



Qenos

# 07

## PIPE AND TUBING EXTRUSION

—  
TECHNICAL GUIDE



Alkadyne®



### **Front Cover**

Polyethylene pipe is an engineered product, required to withstand internal pressure and external influences for up to 100 years. Qenos has invested in the largest pipe pressure testing facility in the southern hemisphere, where *Alkadyne* PE100 pipe resin is extruded for testing and then subject to high pressure and elevated temperature for up to three years. This testing is also applied to specially notched pipe samples to ensure damage during installation does not result in premature failure. *Alkadyne* PE100 pipe resin – *Engineered to Outperform*.

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# PIPE AND TUBING EXTRUSION

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## INTRODUCTION

*Alkadyne* polyethylene grades are used for the extrusion of pipe. The application areas in which *Alkadyne* pipe resin is typically used include:

- Mining for conveyance of corrosive and abrasive slurries and tailings
- Water management projects such as large scale irrigation for agriculture
- Residential water distribution
- Civil work such as sewers
- Residential and industrial gas distribution
- Gas and water management in Coal Seam Gas extraction
- Management of industrial fluids
- Drainage
- Rural applications such as management of water on farms, etc.
- Pipeline renewal and rehabilitation, including trenchless techniques such as horizontal directional drilling, slip lining, and pipe bursting

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# 7 PIPE AND TUBING EXTRUSION

## INTRODUCTION

Alkadyne polyethylene grades (Table 1) are used for the extrusion of pipe. The application areas in which Alkadyne pipe resin is typically used include:

- Mining for conveyance of corrosive and abrasive slurries and tailings
- Water management projects such as large scale irrigation for agriculture
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- Residential and industrial gas distribution
- Gas and water management in Coal Seam Gas extraction
- Management of industrial fluids
- Drainage
- Rural applications such as management of water on farms, etc.
- Pipeline renewal and rehabilitation by trenchless techniques

Pipe materials have high strength and exceptionally high toughness. At present PE 100 is the highest classification for polyethylene resins and compounds from which to make pressure pipe. This means that in addition to retaining the generally acknowledged good properties of PE-HD pipes, such as weldability, flexibility, chemical resistance and abrasion resistance, PE 100 pipes also

bring marked improvements in important properties such as creep strength, notch resistance and resistance to rapid crack propagation.

Qenos developed Alkadyne HCR193B, Australia's first PE100 pipe resin with high stress-crack resistance (PE100 HSCR), which features significantly improved resistance to slow crack growth. HCR193B is highly suitable for pipes in applications that carry a higher risk of damage during installation or service life.

## PIPE APPLICATION REQUIREMENTS

The operating pressures for pipe systems could be as high as 2.5 MPa (25 bar) for example in the transportation of water. For gas applications the pressure is usually contained below 1.0 MPa (10 bar). The ability of the pipe to withstand sustained pressure is important and dimensions and pressure ratings for pipe made from polyethylene are specified by relevant standards. A very high resistance to cracking is required, because of the wide range of environments and installation techniques that can be encountered in the field. The pipe must have excellent weathering resistance because of extended outdoor exposure.

Specifications for polyethylene resins to be used in pipes for the transportation of fluids under pressure are outlined in relevant standards.

## ALKADYNE GRADE SELECTION FOR PIPE

Table 1: Alkadyne Pipe Extrusion Grades

| Grade                | Melt Index @ 190°C, 5kg (g/10min)* | Density# (g/cm <sup>3</sup> ) | Application  |
|----------------------|------------------------------------|-------------------------------|--|
| HCR193B <sup>1</sup> | 0.2                                | 0.959                         | High Density black PE100 type resin with high stress crack resistance (HSCR) certified to AS/NZS 4131 and in accordance with PIPA guideline POP016, for use in pressure pipes and fittings. Designed for trenchless installations and high abuse environments. |
| HDF193B              | 0.3                                | 0.961                         | High Density black PE100 type resin certified to AS/NZS 4131, for use in pressure pipes and fittings. Excellent low sag properties and throughput, suitable for the majority of PE100 pipe dimensions.   |
| HDF193N              | 0.3                                | 0.952                         | High Density natural resin designed for extrusion into a full range of non-standards pipe products and as a base for PE100 Type striping and jacket compounds. HDF193N is not UV stabilised.   |

1. PE100 HSCR striping compounds available upon request in blue, yellow, cream, purple and white.

\*Melt Index according to ASTM D1238. #Density according to ASTM D1505.





## CLASSIFICATION OF POLYETHYLENE PIPE AND PIPE COMPOUNDS

Specifications for polyethylene compounds for use in pressure pipes and pipes for pressure applications in Australia are covered by two Australian Standards:

- AS/NZS 4131 “Polyethylene (PE) compounds for pressure pipes and fittings”
- AS/NZS 4130 “Polyethylene (PE) pipes for pressure applications”

The maximum allowable working pressure (and therefore class) of the pipe at 20°C is determined by:

- The type of compound used to make the pipe, and
- The dimensions of the pipe

Polyethylene compounds for pipe extrusion are designated by the material type (PE) and an appropriate level of Minimum Required Strength (MRS), details of which are given in Table 2.

**Table 2: MRS and Hydrostatic Design Stress Requirements for PE 100 and PE 80 Compounds**

| Designation | Minimum Required Strength (MRS) (MPa) | Hydrostatic Design Stress (MPa) |
|-------------|---------------------------------------|---------------------------------|
| PE/MRS100   | 10.0                                  | 8.0                             |
| PE/MRS80    | 8.0                                   | 6.3                             |

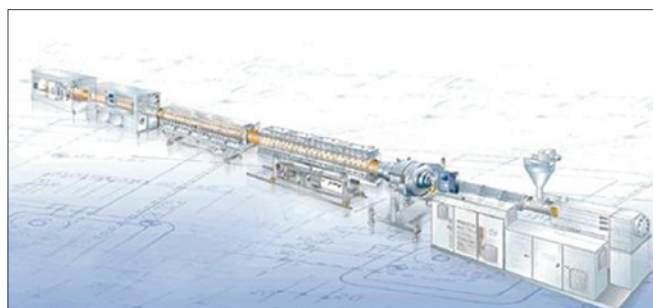
The value of the minimum required strength is based on the long-term hydrostatic stress in the pressure pipe when extrapolated to a 50-year life at 20°C. The hydrostatic design stress is arrived at by applying minimum safety factor of 1.25 to the value of MRS. Reference should be made to the data sheets for *Alkadyne* pipe grades for details of their conformance to these requirements.

For each of the above designations, there are several pressure classes with different wall thicknesses for each nominal pipe diameter.

The performance requirements for PE100 with high stress-crack resistance (PE100 HSCR) are outlined in the POP016 guideline published by the Plastics Industry Pipe Association of Australia (PIPA). It requires PE100 HSCR resins to pass four different slow crack growth tests that take into account different specimen geometries and processing history. Manufacturers of PE100 HSCR also need to ensure this performance is validated for every batch via a batch release protocol for slow crack growth resistance. Finally, pipes made from PE100 HSCR also require striping compounds for identification that are made from a base resin that is classified PE100 HSCR.

## PIPE EXTRUSION TECHNOLOGY

A pipe extrusion line consists of a number of pieces of equipment. An extruder converts the polyethylene raw material to a continuous tubular melt by extrusion through an annular die. The molten pipe then proceeds through a sizing or calibration device (which fixes its dimensions) to a cooling trough. After being cooled, the pipe passes via a haul-off to handling equipment for cutting into final lengths or coiling. Printing devices may also be inserted into the line to mark the extruded pipes with specific details. A portion of a pipe extrusion line is shown in Figure 1.



**Figure 1: Illustration of a Pipe Extrusion Line**

## Granule Pre-treatment

Polyethylene is a hydrophobic material. However, for polyethylene compounds that contain carbon black that is hygroscopic in nature, problems can arise if the moisture content of black polyethylene compound reaches > 0.03 w/w%. During extrusion, moisture could cause formation of voids in pipe wall and rough pipe surface.



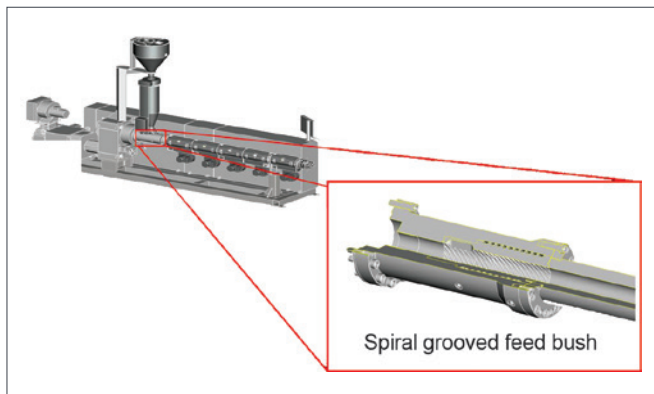
**Figure 2: Photograph illustrating a Pipe with Voids and a Rough Pipe Surface due to Excessive Moisture in the Polymer Compound**

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Such problems can be overcome by drying the polymer granules in a hopper dryer at 70 – 90°C for 1.5 – 2 hours immediately before feeding them into the extruder. The duration of drying and the drying temperature should be such that the moisture content is reduced to < 0.02 w/w%.

### Extruder

For processing HDPE and MDPE into pipes, single screw extruders are used. To achieve the high throughput required for pipe production, high-speed extruders with forced-conveying feed systems have been developed and widely used throughout the industry (see Figure 3).

