at the worksite in order to achieve a good quality welded surface that is capable of lasting as long as the pipe components of the installation. This requirement is no different to welding of any type of material, to achieve good weld quality the physical dirt deposits, precipitation and surface oxide residues must be removed from the pipe.

When undertaking an electrofusion welding operation, the process should be viewed as a continuous process, once started it should be seen through to completion without stopping to carry out other works.

During the welding process, the body of the electrofusion fitting and the surface of the pipe will become partially molten, with internal temperatures in the range 100-200°C. It is important that the fitting is correctly clamped at the specified force to the pipe to ensure that the optimum pressure and temperature conditions can be achieved without the molten PE being displaced from within the joint.

It is also important to ensure that the fitting is correctly fitted to the surface of the pipe. Two main considerations apply; the fitting should be squarely fitted to the pipe and the pipe and fitting should be sufficiently rounded to ensure a good fit between the base of the fitting and the pipe. It may be necessary with some coiled pipes, in particular with the larger 160 & 180mm coiled pipes to use pipe re-rounding clamps to minimise the ovalisation to ensure that an adequate fit is achievable. Finally, before cutting through into the parent main, always pressure test the new connection to ensure that it us sound.

Basic procedure for electrofusion welding of solid wall polyethylene pipes

a. Prepare the immediate environment around the pipe and fitting to be jointed. The environment needs to be clean, dry and all tools necessary to complete the task should be brought together. If trench conditions are muddy then attempts should be made to drain excess water to a sump from which it can be pumped dry. It is desirable to place a section of clean plastic sheet beneath and around the area where the weld is to be made to prevent dirt being drawn up from the ground onto the pipe surface during the assembly preparation. Welding shelters assist in preventing airborne dust or rain from contaminating the pipe surface once prepared, there use is strongly recommended. Check that the generator has sufficient fuel in its tank to complete the weld once started.

b. Using cleaning cloths, clean the area of the pipe where it is intended to weld the fitting. Without removing the fitting from its packaging (and it must be supplied to site protected in its factory sealed bag otherwise do not use it), place the fitting onto the pipe at the position where it is to be welded and with a permanent marker pen, mark around the base of the fitting the area that will need to be scraped to remove surface dirt and oxide layers.

c. Use the permanent marker pen to make a hatched pattern across the area of the pipe to be scraped so that it is immediately obvious if a patch has been missed when scraping. Using a hand-scraping tool, scrape a uniform thickness of material, nominally 0.2 to 0.4mm off the surface of the pipe over the entire area of the pipe to which the fitting is to be welded, ensuring that there are no gouges or scores left with dirt once this is complete (if the scoring is excessively deep, the preferred practice if more than 0.4 to 0.8mm of material is to be removed by double scraping, is to select a second position to which the connection can be made which is not scored to the same degree). Do not touch the pipe surface once it is scraped, if it is contaminated with dirt before the fitting is placed onto the pipe for welding, the dirt must be removed by a light scraping of the surface of the pipe; it is not permissible to use wet wipes or other cleaning cloths/rags.

d. Remove the fitting from its packaging and then remove the cap to expose the top of the integral cutter which should be flush with the top of the fitting.

e. Ensure the loading screw on top of the top loading clamp tool is fully unscrewed so that the maximum travel is available on the mechanism. Locate the tool in the hex socket of the tapping tee cutter.

f. Remove the cardboard protector from the base of the tapping tee and position the fitting onto the previously prepared area of the pipe. Secure the top loading clamp and apply the correct top load of between 1kN and 1.5kN in accordance with the manufacturers instructions for the style of clamp being used. During the latter two steps, it is imperative to ensure that the scraped pipe surface and the fusion pad of the tapping tee are kept clean, dry and free from contamination.

g. Check that there is sufficient fuel in the generator to complete the fusion cycle and then start the generator. Allow the generator to warm through and the output to stabilise before connecting the control box.

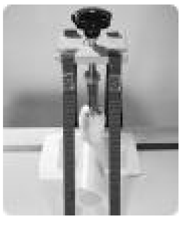
h. Follow the instructions given on the control box and enter the correct information in response to the prompts given. When requested, connect the leads from the control box to the fitting. Data will either need to be entered manually into the box in response to the prompts or using the bar code reader to scan the fitting barcode, depending on the style of box being used. Monitor the operation of the box for the full duration of the welding cycle to ensure that no error messages are generated and that the cycle is correctly completed. Once fused the fitting should be left clamped for the full cooling time stated on the fitting.

i. On completion of the weld check that the melt well located beside the fitting stack has filled and is either flush or just slightly proud of the hole in the fitting. Once complete, the service or branch pipe can be fabricated onto the spigot outlet of the tapping tee using the process described for an electrofusion coupler. For the purpose of this process, the spigot of the tapping tee is treated as a pipe end and must be scraped in the conventional manner. The complete installation should then be pressure tested to verify the integrity of the pipe, fittings and welded joints. Test pressure is specified by the undertaker but is normally taken to be at least 1.5 times the design maximum operating pressure of the system.

j. When you are ready to commission the service pipe, the final step is to cut a coupon out of the parent pipe using the integral cutter in the body of the tapping tee. The 12mm A/F hexagon tee bar should be used to turn the cutter in a clockwise direction through the wall of the PE pipe. Operators can choose to mark the expected depth of travel onto their tee bar, or can rely on feeling the sudden reduction in load as the cutter penetrates through the wall of the pipe to judge when to stop winding the cutter down. At this point, wind the cutter 2 full addition turns to ensure any remaining ligaments are severed. The tee bar should then be turned in an anti-clockwise direction until it is once again brought flush with the top of the stack on the tapping tee and then the cap should be replaced and tightened hand tight onto the fitting.

As with the electrofusion procedure detailed in section 6(a) of this manual, the main difference in the use of peelable skin pipes is that the section of the pipe skin must be peeled from the surface of the pipe, over an area slightly larger than the base of the fitting. Provided the surface is not contaminated during the peeling preparation stage, the fitting can then be clamped directly to the surface of the pipe and welded. If the surface is contaminated after peeling, then the contamination should be scraped off the pipe surface. Only an approved tool should be used to cut through the ProFuse skin layer and under no circumstances may sharp open bladed knives be used (refer to the guide in section 6(a) for additional advice on the operation of the hand tool).





The other variation to the standard procedure to be aware of, is when the tapping tee is fitted with what is known as a cutter “follower”. These are fitted to tapping tees being used to cut through thicker wall pipes and spread the force required to cut through the main over a greater number of threads in the tapping tee, allowing higher forces to be transferred to the cutter to enable it to cut its way through the pipe wall. Followers will, or should be, obvious as removing the cap from the tapping tee will reveal a label on top of the follower rather than the normal hex socket for the top of the cutter. The label explains that a follower is present. The procedure for installing the tapping tee and cutting through into the main is predominantly the same, with the only difference being that when the cutter is retracted after breaking through the pipe wall into the parent main, the thread follower should be fully withdrawn from the fitting and disposed of, the cutter should be retracted and left flush with the top of the stack as per the standard procedure, thus ensuring that the outlet of the tapping tee is not blocked off by the cutter.

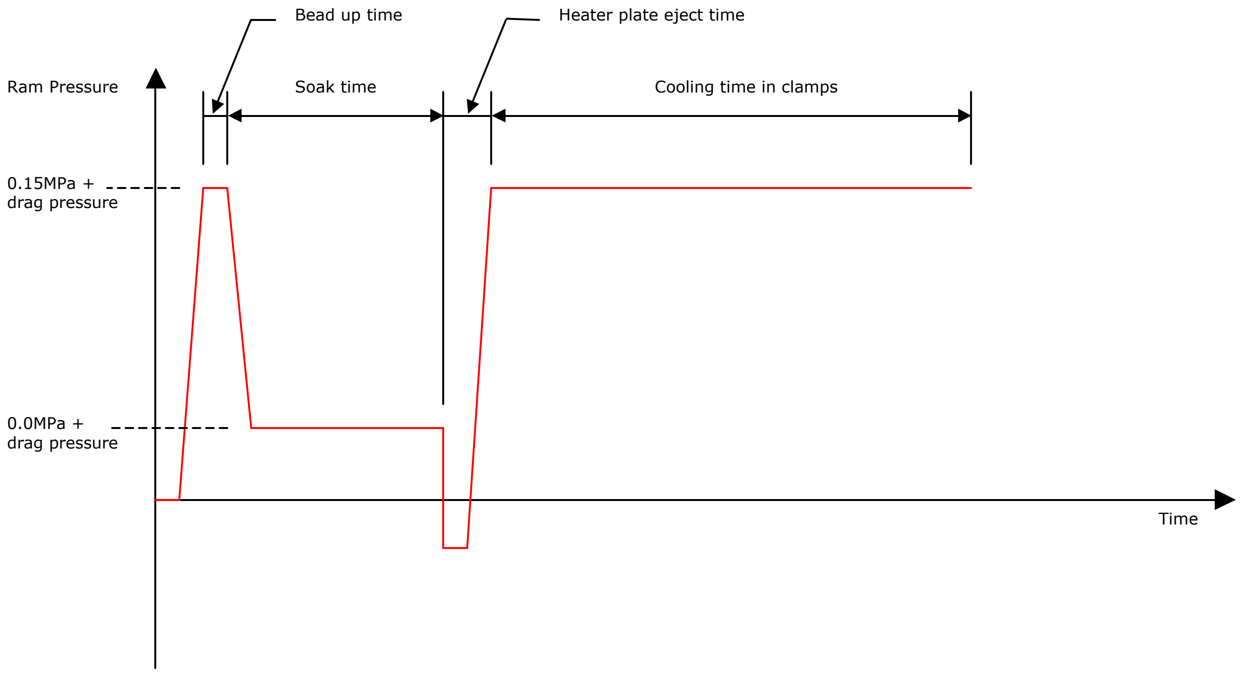

5.3 Butt fusion practice

Butt fusion jointing of polyethylene pipes is a technique that enables welding of pipes within a street works environment that are made from the same material (i.e. PE80 to PE80, or PE100 to PE100), and have the same nominal outside diameter and wall thickness. It is not permissible to join other permutations of pipes, the alternative and accepted practice is for electrofusion socket fittings to be used.