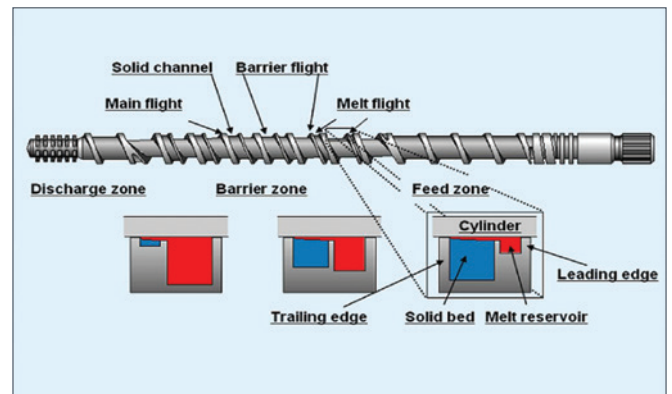


**Figure 3:** Illustration of a Single Screw Extruder with a Spiral Grooved Feed Bush used for High Polymer Throughput

These extruders have a cooled, grooved feed bushing which is thermally insulated from the extruder barrel. As a result, the conveying efficiency of the pelleted feedstock is greatly enhanced achieving higher extruder throughput. For optimal operation of a grooved bush system, it is required to keep the bush cold to prevent melting of the pellets and fouling of grooves. In order to ensure effectiveness of the grooved zone, these systems are cooled with a high flow of chilled water (e.g. water flows of ~10 L/min and water temperature of approximately 10–20°C).

Recent developments in screw design have seen the creation of barrier screws with enhanced melting capability through the incorporation of a second spiral flight that separates the polymer melt from the unmelted product (see Figure 4).

In addition to the barrier screw, mixing elements are generally used at the melt delivery end of the screw to assist with homogenisation of the polymer melt (see Figure 5).



**Figure 4:** Schematic of a Barrier Flighted Screw incorporating a Pin Mixer



**Figure 5:** Photos Illustrating some more Commonly Employed Mixing Sections Located at the Melt Delivery End of the Screw

The typical screw length used in modern pipe extruders is generally around 30 L/D (e.g. screw length is described as a ratio of length divided by the screw diameter that is measured at the flight). The newest generation high throughput pipe line extruders have even higher screw lengths of 40 L/D.

For example, a 90 mm well designed grooved feed extruder, would operate at an output of close to 1,000 kg/hr and some advanced extruders may achieve an output of 1,500 kg/hr.

Table 3 shows expected specific screw output ranges (expressed as kg/hr/rpm) of pipe extruders versus screw diameter for high-speed-extruders with forced-conveying feed sections. Advanced extruders will have outputs close to the maximum of the designated output specification.

**Table 3: LDPE and HDPE Specific Screw Output Data Versus Screw Diameter**

| Screw diameter<br>mm | Specific output [kg/hr/rpm] |           |
|----------------------|-----------------------------|-----------|
|                      | LDPE                        | HDPE      |
| 45                   | 0.4 – 0.6                   | 0.5 – 0.8 |
| 60                   | 0.9 – 1.2                   | 1.2 – 1.7 |
| 75                   | 1.8 – 2.4                   | 2.5 – 3.0 |
| 90                   | 3.0 – 4.0                   | 4.0 – 5.0 |
| 120                  | 6.0 – 8.0                   | 8.0 – 11  |
| 150                  | 10 – 13                     | 12 – 16   |

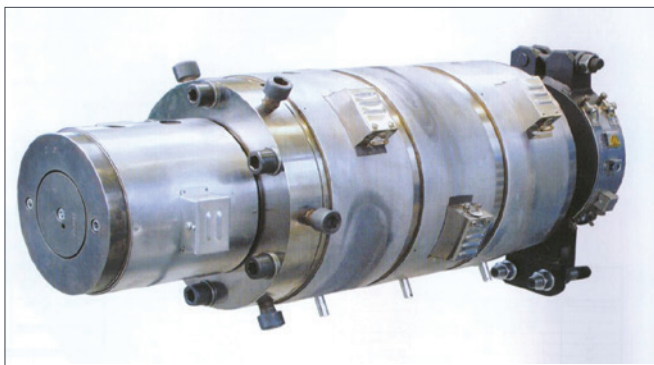
The economics of a pipe production plant will depend on the following:

- The range of pipe sizes – e.g. diameter sizes
- The length of pipe runs – e.g. producing pipe of a set dimension
- The available length of the cooling unit in the production building

Bearing this in mind, increasing plant production capacity might not be as straight forward as installing larger and higher throughput extruders.

## Pipe Dies

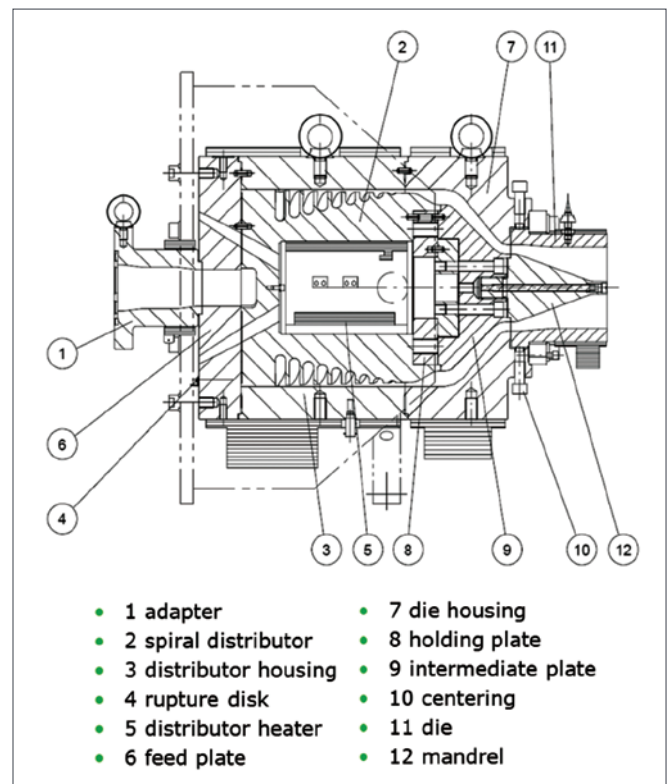
Today, manufacturers of pipe extrusion lines supply pipe dies (see Figure 6) which they have developed themselves but which are essentially based on a common design principle.



**Figure 6: Photograph of a Pipe Die**

High production extruder throughput has resulted in the polymer experiencing low residence times in the extruder. This lack of residence time can lead to concerns about melt homogeneity and whether an even temperature distribution has been achieved throughout the melt. Modern pipe resin grades also have high melt viscosity and elasticity that are required for the strength of the final product, as well as for the ability to make large and thick walled pipes within dimensional tolerances respectively. These polymer features make the extrusion line die absolutely essential for the successful manufacture of pipe, especially with respect to its capacity to even up any melt inhomogeneity and shape it into the pipe without the generation of weld lines or any other memory effects which could potentially compromise the strength or appearance of the final product.

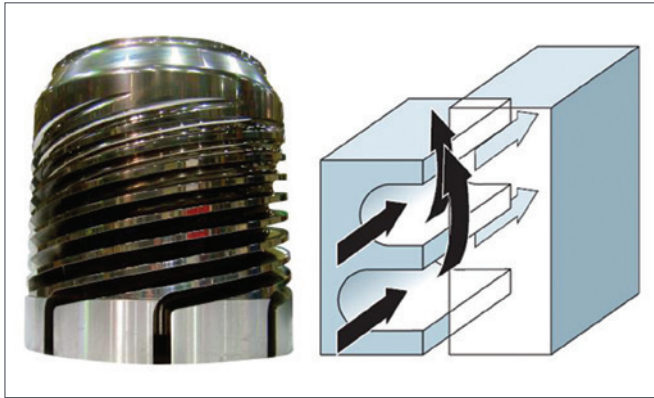
One of the established die designs is a “Spiral Mandrel”. The wide acceptance of this die has seen it incorporated into many new pipe production line designs. This die design has an excellent capability to homogenise melt and shape it into pipe without generating any imperfections which could compromise the final quality or integrity of the pipe (see Figures 7 and 8).



**Figure 7: Schematic Diagram Detailing the Components of a Spiral Mandrel Die**

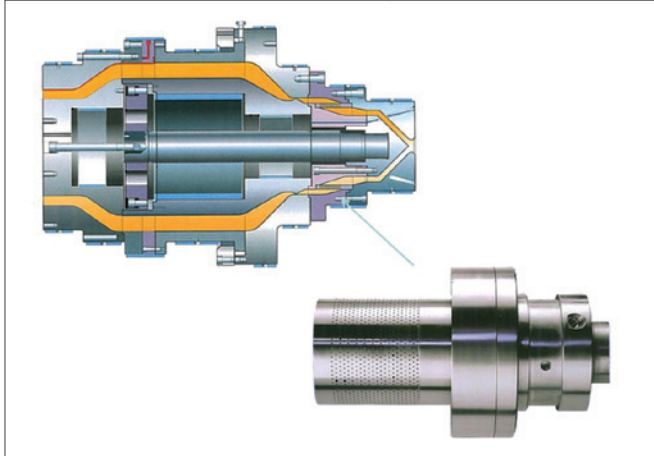


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**Figure 8:** A Spiral Distributor and its Operating Principle for Melt Homogenisation

Another die design which has found wide approval and use in pipe manufacture, for its performance, is the Lattice-Basket type die. This design results in relatively low extrusion melt pressure and consequently relatively low melt temperature, both favourable for high extruder output (see Figure 9).



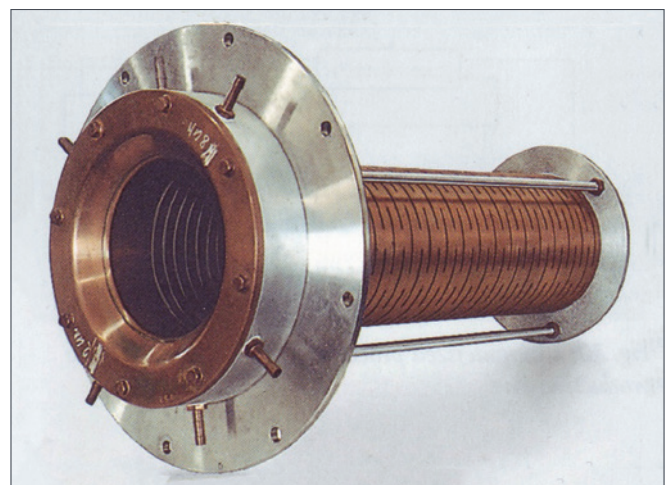
**Figure 9:** A Lattice-Basket Die and the Basket Part of the Die

### Sizing and Cooling

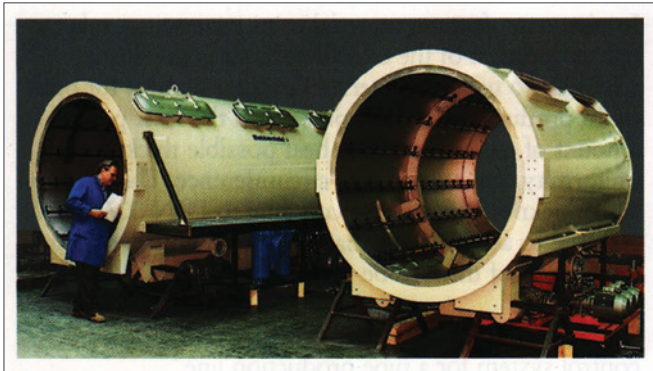
In the state-of-the-art pipe manufacturing lines produced today, vacuum tank sizing is the predominant method used to shape the pipe from the melt. This includes the manufacture of the very largest pipes that have dimensions of 2000 mm. Unlike vacuum sizing, the internal pressure sizing method, where a positive pressure is built up within the pipe through the use of a floating plug, has been rapidly phased out due to safety concerns.

These concerns are associated with potential of building up excessive internal pressure within the pipe and leading to an uncontrolled rupture including release of the floating plug. Vacuum sizing technology enables quick starting up of an extrusion line. In addition, the melt emerging from the die can be drawn down to obtain a range of final pipe diameters so that it is possible to produce at least two standard pipe sizes with a single die/calibrator combination.

The pipe is shaped by a slotted sizing sleeve commonly referred to as a “calibrator”. The calibrator is placed at the entrance of the first vacuum tank and it is the first downstream piece of line that the polymer melt sees after having exited the die. Calibrators are usually made from non-ferrous metal for rapid removal of heat (see Figures 10 and 11). A film of water is fed to the inlet of the calibrator to enable rapid cooling (e.g. below the crystallisation temperature of the polymer) to solidify the external pipe layer in order to pull the pipe into the calibrator without tearing the molten tube apart. Water also acts as a lubricant to reduce frictional forces on the pipe’s surface whilst it is being pulled through the calibrator. The vacuum tank, in which the calibrator is placed, applies a vacuum which pulls the still hot, malleable tube against the wall of the calibrator, thereby setting the outer pipe diameter to ensure conformance to the pipe’s dimensional specification. The vacuum is operated at about 0.05 MPa, absolute pressure, which could vary depending on the pipe dimensions. The calibrator is usually 3 – 5% larger than the required final outer pipe diameter to provide for shrinkage which takes place during pipe cooling.



**Figure 10:** Sizing Sleeve for Vacuum-tank Sizing



**Figure 11:** Vacuum Tanks for Sizing Pipes up to 1,400 mm in Diameter

Downstream of the 1<sup>st</sup> vacuum tank there could be another vacuum tank and certainly more cooling tanks to ensure that the pipe completely solidifies by the time it gets to the saw (see Figure 12). The additional cooling is important to achieving the final pipe dimensions within the desired tolerances.



**Figure 12:** Photographs of Spray Water Bath

The length of the cooling zone is dependent on the output and the given dimensions of the pipe. The total length (L) of the required cooling zone, can be calculated on the assumption that a molten polymer extrudate, at a temperature of ~220°C, has to be cooled with water to an external pipe temperature of ~20°C, at which point the internal surface temperature of the pipe is a maximum of 85°C.

Using these assumed temperatures, the total cooling-zone length can be calculated as follows:

$$L = L_{\text{spec}} \cdot Q \text{ (m)}$$

where

$L_{\text{spec}}$  = specific cooling-zone length (m.hr/kg)

$$Q = \text{output (kg/hr)}$$

$L_{\text{spec}}$  relative to the pipe dimension is outlined in Table 4 below:

**Table 4:**  $L_{\text{spec}}$  Relative to the Pipe Dimension

| Pipe SDR*                  | 41    | 33   | 26    | 17.6  | 11   | 7.4  |
|----------------------------|-------|------|-------|-------|------|------|
| $L_{\text{spec}}$ for HDPE | 0.016 | 0.02 | 0.024 | 0.036 | 0.06 | 0.08 |

\*SDR = Standard Dimension Ratio; a nominal ratio of the pipe outside diameter to its wall thickness

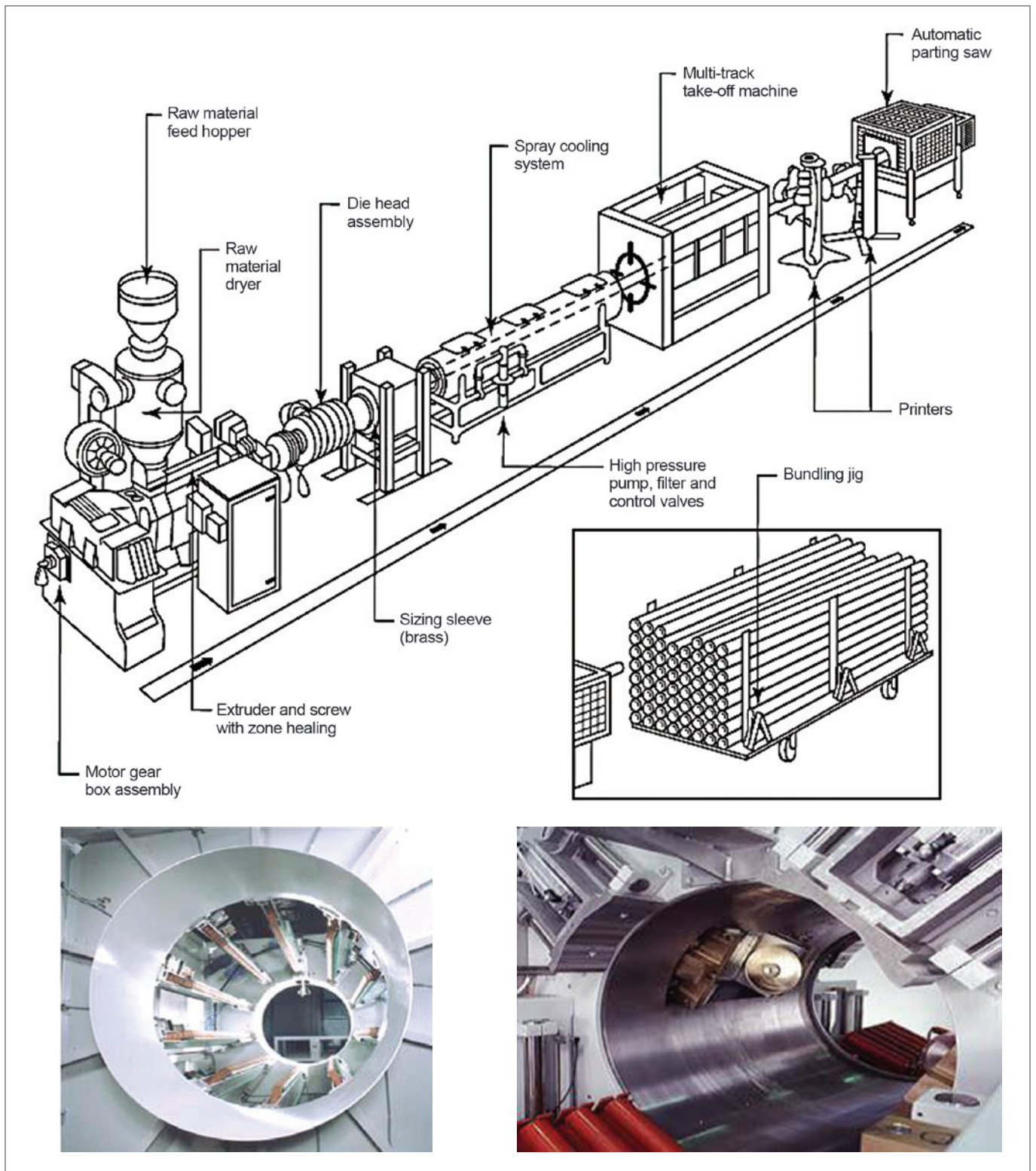
## Downstream Equipment

Downstream equipment covers all other plant units besides the extruder, die, sizing and cooling systems (see Figure 13). Most pipe manufacturing lines will have:

- **Ultrasonic Thickness Meter** – that continuously measures the wall thickness around the circumference of the pipe
- **Caterpillar Haul Off Unit** – with concentrically arranged caterpillars held under pneumatic pressure against the pipe to transmit the haul-off forces. For start-ups, the haul-off unit can be switched to operate in the reverse to enable a pipe to be run back through the cooling and sizing systems to the point where the melt exits from the pipe die. There the pipe can be welded to the extrudate.
- **Marking Unit** – where the pipe is marked with standard specifications
- **Automatically Adjustable Saw** – mounted on a table cuts the pipe into the desired lengths
- **Coiling Unit** – where smaller diameter pipes can be wound into coils or onto reels up to the appreciable pipe size of 250 mm pipe diameter



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**Figure 13:** Schematic of a Pipe Extrusion Line showing Haul Off and Automatic Pipe Cutter

## Process Control

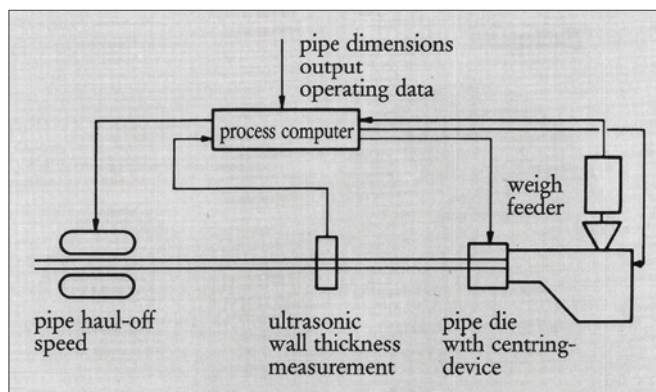
In new pipe production lines, process control computers are used to automate production.