It is recommended that a fully automatic butt fusion machine is used for the butt fusion welding of polyethylene pipes. In the hands of a suitably skilled operator a semi-automatic machine is permissible provided the operator is able to demonstrate consistency and reliability in their operating practice. A fully automatic butt fusion machine is defined as a machine which automatically brings the pipe ends against a heater plate which may be manually placed into the machine, which controls the ram pressures automatically during the bead up and heat soak phases, which opens and automatically ejects the heater plate at the end of the soak stage and then brings the two pipe ends together at the correct interface pressure and holds them in place for the duration of the cooling cycle.

When specifying a machine for the welding of polyethylene pipe for gas distribution applications, it should be configured for the nominal pipe diameter, SDR and PE grade (i.e. PE80 or PE100) which is to be welded, and additionally configured for GAS parameters. GAS parameters are the particular timings and pressures to be used during the butt fusion process and tend to be unique to each market (despite the similarity of the materials and the process, the gas and water companies of the UK still maintain significantly different butt fusion jointing practices to each other).

To help explain the parameters, a chart has been reproduced overleaf which illustrates the hydraulic pressure in the rams which basically bring the pipe ends together or away from each other in the butt fusion machine. The corresponding method for calculating the timings and pressures is then listed beneath the chart. Note; the heater plate used for the butt fusion process should normally be in the range 225 to 235°C across the area in contact with the pipe ends and this should be manually checked for confirmation prior to commencing welding operations.



Initial bead up time reflects the requirements for the following initial bead size which is formed when the pipe end is pressed against the heater plate:

- Pipes less than or equal to 180mm, initial bead size 2mm
- Pipes greater than 180mm, less than or equal to 315mm, initial bead size 3mm
- Pipes greater than 315mm, initial bead size 4mm

Once the initial bead has been formed the ram pressures are dropped to a level of 0MPa plus drag pressure (drag pressure is the pressure required to overcome the friction in the machine and just make the pipes move along the chassis), and held for the soak time.

- Soak time (seconds) = $10 * \sqrt{OD}$ in millimetres

At the end of the soak period the pipes pull back off the heater plate and the heater plate is ejected. The pipe ends must be brought back together again so that the time from initial pull back from the heater plate to pressing the molten pipe ends together does not exceed:

- For pipe diameters less than or equal to 315mm, 4 seconds
- For pipe diameters greater than 315mm, 8 seconds

Once the pipe ends have been brought back together again with the loading pressure of 0.15MPa plus drag pressure, they must be held for the cooling period in clamps (i.e. the time they must remain clamped in the butt fusion machine under pressure).

- Cooling time in clamps (seconds) = $30 * \sqrt{OD}$ in millimetres

Thereafter the pipe can be removed from the machine with care and should be left for an additional cooling time outside of the clamps during which the pipe is not subject to any loading forces.

- Cooling time out of clamps is 1.5xeach mm of wall thickness (minutes) to a maximum of 20 minutes.

The butt fusion process should be undertaken at a worksite where high standards of hygiene are maintained within the working environment. The chosen site for jointing should be sheeted to prevent dust and biological matter being drawn up into the butt fusion machine from the ground. The machine should be in a suitable welding shelter to insulate the machine from climate effects and to maintain resistance to airborne contamination or precipitation. Finally, the open ends of the pipe strings being jointed (i.e. the opposite end of the pipe to the end being joined) should be sealed to prevent wind tunnelling through the pipeline.

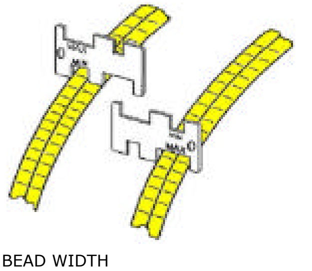
When commissioning a butt fusion machine special care should be taken to check all parts of the machine that come into contact with the pipe to ensure that they are clean and free from any form of contaminant that could be transferred to the pipe end. Contaminated or defective parts should be replaced prior to commencing the jointing activity.

Each time the machine is switched on, or after any operation to clean contamination from the heater plate for example, a dummy joint must be made to fully clean the heater plate. A dummy joint is a joint made as normal but aborted during the heater plate eject cycle so that the molten pipe ends are not brought back together. Within the gas industry a minimum of one dummy joint should always be performed, more may be necessary if contamination is still evident on the heater plate when inspected.