To produce pipe in the required dimensions, the relevant operating data is entered, for example:

- Required throughput
- Pipe dimensions
- Screw speed
- Haul-off rate

The set-point values and permissible deviations are suitably fed-back to the controller for process data monitoring.

In pipe manufacture, material costs represent a substantial proportion of the overall costs of production. It is therefore advisable to use computerised process control for optimum production of pipes with the least possible waste of material and the best possible thickness uniformity around the pipe circumference. Figure 14 shows a schematic diagram of a computerized process control system for a pipe production line.



**Figure 14:** Computerized Process Control System for a Pipe Production Line

The most commonly employed control system operates on the basis of interaction between the following options:

- **Weigh Feeder** – the extruder is equipped with a weigh feeder. Weighed granule portions are fed to the extruder operating at required speed to achieve set off-take of the weighted granulate feed. Any deviation from the set output resulting from the constant weight feed is compensated for by speed adjustment of the extruder screw via the control system.
- **Haul Off Control** – the haul-off is set to a speed calculated from the specified output and the required weight per metre of the pipe. Pipe wall thickness is measured around the circumference with an ultrasonic wall thickness meter.

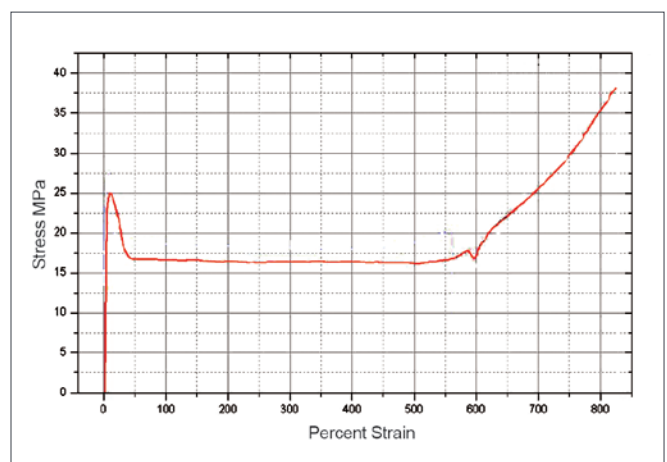
## MECHANICAL PERFORMANCE OF POLYETHYLENE PIPE GRADES

### Short-term Behaviour at Low Deformation Rates

A typical stress/strain curve for HDPE pipe (PE 100 type pipe compound) is shown in Figure 15.

The tensile test reveals the characteristic stress/strain curve for cold stretching of an unreinforced, partially crystalline polymer. Initially, tensile stress increases up to the yield point. This is followed by spontaneous necking-down of the test specimen accompanied by an apparent decline in tensile stress, since the stress is related to the initial cross section and not to the necked-down cross section at the yield point. When the necking-down has progressed along the entire length of the test specimen to the clamps, tensile stress increases again as a result of material strengthening due to macromolecular network straining and orienting until the breaking point is reached (ultimate tensile strength, elongation at break).

Because of the special deformation characteristics of polyolefins, it is advisable to use an extensometer to determine elongation at break. Assessment is only possible when the necking-down has progressed beyond the measuring zone at each end. A polyolefin only retains its useful application properties up to the yield point and so it is better to dispense entirely with measurement of ultimate tensile strength and elongation at break.

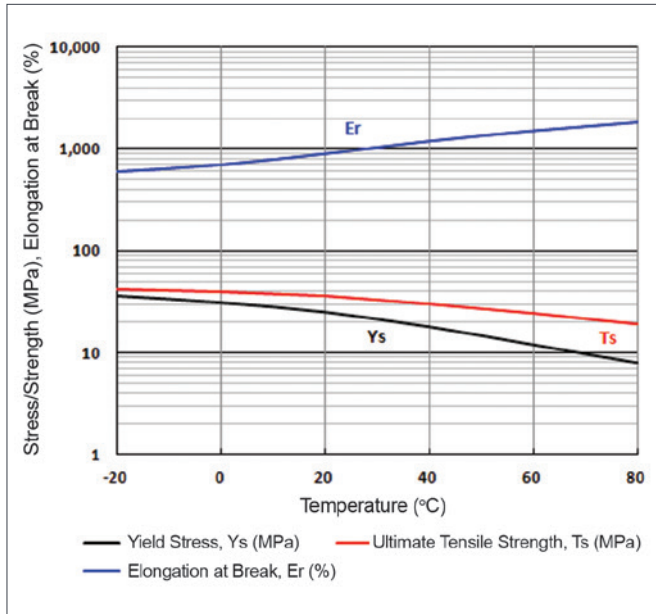


**Figure 15:** Typical Stress/Strain Curves for HDPE Measured in a Tensile Test on Test Specimen Prepared from Compression Moulded Sheet; Test Temperature 23°C, Testing Rate 50 mm/min



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The effect of temperature on the yield stress, ultimate tensile strength and elongation at break of a typical HDPE pipe grade is shown in Figure 16.



**Figure 16:** Yield Stress, Ultimate Tensile Strength and Elongation at Break of HDPE as Functions of Temperature

## Long-term Behaviour

High density polyethylene is a viscoelastic material. Like all thermoplastics, it exhibits the property known as creep, i.e. over a period of time it undergoes deformation even at room temperature and under relatively low stress. After removal of stress, a moulding more or less regains its original shape, depending on the time under stress and the magnitude of the stress. The recoverable deformation is known as elastic deformation whereas the permanent deformation is called plastic deformation.

It should be remembered that the mechanical properties of a plastic are dependent on the three important parameters of time, temperature and stress.

In design calculations for moulded components, the mechanical property values (which in most cases are determined by long-term tests) must be divided by a safety factor.

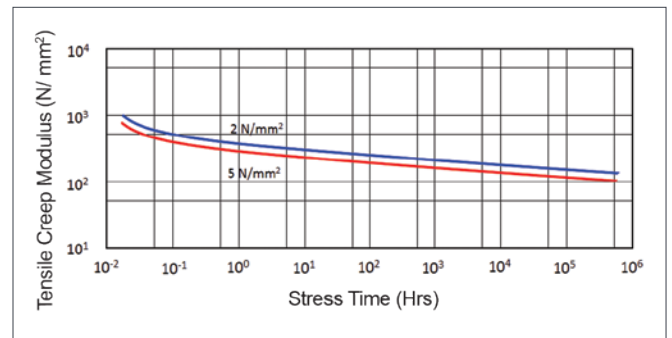
## Creep Behaviour Under Uniaxial Stress

A distinction is made between creep and relaxation tests.

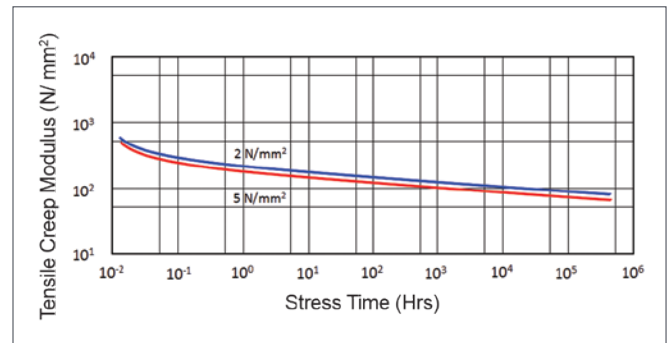
## Creep Test

In the creep test, the increase in deformation with time of a specimen held under a constant stress is measured and from this, the creep modulus is calculated.

Measurement can be carried out in a flexural creep test or a tensile creep test. It should be noted that the creep modulus is dependent on the level of stress as well as on temperature and time. Typical creep curves are shown in Figures 17 and 18.



**Figure 17:** Typical Tensile Creep Modulus Curves of HDPE Determined at 23°C



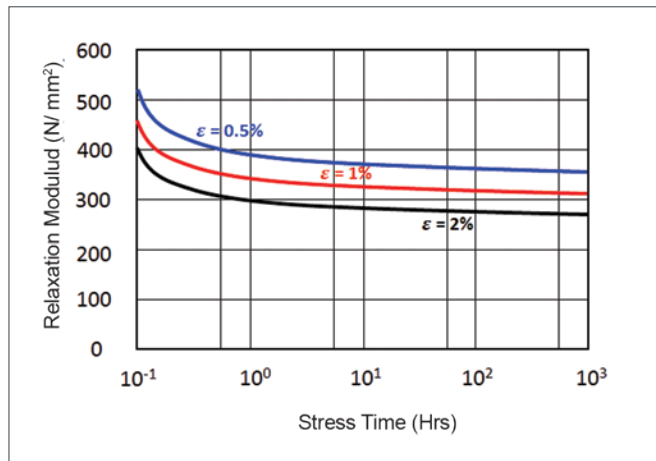
**Figure 18:** Typical Tensile Creep Modulus Curves of HDPE, Determined at 40°C

Similar tests have been carried out to determine creep moduli under compressive stress. Taking scatter into account, these gave approximately the same results as those for tensile stress.

The creep modulus can be used in design calculations for moulded parts which are to be exposed to constant stress over an extended period of time.

## Relaxation Test

In the relaxation test, the stress decay with time of a specimen held under constant deformation is measured and from this, the relaxation modulus is calculated.