For specification guidance on the operation of a butt fusion machines, the guidance of the machine manufacturer should be followed. On completion of the joint, the joint record should be inspected and then the joint inspected to ensure that all have been correctly completed in accordance with the industry procedure and that a quality joint has been produced.

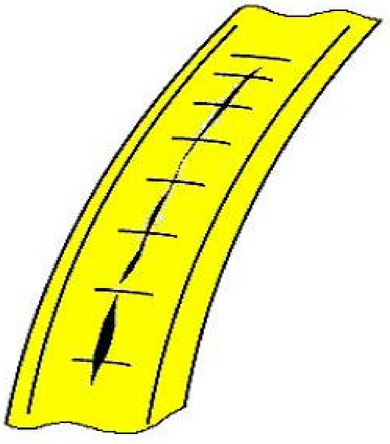
Joint records are printed off from the control unit, normally using a hand held printer unit. The record will provide a unique number which is a reference for the joint and this should be written onto both the pipe adjacent the joint and also onto the weld bead using a permanent marker pen. The printed record should then be checked to ensure that the correct welding pressures and timings have been achieved.

The next step is to inspect the bead on the pipe and check that it is reasonably continuous and consistent in width around the pipe, free from any obvious physical contamination. At this stage a bead gauge can be used to check for minimum or maximum bead thickness if required by the undertaker.

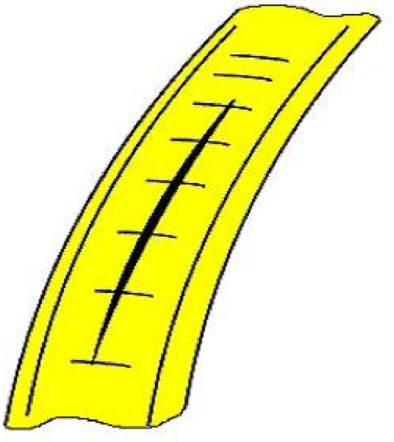


BEAD WIDTH
Run the max/min bead gauge around the bead to check that it is within the recommended limits

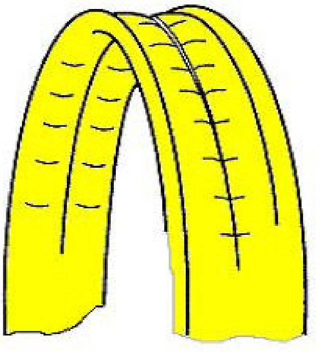
After the initial check of the bead on the pipe, the bead should be removed using a purpose designed tool (for example the Universal Debeading Tool) and a reverse bend test applied to stress the joint element within the bead and examine for any resulting signs of brittle splitting.



CONTAMINATION
Examine the underside of the bead over its complete length for contamination



SLIT DEFECTS
Examine the underside of the bead over its complete length for any split or "slit" defects having a brittle or glassy finish



BEND TEST
Perform a bend test by bending the bead backwards on itself, repeatedly along its full length. If defective, splits of a glassy or brittle nature will be visible.

On satisfactory completion of the bend test the bead and the joint record should be retained, together with an annotation on the site drawings showing the location and identifying number of the butt joint. This shall be retained until the pipeline is commissioned and accepted by the undertaken.

On occasion, a risk assessment or a request by the undertaken requires destructive testing to be performed to provide additional confidence in the quality of the as laid pipeline. To enable destructive testing to be performed, a section of pipe should be removed at least 300mm long either side of the butt fusion joint being assessed. The joint is then sent to a test house which will remove samples of the joint in the form of dumbbells cut from the pipe at equidistantly spaced positions around the full circumference of the joint. These dumbbells are then subject to tensile separation to ensure that they achieve the minimum yield strength expected for the pipe type and that they exhibit a broadly ductile surface when pulled to the point of ultimate failure.

5.4 Flange connections

Flange connections are often used to connect polyethylene pipes to existing iron or steel pipe installations, and to control units such as pressure reduction equipment and valves. Polyethylene stub flanges are generally made from the same material as the pipe so that they can be joined to the pipe element using either the techniques of electrofusion or butt fusion. They are provided with a metallic backing ring that is generally loose fitting so that it can be rotated to line up the bolt holes with those of the metallic element to which it is to be jointed. Flange kits should be provided by the flange manufacturer with gaskets suited to use in contact with gaseous fuels (normally nitrile rubber) and bolt sets with adequate coatings to resist corrosion effects and of the correct length to enable assemblies to be made.

Some general rules for polyethylene flange assemblies need to be recognised:

- Polyethylene stub flanges should only be jointed to pipes corresponding to the diameter and SDR class of the flange as stated on the product description. The only variation to this is that flanges of a thicker wall section can be jointed to pipes of the same nominal diameter but having a thinner wall section (i.e. join an SDR11 flange to an SDR17.6 pipe of the same outside diameter and material is permissible but not vice versa). The logic behind this is that flanges must be tested to demonstrate that they are fully end load bearing and if they are connected via a reducer to a larger diameter pipe, then this approval will no longer be valid and raises the unnecessary risk of the pipe pulling out of the joint assembly. This guidance applies irrespective of the materials or design used for the manufacture of the polyethylene flange assembly. If in doubt consult the manufacturer directly.

- Polyethylene stub flanges should be bolted up in the correct sequence and to the correct torque specified to ensure that the flange is not under or over loaded within the jointed assembly. Suitable torque spanners or sockets are available to achieve this from general tooling suppliers.

- Polyethylene stub flanges should only be used to connect to metallic flanges, as they are not normally approved as a connection method for PE to PE (i.e. do not bolt two PE stub flanges together, the preferred method of jointing PE is to use either electrofusion or butt fusion welding techniques, or a mechanical compression fitting designed for this purpose).

When specifying a flange, the normal format would be to quote the request as follows:

- (PE pipe diameter & SDR) x (flange specification)

For example, to connect a 315 SDR 17.6 PE80 pipe to a DN300 NP16 steel flange, a PE stub flange would be requested with the following definition:

- 315 SDR 17.6 PE80 x DN300 NP16 stub flange kit

PN16 refers to an industry specification that is detailed in BS 4504 and is the most common flange dimension found in the United Kingdom. The NP16 in this context ensures that the PE stub flange has a backing ring which can mate with the flange on the metallic system, and that the bolt holes are the correct number, size and position.

When bolting PE stub flanges to metallic flanges, the bolts should first be hand/finger tightened around the whole assembly. Then starting with the top dead center bolt, the bolt should be tightened to 50% of the final torque setting stated in the table below, followed by the bolt diametrically opposite. The next bolt is then the next clockwise bolt from top dead centre, followed by its diametrical opposite, working around the whole flange until all bolts have been set. The process should then be repeated at 75% of final torque, followed by final setting at the stated value.

Flange	Flange outside diameter	Flange PCD	Number of holes	Hole diameter	Bolt	Bolt torque
DN50	165	125	4	18	M16	35 Nm
DN80	200	160	8	18	M16	30 Nm
DN100	220	180	8	18	M16	40 Nm
DN150	285	240	8	22	M20	70 Nm
DN200	340	295	12	22	M20	80 Nm
DN250	405	355	12	26	M24	100 Nm
DN300	460	410	12	26	M24	120 Nm
DN400	580	525	16	30	M27	200 Nm
DN450	640	585	20	30	M27	200 Nm
DN500	715	650	20	33	M30	300 Nm

6. PRESSURE TESTING OF NEW INSTALLATIONS

When pressure testing new installations it is normal to subject the pipeline to a pressure significantly higher than the expected in service operating pressure (normally 1.5 times the design maximum operating pressure) in order to confirm both the strength of the installation and also the leak tightness. A full treatment of the preferred approach to pressure testing and commissioning of new gas pipelines, including polyethylene materials, is given in section 7 of IGE/TD/3 and this should be referred to in the first instance.

IGE/TD/3 does not include the information required for the new generation SDR 21.0 PE100 peelable skin pipes such as ProFuse and the appropriate details are reproduced below for reference.

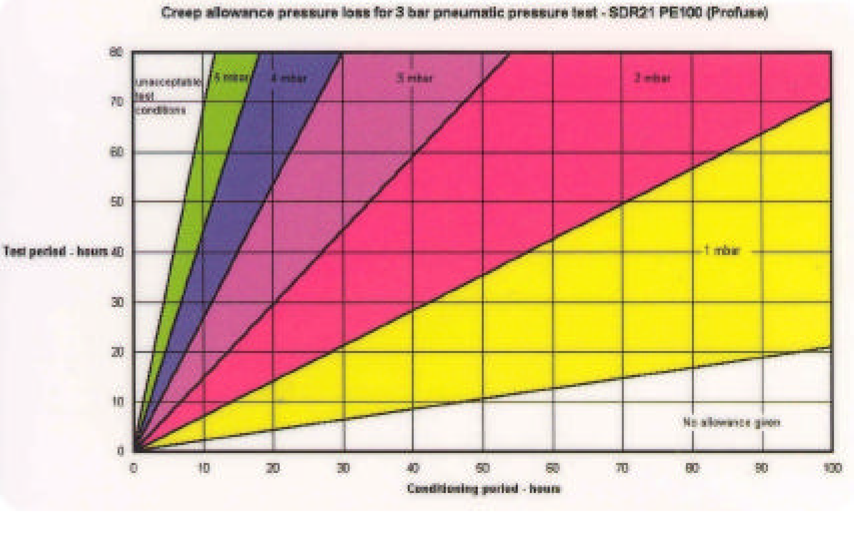
Pressure testing of ProFuse PE100 SDR 21 pipes

- For all installations irrespective of pressure class, the pipe volume shall first be calculated. The volume V (m^3) can be calculated using the equation $V=L\times 0.25\times\pi\times(D-2\times D/SDR)^2$, where L is the length of the pipe and D is the outside diameter, both in metres. Alternatively, multiply the length L by the factor in the table below to obtain the volume.