**Figure 19:** Typical Relaxation Modulus Curves of HDPE, Determined at 23°C

It should be noted that the relaxation modulus is dependent on the level of strain as well as on temperature and time.

The relaxation modulus (see Figure 19) can be used in design calculations for moulded parts that are to be exposed to constant strain or compression over an extended period of time.

## Behaviour at High Deformation Rates

Information on the toughness characteristics of polymer materials at high deformation rates is provided by flexural and tensile impact strength tests. The results of impact strength tests (values for impact strength, notched impact strength and tensile impact strength) are considerably influenced by the conditions under which the test specimen is prepared. Injection moulded test specimens because of their rapid cooling rate are less crystalline when solid and therefore more impact resistant than those prepared from compression moulded sheet. The orientation produced by injection moulding also has an effect.

## QUALITY TESTING OF POLYETHYLENE PIPE

### PE 100: A Package of Good Properties

The designation PE 100 indicates that a PE-HD material has been assigned to performance class MRS 10 where MRS stands for Minimum Required Stress. The minimum creep strength is thus 10 MPa stress in the pipe wall at 20°C and 50 years. However creep strength alone does not determine assignment to material class 100 but rather a whole range of improved properties resulting from the much improved toughness of these materials, the most notable being:

- High resistance to Slow Crack Growth (SCG)
- High resistance to Rapid Crack Propagation (RCP)

### Hydrostatic Pressure Tests

Undoubtedly the most important property of plastic pipes is their hydrostatic strength behaviour under internal pressure or “Creep Strength”. This is what determines the service life expectancy of the pipe under internal pressure.

The equivalent stress (resulting from the action of the applied pressure within the pipe) corresponds in practice to the hoop stress acting on the pipe internal surface. Knowledge of the permissible stress for the material concerned forms the basis for designing a pipe under a given internal pressure using the calculation formula for pressure vessels.

The pressure to be used in the test is calculated from the equation below, knowing the dimensions of the pipe and the required hoop stress.

$$P = \frac{2ST}{D_{m \text{ min.}} + T}$$

where:

P = maximum working pressure at 20°C (MPa)

S = hoop stress of hydrostatic design stress at 20°C (MPa)

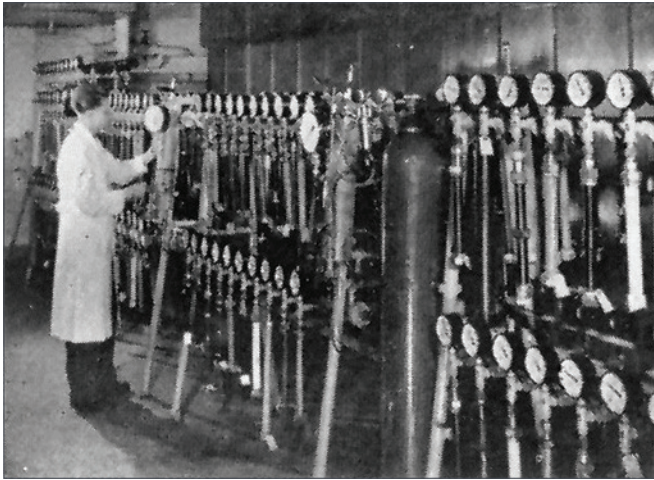
T = minimum wall thickness (mm)

$D_{m \text{ min.}}$  = minimum mean inside diameter (mm)

### Creep Test Under Internal Pressure

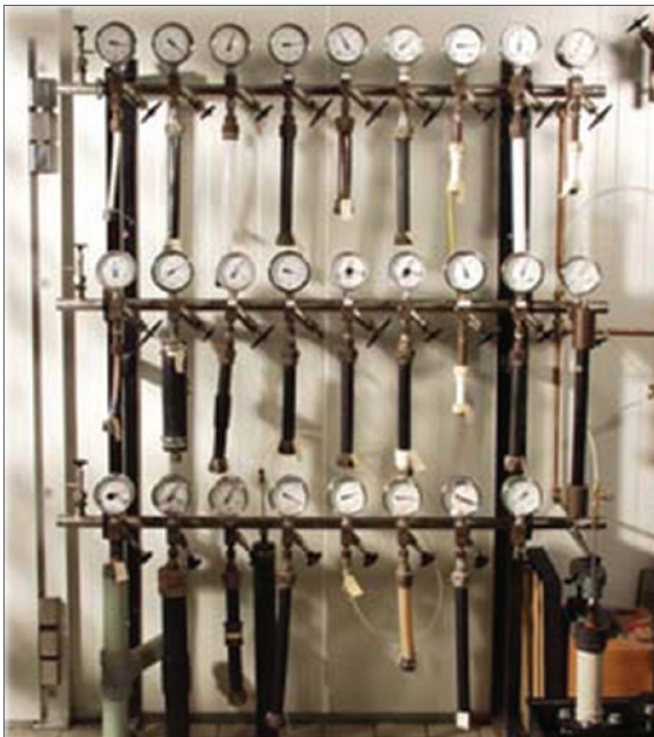
The stress that leads to rupture in plastic pipes depends on the time under stress and the temperature of the test. Creep behaviour has been studied in long-term tests over many years, in some cases, since 1956 (see Figure 20). ISO 9080 standard “Plastics piping and ducting systems — Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation” sets out rules for the determination of the long-term hydrostatic strength of polyethylene pipes.

## 7 PIPE AND TUBING EXTRUSION



**Figure 20:** The First Creep Rupture Test Started In 1956 In HOECHST (today known As Lyondell Basell) Laboratory, Frankfurt

The same test rig, and “original” pipes are still in operation today (see Figure 21). On 18th October 2006, two pipe specimens on this “historical” test stand finally confirmed the predicted service of 50 years.



**Figure 21:** The First Creep Rupture Test Started in 1956 in HOECHST (today known as Lyondell Basell) Laboratory, Frankfurt, is still on test

The hydrostatic tests that are carried out on pipe sections under internal pressure take into account the effect of the multi-axial strain occurring in practice. The pipes are filled with water and suspended in a temperature-controlled environment such as a water bath (see Figure 22).

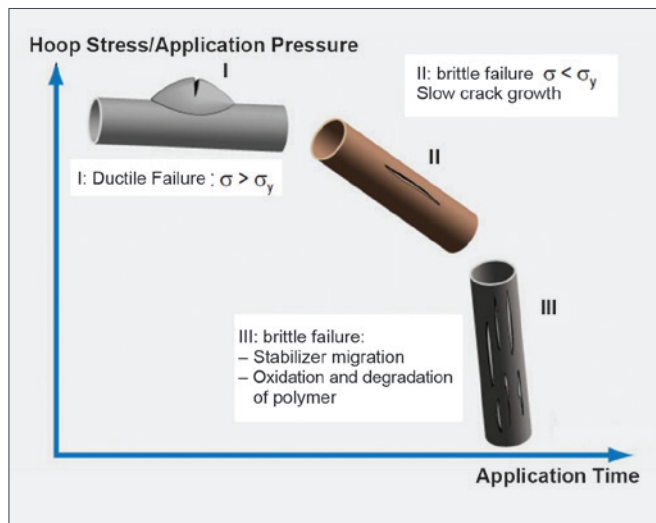


**Figure 22:** Extensive Hydrostatic Pipe Testing at Qenos Technical Centre



## Pipe pressure Curve and Service Life Extrapolation

The results of these tests are plotted on a log-log scale. Test stress is plotted against endurance time. After sufficiently long testing times, the typical pipe curve obtained from this plot shows three different regions or stages (see Figure 23).



**Figure 23:** Representation of Pipe Curve According to the 3-stage Model (Illustration by Studsvik Material AB now known as Exova)

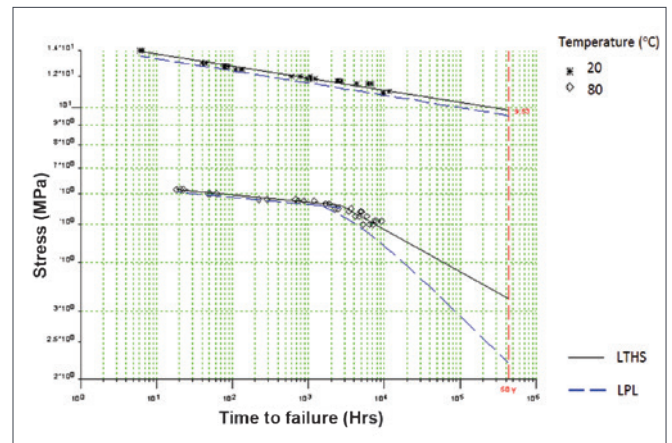
Starting with short endurance times, a flat, straight branch can be seen which is followed by a straight, steep branch. With the PE 100 grades currently used, this steep branch does not begin for 10 000 hours, even at elevated temperature (e.g. 80°C). After very long endurance times, a vertical, stress-independent branch of the curve could be expected to follow for testing at 80°C, effectively indicating resin has degraded due to long exposure to high temperature.

Each of the three curve stages is associated with three different failure mechanisms. In the flat stage of the pressure curves at 20°C and 80°C represented on Figure 25, only ductile fractures are observed. Ductile type failure shows a visible deformation on the pipe in the failure region. Figure 24 shows a section of pipe that has failed in a ductile mode.



**Figure 24:** Pipe Failed in Ductile Mode

Ductile failure indicates ultimate pressure bearing capability of the pipe. The flat branch therefore marks the stress limit for ductile failure.

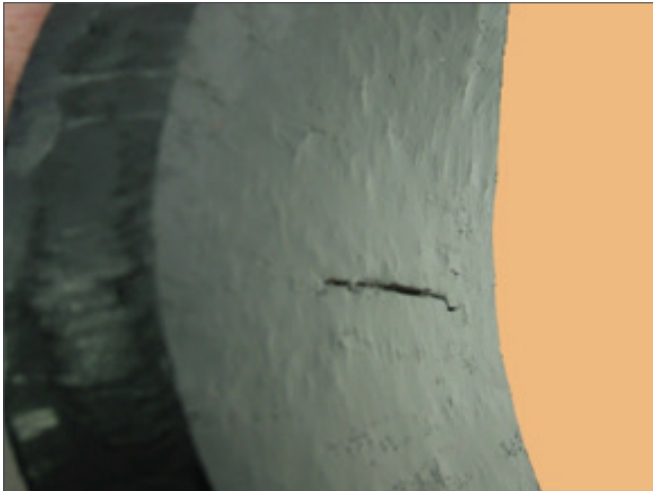


**Figure 25:** Qualitative Interpretation of Pipe Curve as Generated on PE 80 Pipe Grade. Testing was According to ISO 9080.

For the long-term properties of a pipe material, the position of the steep branch is crucial (e.g. in practice the steeper branch in the pressure test is referred to as a “knee”). It is determined by the resistance of the material to slow crack propagation. This material property, also referred to as brittle fracture resistance, determines the service life of the pipeline. In other words pipelines are designed to operate in a “ductile” failure regime. The inflection point (the transition between the flat and steep branches) can be observed, if at all, only at high temperature and after very long endurance times. This position denotes the transition from “ductile” to “brittle” type behaviour of pipe under pressure.

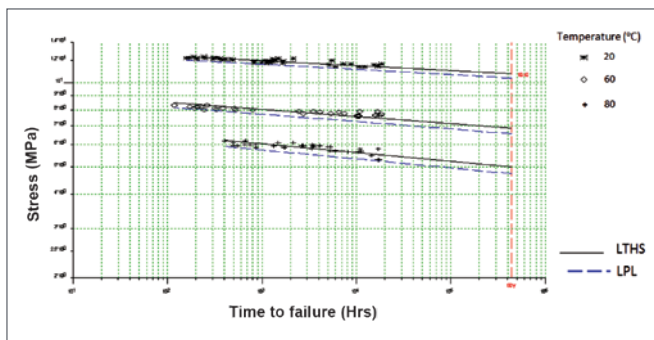
Pipe that has failed in a brittle mode doesn’t show visible ductility in the failure region (see Figure 26).

## 7 PIPE AND TUBING EXTRUSION



**Figure 26:** Pipe Failed in Brittle Mode

Modern pipe grades such as PE 100 should not show “brittle” like pipe failures in hydrostatic tests, even at 80°C, within the required one year testing time (see Figure 27).



**Figure 27:** Creep Rupture Curve for Qenos PE 100 Grade Alkadyne HDF193B. Testing was According to ISO 9080.

When a PE piping system is to operate at a continuous temperature higher than “designated standard” temperature of 20°C, ISO 9080 analysis could be used to demonstrate capability of the pipe network in terms of extrapolated values for application stress and life time. Actual service life time of the PE pipe network will depend on application conditions and ISO 9080 extrapolation should not be used to infer actual service life time of the PE network.

### TEMPERATURE RE-RATING OF PE PIPES

The Maximum Allowable Operating Pressure (MAOP) of a polyethylene (PE) pipe system is influenced by the temperature of the pipe wall. The nominal pressure rating (PN) assigned to an AS/NZS 4130 PE pipe equates to performance at 20°C, i.e. a PN16 pipe is capable of withstanding a MAOP of 160 m head (or 1.6 MPa or 16 bar pressure) when operating continuously at 20°C. However, as the temperature of the pipe wall increases, the MAOP of the pipe is reduced progressively, in other words the pipe system is re-rated with increasing temperature.

The guidance provided in this document is based on typical PE compounds used in Australia and New Zealand to manufacture AS/NZS 4130 PE pipe and listed in PIPA Guideline POP004, *Polyethylene Pipe Compounds*.

Note: These guidelines apply to pipe used for the conveyance of water. Where other incompressible fluids are being considered, the designer must assess the effect of the fluid on the PE pipe system at the operating temperature. For example internal fluids such as aggressive condensates when absorbed may have the effect of reducing the material strength upon which design stress is based.

**The derating factors in this guideline are expressed in terms of metre head of water and are not for use with compressed air or gas applications.**

The following information details how to determine the temperature of the pipe wall and, then using Table 5 and 6, determine the de-rated MAOP value for the system. These recommendations are not to be taken as detailed specifications.

### Determining the Temperature of the Pipe Wall

The pressure rating of PE pressure pipe systems is based on the temperature of the pipe wall, which may be determined from either:

- An assumption of a constant pipe wall temperature typical for continuous service at a set temperature, e.g. cold water service; or
- The determination of an average service temperature where temperature variations are likely to occur in a predictable pattern (refer below), e.g. in cavity walls or roof spaces; or
- The maximum service temperature less 10°C for installations where large unpredictable temperature variations occur up to a maximum of 80°C, e.g. above-ground installations such as irrigation systems.

## Predictable Temperature Variations

For installations where predictable temperature variations occur, the average material temperature is determined from Item (d) or Item (e) as follows:

d. *Across the wall of the pipe* — the material temperature taken as the mean of the internal and external pipe surface temperatures, where a temperature differential exists between the fluid in the pipe and the external environmental.

The pressure and temperature condition, where flow is stopped for prolonged periods, should also be checked. In this event, fluid temperature and outside temperature may equalise.

e. *With respect to time* — the average temperature may be considered as the weighted average of temperatures for the proportion of time spent at each temperature under operational pressures; it is calculated with the equation:

$$T_m = T_1L_1 + T_2L_2 + \dots + T_nL_n$$

where:

$T_m$  = average pipe material temperature for the period of time under consideration, in °C

$T_n$  = average pipe material temperature for a proportion of pipe life, in °C

$L_n$  = proportion of life spent at temperature  $T_n$

## Determining the MAOP Value

Once the temperature of the pipe wall has been determined using any one of the methods (a), (b) or (c) above, the following tables can be used to determine the re-rated MAOP for the PE pipe system.

Table 5 nominates the corresponding MAOP for a given temperature for PE 80B material. Table 6 provides the same information for PE 100 material.

**Table 5: Maximum Allowable Operating Pressure – PE 80**

| Temp (°C) | Min Life (yr) | Design Factor | PN 3.2 | PN 4 | PN 6.3 | PN 8 | PN 10 | PN 12.5 | PN 16 | PN 20 |
|-----------|---------------|---------------|--------|------|--------|------|-------|---------|-------|-------|
| 20        | 100           | 1.0           | 32     | 40   | 64     | 80   | 102   | 128     | 160   | 200   |
| 25        |               | 1.0           | 32     | 40   | 64     | 80   | 102   | 128     | 160   | 200   |
| 30        |               | 1.2           | 27     | 33   | 53     | 67   | 85    | 107     | 133   | 167   |
| 35        |               | 1.3           | 25     | 31   | 49     | 62   | 78    | 98      | 123   | 154   |
| 40        |               | 1.3           | 25     | 31   | 49     | 62   | 78    | 99      | 123   | 154   |
| 45        |               | 1.4           | 23     | 29   | 46     | 57   | 73    | 91      | 114   | 143   |
| 50        | 36            | 1.6           | 20     | 25   | 40     | 50   | 63    | 80      | 100   | 125   |
| 55        | 24            | 1.7           | 19     | 24   | 38     | 47   | 60    | 75      | 94    | 118   |
| 60        | 12            | 1.8           | 18     | 22   | 36     | 44   | 56    | 71      | 89    | 111   |
| 80        | 1             | 2.4           | 13     | 17   | 27     | 33   | 42    | 53      | 67    | 83    |

**Table 6: Maximum Allowable Operating Pressure – PE 100**

| Temp (°C) | Min Life (yr) | Design Factor | PN 4  | PN 6.3 | PN 8  | PN 10 | PN 12.5 | PN 16 | PN 20 | PN25   |
|-----------|---------------|---------------|-------|--------|-------|-------|---------|-------|-------|--------|
|           |               |               | SDR41 | SDR26  | SDR21 | SDR17 | SDR13.6 | SDR11 | SDR9  | SDR7.4 |
| 20        | 100           | 1.0           | 40    | 64     | 80    | 100   | 127     | 160   | 200   | 250    |
| 25        | 100           | 1.1           | 36    | 58     | 73    | 91    | 115     | 145   | 182   | 227    |
| 30        | 100           | 1.1           | 36    | 58     | 73    | 91    | 115     | 145   | 182   | 227    |
| 35        | 50            | 1.2           | 33    | 53     | 67    | 83    | 106     | 133   | 167   | 208    |
| 40        | 50            | 1.2           | 33    | 53     | 67    | 83    | 106     | 133   | 167   | 208    |
| 45        | 35            | 1.3           | 31    | 49     | 62    | 77    | 99      | 123   | 154   | 192    |
| 50        | 22            | 1.4           | 29    | 46     | 57    | 71    | 91      | 114   | 143   | 179    |
| 55        | 15            | 1.4           | 29    | 46     | 57    | 71    | 91      | 114   | 143   | 179    |
| 60        | 7             | 1.5           | 27    | 43     | 53    | 67    | 85      | 107   | 133   | 167    |
| 80        | 1             | 2.0           | 20    | 32     | 40    | 50    | 63      | 80    | 100   | 125    |

Note: the minimum life periods may be considered to be the minimum potential service lives and represent the maximum extrapolated periods permitted by the ISO 9080 extrapolation rules given the available test data.

## 7 PIPE AND TUBING EXTRUSION

### NOTCH RESISTANCE (SCG) OF PE PIPES

Behind the phenomenon of creep strength and notch resistance lays the process of slow crack propagation. The brittle fracture observed is initiated by small defects or notches in the pipe. An increase in temperature accelerates this process. The fracture diagram (see Figure 23) shows a small crack running lengthwise along the pipe. As a partially crystalline polymer, polyethylene reacts to the stress concentration at the crack tip (notch root) by forming a crazing zone. This crazing zone develops into a fully propagating crack that leads to a “brittle” type failure. Application stress, which could lead to craze initiation and crack propagation, is of the magnitude that is observed for the hoop stress the pipe experiences in operation due to the presence of an applied operating pressure.