Pipe ∅	250	315	355	400	450	500	630
Factor	0.0402	0.0638	0.0810	0.1029	0.1302	0.1607	0.2552

- For systems with a maximum operating pressure of 75 millibar, the test time shall be equal to 1.0158 x V (hrs). There is no creep allowance for this pressure class, the test pressure is 350 millibar gauge (1.35 bar absolute) and the permissible instrument loss is 10 millibar.

- For systems with a maximum operating pressure of 2 bar, the test time shall be equal to 0.877 x V (hrs). The permissible creep allowance is shown on the graph below and is in addition to the 3 millibar permissible instrument loss. The test pressure is 3 bar gauge (4 bar absolute).



7. FLOW STOPPING OF POLYETHYLENE PIPELINES

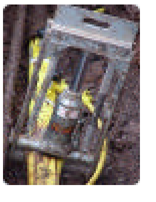
Flow stopping is the process of interrupting the flow of gas through the pipeline, providing a temporary blockage or closure of the pipe. To permanently stop the flow of gas through a pipeline, a valve designed for the purpose should be used, or an end cap fitted to the pipe.

Polyethylene is probably unique as a pipeline material in that one of the methods of flow stopping is to actually compress the pipe between 2 parallel bars, to a defined pressure, enabling a gas tight seal to be achieved. The process is reversible so that once released the pipe can be rounded again and continue in service for the expected lifetime of the installation. This technique is known as **squeeze off**.

The alternative technique for flow stopping of a polyethylene pipe is to use a system where a saddle is fitted to the pipe which is designed to allow an inflatable stopper to be inserted into the line, where it can be inflated inside the pipe to stop the flow. This technique is known as **bagging off**. Bagging off techniques as a general rule are limited in application to polyethylene pipes having a maximum internal bore of around 300mm (i.e. 355mm polyethylene) and a maximum operating pressure of 75 millibar (i.e. low pressure gas systems).

For guidance on the configuration of isolation points, pressure points, purge points and bypass systems, and the order of decommissioning and recommissioning, the guidance within IGE/TD/3, section 8 should be followed.

Squeeze off technique



The squeeze of technique involves using a hydraulic or mechanically actuated system which is capable of compressing the PE pipe between two bars, the bars have a defined shape. The tool is designed so that the bars have limit stops fitted to prevent damage to the pipe and these must be correctly set by reference to the pipe outside diameter and SDR rating.

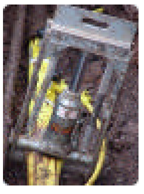
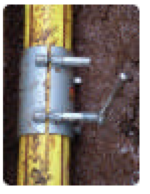
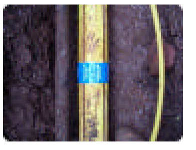
The calculation for the minimum stop setting on a squeeze off tool is worked out as follows:

- Calculate minimum wall (t) = nominal outside diameter/SDR
- For pipes less then or equal to 250mm, minimum stop gap = 0.8 x (2 x t)
- For pipes greater than 250mm, minimum stop gap = 0.9 x (2 x t)

To prevent damage to joints in the pipe system it is a requirement that a squeeze off tool should not be used closer than 2.5 times the pipeline diameter to any fitting, whether it is a socket or butt weld between two pipes, or a saddle fitting for a branch connection.

Squeeze tools should be used in accordance with the manufacturers instructions; particular care should be taken with tools for the 250 & 315 SDR 11 PE100 pipes, to ensure that the slow rate of release feature is used when releasing the squeeze off tool from the pipe.

Once the squeeze off tool has been removed from the pipe, the pipe should be re-rounded using either a mechanical or hydraulically actuated re-rounding clamp. This restores the pipe cross section and circular form which is essential to maintain the design capacity and ensure the pipe can resist external collapse pressures generated by the soil loads. Once re-rounded, marker tape should be fixed to the pipe to indicate that it has been squeezed off at that point. Note: Pipes should not be squeezed off at the same position on a pipe more than once.

The table below provides a guide to the pipes which are currently considered suitable for either squeeze off flow stopping, or inflatable bag flow stopping. Where there is no entry, this is either due it not being a common pipe in use, to it not being suitable or to date, no one has developed suitable tooling for field application.