Therefore, it is widely accepted in the field that the most application relevant pipe property is its resistance to slow crack growth, in other words, its susceptibility to “brittle” failure.

#### Notch Test

The notch test according to ISO DIS 13479 may be regarded as a variant of the pressure creep test in which crack propagation resistance is specially assessed. Unlike the creep test under internal pressure, the failure point in this test is predetermined by notching.

In this test, four notches are cut in the outer surface of the pipe specimen in the longitudinal direction, each at 90° to the pipe circumference and with a defined geometry (Vee angle 60°, notch depth = 20% of wall thickness). See Figures 28 and 29 for details.

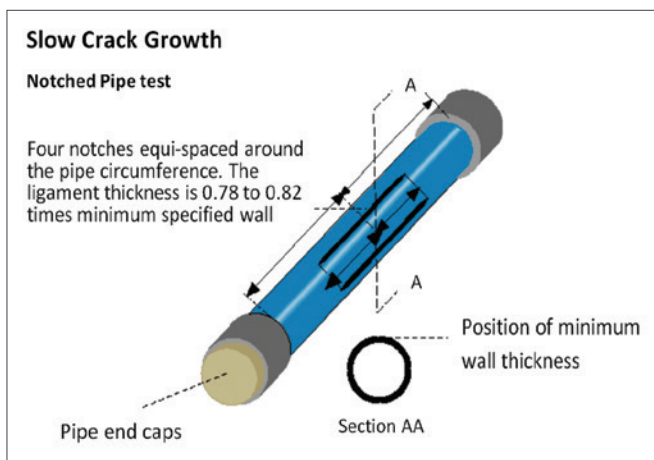


Figure 28: Illustration of Notched Pipe Test

This pipe is then pressure creep-tested under the following conditions:

- PE 100: 80°C; 4.6 MPa Hoop Stress; endurance time > 500 hrs
- PE100 HSCR: 80°C; 4.6 MPa Hoop Stress; endurance time > 5000 hrs

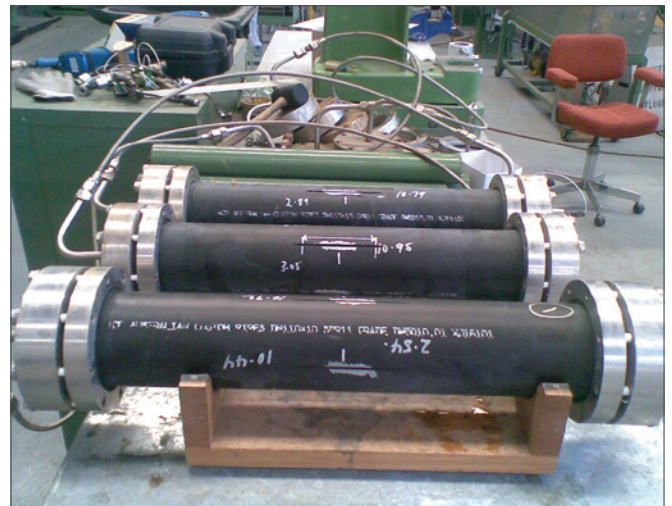
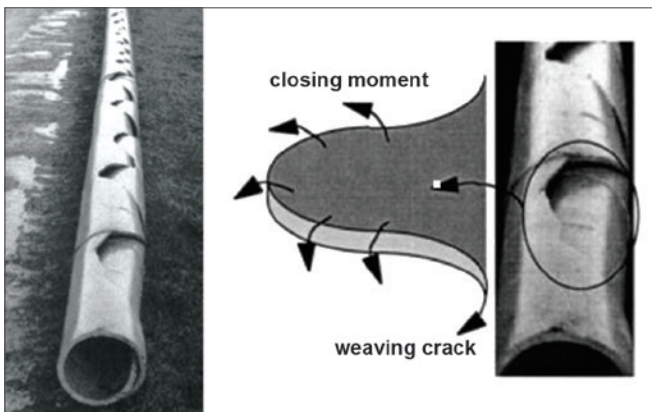


Figure 29: Pipes Notched and Assembled to be Tested for Slow Crack Growth Property as per ISO 13479. Pipes made from Qenos Pipe Grade Alkadyne HDF193B.

### RESISTANCE TO RAPID CRACK PROPAGATION (RCP) OF PE PIPES

By rapid crack propagation we mean the following phenomenon: if a gas pipe during operation is damaged by an external force (e.g. by construction machinery) or by a stress-induced crack (e.g. in a defective weld) then, under the action of internal pressure and hence of the potential energy stored in the gas, the crack can spread over an extended length at almost the speed of sound (see Figure 30). In the case of PE 100, the range of applications is widened to include higher operating pressures; therefore pipe designers must be given highly reliable assurances as to the resistance of the pipe material to rapid crack propagation.

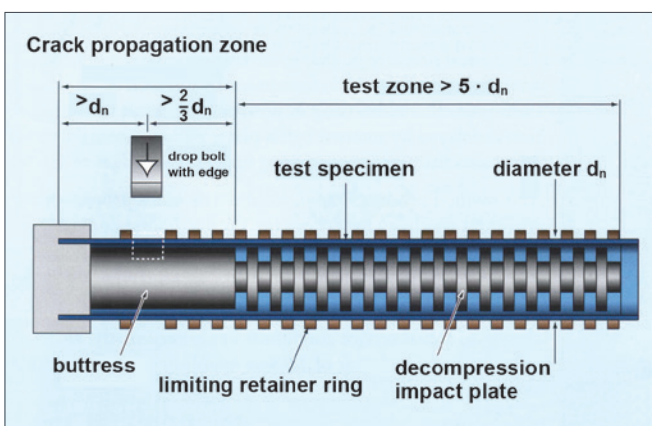




**Figure 30:** Example of Rapid Crack Propagation Fracture in Pipe Which Shows the Actions of Residual Stresses on the Cracked Pipe During RCP

## S4 Test

Commonly employed testing methodology for RCP is based on the ISO 13477 standard. It is known in industry as the S4 test (small-scale, steady-state test). The S4 test is carried out as follows: a weight with a knife attached to the end is dropped onto a pipe of standardised length and under a constant internal gas pressure near one of its ends to produce a rapidly progressing axial crack. The crack initiation process should damage the pipe as little as possible. The term crack propagation is used if the crack length,  $a$ , is greater than or equal to  $4.7 d_n$  ( $4.7$  times the nominal outside diameter). See Figures 31 and 32 for details.



**Figure 31:** Schematics of a Test Rig for the S4 Test



**Figure 32:** Actual Test Rig for the S4 Test

A series of tests at  $0^{\circ}\text{C}$  but varying in testing pressure lead to the determination of the critical pressure at which there is a sharp transition from abrupt arrest of the initial crack to continued, steady-state, crack propagation. This method arrives at the “Critical Pressure” at which RCP occurs.

Alternatively, tests can be carried out at the set pressure but varying test temperatures to determine the “Critical Temperature” at which RCP occurs (see Tables 7 and 8).

In designing a pipeline, to carry gas at high pressure or at sub-zero temperatures the RCP property of pipe resin needs to be considered and a safety factor must be taken into account.

For gas pipelines made from Qenos *Alkadyne* PE 100 grades, the high RCP property ensures safe pipe line operation at high operating pressures as well as sub-zero temperatures.

## 7 PIPE AND TUBING EXTRUSION

**Table 7: RCP Testing of PE 100 Pipe at a Fixed Pressure and Varying Temperature**

| Pipe No. | Temperature (°C) | Pressure (MPa) | Crack Length $l_c$ (mm) | $l_c/d_n$ | Results      |
|----------|------------------|----------------|-------------------------|-----------|--------------|
| 1        | -5               | 0.5            | 120                     | 1.1       | Crack Arrest |
| 2        | -10              | 0.5            | 135                     | 1.2       | Crack Arrest |
| 3        | -15              | 0.5            | 165                     | 1.5       | Crack Arrest |
| 4        | -20              | 0.5            | 360                     | 3.3       | Crack Arrest |
| 5        | -25              | 0.5            | 300                     | 2.7       | Crack Arrest |

The critical temperature  $T_c$  of the PE pipes (110 mm diameter) SDR11, Qenos grade *Alkadyne* HDF145B (discontinued grade), at a pressure of 0.5 MPa, is lower than or equal at -25°C

**Table 8: RCP Testing of PE 100 Pipe at a Fixed Temperature and Varying Pressure**

| Pipe No. | Pressure (MPa) | Crack Length $a$ (mm) | $a/d_n$ | Results         |
|----------|----------------|-----------------------|---------|-----------------|
| 1        | 0.0            | 85                    | 0.8     | Initiation Test |
| 2        | 0.4            | 110                   | 1.0     | Crack Arrest    |
| 3        | 0.6            | 120                   | 1.1     | Crack Arrest    |
| 4        | 0.8            | 130                   | 1.2     | Crack Arrest    |
| 5        | 1.0            | 125                   | 1.1     | Crack Arrest    |

The critical pressure  $P_{c,s4}$  of the PE pipes (110 mm diameter) SDR11, Qenos grade *Alkadyne* HDF145B (discontinued grade), at a temperature of 0°C, is higher than or equal to 1.0 MPa

**Table 9: Collation of ISO to Australian Standards for Set Items, Equipment, Installation and Testing**

| International Standard | Subject Matter            | Australian Standard     |
|------------------------|---------------------------|-------------------------|
| ISO 8085-2             | Fittings                  | AS/NZS4129 Section 6    |
| ISO 4437               | Gas Pipe                  | AS/NZS4130              |
| ISO 4427               | Water Pipe                | AS/NZS4130              |
| ISO 12176-1            | Equipment                 | Not applicable          |
| ISO/TS 10839           | Installation              | AS/NZS2033, AS/NZS 4645 |
| ISO 13593              | Tensile Test              | Not applicable          |
| ISO 1167-1             | Hydrostatic Pressure Test | AS/NZS 4130 Clause 10.1 |
| ISO 1167-3             | Hydrostatic Pressure Test | AS/NZS 4130 Clause 10.1 |
| ISO 1167-4             | Hydrostatic Pressure Test | AS/NZS 4130 Clause 10.1 |
| ASTM F2634             | High speed tensile test   | Not applicable          |

## JOINING PE PIPES

### Butt fusion jointing of PE pipes and fittings

Note: Information is based on POP 003 prepared by PIPA (Polyolefin Industry Pipe Association) as a guide to the butt fusion of polyethylene pipe using AS/NZS 4130 material as a basis.