Outside diameter (min)	SDR 21.0 ProFuse	SDR 17.6 PerformOR	SDR 11.0 PE80 or SDR 11.0 PerformOR
25	-	-	Squeeze off
32	-	-	Squeeze off
40	-	-	Squeeze off
55	-	-	Squeeze off
63	-	Squeeze off	Squeeze off
75	-	-	Squeeze off
90	Squeeze off	Squeeze off	Squeeze off
110	Squeeze off	-	Squeeze off
125	Squeeze off	Squeeze off	Squeeze off
140	Squeeze off	-	Squeeze off
160	Squeeze off	-	Squeeze off
180	Squeeze off	Squeeze off	Squeeze off
250	Squeeze off	Squeeze off	Squeeze off*
280	Squeeze off	-	-
315	Squeeze off	Squeeze off	Squeeze off*
355	Squeeze off	-	-
400	Squeeze off	-	-
450	Squeeze off	-	-
500	Squeeze off	-	-
630	-	-	-

* Industry recommendation that a metallic repair clip be fitted over the squeezed pipe to reinforce it post flow stopping

8. GUIDANCE ON WORKING WITH IMPERIAL PIPE SYSTEMS



When polyethylene pipes were first introduced to the United Kingdom, in 1969, they were supplied in imperial dimensions. The use of these pipes continued until 1977, after which the gas industry completed the conversion to metric pipe dimensions. The table below shows the dimensions of the pipes which were supplied.

Nominal Size	SDR	Outside Diameter		Wall Thickness	
		Min (mm)	Max (mm)	Min (mm)	Max (mm)
¾″ IPS	11.0	26.6	26.9	2.5	2.8
1″ IPS	11.0	33.4	33.7	3.1	3.5
1¼″ IPS	11.0	42.0	42.3	3.8	4.3
1½″ IPS	11.0	48.2	48.5	4.4	4.9
2″ IPS	11.0	60.2	60.6	5.5	6.2
3″ IPS	11.5	88.6	89.3	8.1	9.1
4″ IPS	11.5	113.9	114.7	10.4	11.7
6″ IPS	11.5	167.8	168.9	14.7	16.5
8″ IPS	11.0	218.5	219.8	19.9	22.3

Working with imperial dimension pipes

The early polyethylene pipes, made from materials such as DuPont Aldyl-A, continue to perform well. At the present time, the usual reason for needing to work with these pipes will be to fit either a repair section following third party damage, or the installation of a tee connection to enable expansion of the existing pipe system. This section has been prepared with this in mind and provides guidance on the following topics;

- Construction of bypass connections
- Specialist fittings for extending 1¼″ and 1½″ service pipes
- Flow stop operations using the squeeze off technique
- Products available to effect a repair or tee connection

Construction of bypass connections

At the present time, the largest bypass that can be constructed on an imperial dimensioned pipe is a 63mm loop. Connection is made via a Unifit tapping tee connection direct to the imperial pipe. The table below summarises the tapping tees that are available for imperial dimension pipes.

Nominal Size	32mm Outlet Tapping Tee Radius Systems Code	63mm Outlet Tapping Tee Radius Systems Code
2″ IPS	10108149383	10108149508
3″ IPS	10108149385	10108149510
4″ IPS	10108149388	10108149516
6″ IPS	10108149394	10108149526
8″ IPS	10108049420	10108149538

Special requirements for 1¼″ and 1½″ pipes

The fitting solutions for the 1¼″ and 1½″ pipes require that the pipe itself be converted to a metric dimension. It is recommended that where these pipes are encountered, that a specialist installer who has completed a training course and been equipped with the required tools undertake the jointing process.

- For the 1¼″ pipe size, connection solutions are available to join directly to 32mm, 40mm and 63mm pipes.
- For the 1½″ pipe size, connection solutions are available to join directly to 32mm and 63mm pipes.

Fittings for these two pipes are supplied as an installed service. To arrange connections to either size of pipe please call 01773 811112 and ask to speak to a UPLUS representative.

Flow stopping of DuPont Aldyl-A pipes

Today, the technique of flow stopping using squeeze off tools is commonplace in the gas industry in this size range. When the first polyethylene pipes were introduced, this was not the case. Indeed it was not until 1973 that the potential of the technique was recognized and testing regimes were introduced into pipe material performance specifications. Some care should therefore be exercised to ensure suitable tools are used to effect squeeze off of these early generation pipes.

The table below specifies the key parameters to be addressed in the selection of a suitable squeeze off tool for use on imperial dimension polyethylene pipe.

Nominal Size	SDR	Minimum gap between squeeze bars mm	Minimum diameter of squeeze bar mm
¾″ IPS	11.0	4.0	26.0
1″ IPS	11.0	5.0	32.0
1¼″ IPS	11.0	6.1	32.0
1½″ IPS	11.0	7.0	32.0
2″ IPS	11.0	8.8	32.0
3″ IPS	11.5	13.0	38.0
4″ IPS	11.5	16.6	38.0
6″ IPS	11.5	23.5	51.0
8″ IPS	11.0	31.8	51.0

Important notes concerning the squeeze off method and DuPont Aldyl-A polyethylene pipes;

- The squeeze tool shall (shall = a mandatory requirement) be located a length equivalent to 3 pipe diameters from any heat fused fitting or butt fusion joint

- The squeeze off tool shall only be applied once. If the squeeze off must be reapplied, then the squeeze tool shall be moved to a new position

- Only squeeze off tools fitted with limit stops and round bars conforming to the dimensions shown in the table above shall be used

- The pipes shall be squeezed slowly, at a steady rate. Reducing the rate of compression will allow some relaxation to take place, which reduces the force required to make the flow stop.

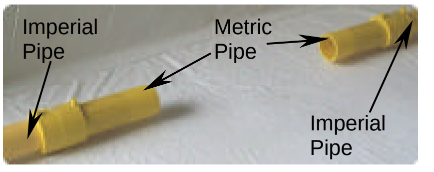
- On completion and removal of the squeeze tool, a reinforcement clamp shall be fitted to the pipe to encircle the squeeze off section, the squeeze position being centered within the clamp.

- Suitable reinforcement clamps are taken to include metallic repair clamps, provided a rubber or polythene sheet of minimum thickness 3mm is used between the pipe and the steel shell of the clamp. The metallic component must not come into contact with the pipe surface.

Fittings for making connections to DuPont Aldyl-A pipe

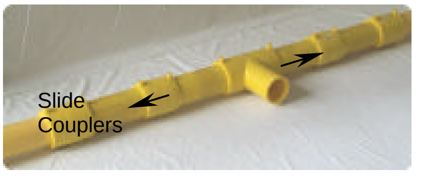
The principle to follow when making any kind of connection to an imperial size polyethylene pipe, is to first convert the pipe end to a metric dimension. Thereafter, all the existing metric pipe, tee or elbow fittings can be used to fabricate repair sections or new connections to the imperial polyethylene pipe. An example showing the insertion of an equal tee is shown below.

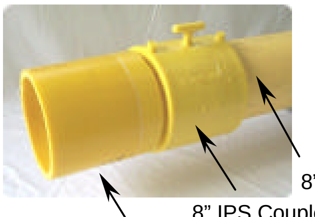
1. A cut out should be made to the imperial size pipe of sufficient length to allow a reducer to be fitted either side, and for the tee, or the repair section to then be inserted.



2. The tee needs to have pipe tails fitted, such that a coupler can be inserted fully over the pipe as shown in the picture. One coupler is required either side of the tee or repair piece.

3. The tee should be positioned in the cut section of the pipeline, so that it lines up, enabling the couplers to slide over to their final installation position.





The same process is followed for the 8″ imperial system, with the main difference being that the transition from the 8″ to the 250mm outside diameter is achieved with a coupler and a spigot reducer rather than a dedicated electrofusion reducer as shown above.

Type of fitting	Imperial Dimension	Metric Dimension	Product Code
EF Reducer	¾″ IPS	20 SDR 9	10102049322
EF Reducer	¾″ IPS	25 SDR 11	10102049323
EF Reducer	¾″ IPS	32 SDR 11	10102049324
EF Reducer	1″ IPS	32 SDR 11	10102049325
EF Reducer	2″ IPS	63 SDR 11	10102049326
EF Reducer	3″ IPS	90 SDR 11	10102049327
EF Reducer	4″ IPS	125 SDR 11	10102049328
EF Reducer	6″ IPS	180 SDR 11	10102049329
Spigot Reducer	8″ IPS	250 SDR 17.6	20102049347
EF Coupler	8″ IPS		10101049132

9. USEFUL CONTACTS

Contaminated Land Pipeline Materials Selection
(The two companies listed below were the collaborative partners in the production of the Contaminated Land Investigation & Pipe Selection database ~ CLIPS)

Advantica Technology Ltd
Holywell Park
Ashby Road
Loughborough
Leicestershire
LE11 3GR

(t) 01509 282000
(f) 01509 283131
(e) info.uk@advantica.biz
(w) www.advantica.biz

Ewan Associates Ltd
Priory Court
Poulton
Cirencester
Gloucester
GL7 5JB

(t) 01285 850415
(f) 01285 850416
(w) www.ewan.co.uk

Disc flow calculators for pipe sizing
Mear's Gas Flow Calculators
M.H Mear & Co Ltd
Britannia Road
Milnsbridge
Huddersfield
West Yorkshire
HD3 4QG

(t) 01484 485404
(f) 01484 650097
(w) www.mhmear.com

Electrofusion control box manufacturers and hire centres
Caldervale Technology Ltd
Bretfield Court
Dewsbury
West Yorkshire
WF12 9DB

(t) 01924 469571
(f) 01924 460951
(w) www.caldertech.com

Hire Centre Utilities (now part of Brandon Tool Hire)
(t) 01179 718535
(f) 01179 801260
(e) info@thehiredesk.co.uk
(w) www.brandontoolhire.co.uk