### Relevant Standards

The butt fusion procedures and parameters are specified in ISO 21307, *Plastics pipes and Fittings – Butt Fusion Jointing Procedures for Polyethylene (PE) Pipes and Fittings Used in Construction of Gas and Water Distributions Systems*.

ISO 21307 specifies three proven butt fusion jointing procedures for pipes and fittings with a wall thickness up to and including 70 mm, taking into consideration:

- The materials and components used
- The fusion jointing procedure and equipment
- The quality assessment of the completed joint

This standard also covers the weld procedure for activities such as surface preparation, clamping, alignment and cooling procedures.

Where ISO 21307 references other International Standards, the equivalent Australian Standard is deemed to apply. Where there is no equivalent Australian Standard then the International Standard applies (see Table 9).

### Jointing Procedures

Butt welding involves the heating of two pipe ends to fusion temperature and then subsequently joining the two ends by the application of force. However, a successful butt weld requires the correct combination and sequence of the welding parameters time, temperature and pressure.

Various proven butt fusion methods with minor differences have been in use in different countries for many years. ISO 21307 contains three distinct fusion methods described below for pipe and fittings with a wall thickness up to and including 70 mm.

**It is essential that the parameters specified for a given method are followed. Do not mix and match parameters from each method.**

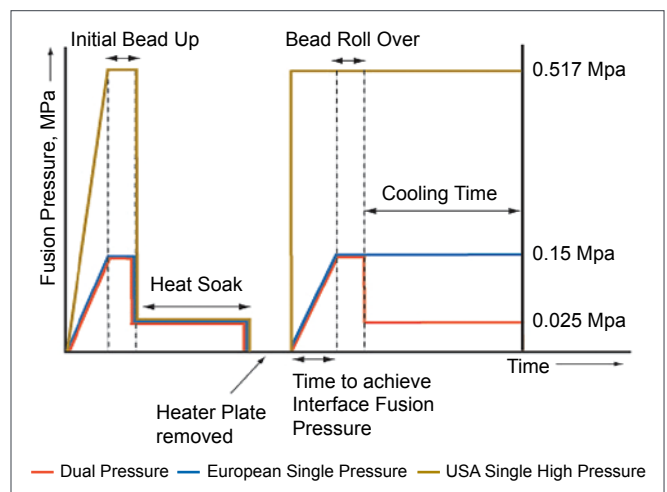
- **Single pressure – low fusion jointing pressure**  
This method has been used by most European countries and in Australia. The single pressure parameters specified are very similar to those previously specified by PIPA. Welders familiar with those parameters will adapt easily to the ISO Single pressure – low fusion jointing method.

- **Dual pressure – low fusion jointing pressure**  
This method is used by the water industry in the UK, and in Europe for pipes with a wall thickness greater than 20 mm. These parameters are not commonly used in Australia.
- **Single pressure – high fusion jointing pressure**  
This method has been used extensively in Northern America. The weld interface pressure is approximately three times the low pressure method and, as a consequence, more of the molten material is extruded from the weld zone, thereby enabling a reduced cooling time. Extra attention is required to ensure that:
  1. Welding machines have sufficient structural strength and hydraulic capacity to achieve the high pressure parameters in a safe manner. Confirmation should be sought from the machinery manufacturer.
  2. The welding operator is sufficiently experienced and proficient with the parameters.

Where the pipe or fitting wall thickness exceeds 70 mm welding parameters should be agreed between the asset owner and the installer. Under these circumstances the pipe and fitting supplier and the equipment supplier should also be consulted.

Schematically all three welding procedures are outlined in Figure 33 and Table 10 which show:

- Procedures are similar in overall approach, i.e. the seven steps of fusion
- Primary differences are in applied pressure and approach to cooling
- When properly performed, all methods result in reliable joints



**Figure 33:** Schematic Diagram of the Various Stages of the Polymer Butt Welding Process

## 7 PIPE AND TUBING EXTRUSION

**Table 10: Parameters Corresponding to the Three Butt Welding Processes**

| Butt Welding Parameter  |   | Unit    | Single Low Pressure   | Single High Pressure | Dual Low Pressure<br>(If $e_n > 20\text{mm}$ ) |
|-------------------------|---|---------|---|----------------------|--|
| Heater pipe temperature |   | °C      | 200 to 245  | 200 to 230           | 225 to 240                                     |
| P1                      | Bead up pressure  | MPa     | $0.17 \pm 0.02$   | $0.52 \pm 0.1$       | $0.15 \pm 0.02$                                |
| T1                      | Bead up time  | Visual  | First indication of melt everywhere around pipe.<br>(Approx. 1mm, maximum 6mm)  |                      |  |
| P2                      | Heat soak pressure  | MPa     | 0 to drag pressure  | 0 to drag pressure   | 0 to drag pressure                             |
| T2                      | Heat soak time  | Seconds | $(11 \pm 1)e_n$   | $(11 \pm 1)e_n$      | $10e_n + 60$                                   |
|                         | Maximum bead size after T2                                    | Mm      | $0.5 + 0.1e_n$  | $0.15e_n + 1$        | $0.5 + 0.1e_n$                                 |
| T3                      | Maximum heater plate removal time                             | Seconds | $0.1e_n + 4$  | $0.1e_n + 8$         | $< -10$  |
| T4                      | Maximum time to achieving welding pressure                    | Seconds | $0.4e_n + 2$  | $0.1e_n + 8$         | $< -10$  |
| P3                      | Fusion jointing pressure                                      | Seconds | $0.17 \pm 0.02$   | $0.52 \pm 0.1$       | $0.15 \pm 0.02$                                |
| T5                      | Cooling time  | Minutes | $e_n + 3$   | $0.43e_n$            |  |
| T5a                     | <i>Fusion jointing time</i>                                   | Seconds |   |                      | $10 \pm 1$                                     |
| T5b                     | <i>Minimum cooling time in machine under reduced pressure</i> | Minutes |   |                      | See ISO 21307                                  |
| P4                      | <i>Cooling cycle reduced pressure</i>                         | MPa     |   |                      | $0.025 \pm 0.002$                              |
| T6                      | Additional cooling time                                       | Minutes | Additional cooling time out of the machine and before rough handling or installation may be recommended, but in most cases is not necessary |                      |  |

### Electrofusion Jointing of PE Pipes and Fittings

Note: Information is based on POP 001 prepared by PIPA (Polyolefin Industry Pipe Association) as a guide to the electrofusion of polyethylene pipes and fittings complying with Australian/New Zealand Standards AS/NZS 4130 and AS/NZS 4129<sup>1</sup>.

These guidelines set out the principal requirements for equipment, jointing procedures, maintenance, servicing and calibration of equipment, records and training for jointing by socket electrofusion (EF) and saddle electrofusion.

The guidelines are also applicable to electrofusion fittings that are available in the size range DN16 to DN800. Development work is being undertaken for larger sized electrofusion fittings.

To consistently make satisfactory joints it is important to follow the jointing procedure with particular emphasis on pipe surface preparation, avoidance of contamination, and machine calibration, as well as temperature control.

Pipes and fittings of different SDR can be joined together by the electrofusion process, e.g. DN250 SDR11 pipe can be successfully electrofused using a DN250 SDR17 fitting. Electrofusion fittings for pressure applications are usually

recommended for use with PE pipes SDR17 or lower (i.e. increased wall thickness).

Pipes of different PE materials- PE 63, PE 80 and PE 100 can also be jointed successfully using electrofusion sockets, provided that all components have adequate nominal pressure rating for the operating conditions and the PE materials comply with AS/NZS 4131.

Some manufacturers supply electrofusion fittings for thinner pipes, down to SDR33 whereas others limit the use of some saddle type fittings to SDR11 or thicker. These limitations are usually detailed on the fitting body or on the packaging. If in doubt, check with the supplier or manufacturer, as unsatisfactory joints are likely to occur if the fitting/pipe combination is incorrect.

**It is recommended to refer to the supplier or manufacturer of the electrofusion fittings for the installation instructions, as the method may be specific to the fitting geometry.**

Accurate record keeping and manual or automatic electrofusion equipment that provides good control of jointing conditions are essential.

1. EF fittings can be used with non-pressure drainage pipes made to AS/NZS 4401 and AS/NZS 5065.

## SDR Pipe to Fitting Fusion Compatibility

The following table provides recommendations of the fusion compatibility of PE pipe to PE electrofusion fittings (see Table 11).

**Table 11: SDR 11 Electrofusion Fittings**

| Pipe DN | Electrofusion Fittings SDR11 |         | Branch Fittings SDR11 |         | Electrofusion Saddles SDR11 |         |
|---------|------------------------------|---------|-----------------------|---------|-----------------------------|---------|
|         | PE Pipe SDR Rating           |         |                       |         |                             |         |
|         | 11                           | 17/17.6 | 11                    | 17/17.6 | 11                          | 17/17.6 |
| 16      | +                            | -       | -                     | -       | -                           | -       |
| 20      | +                            | -       | -                     | -       | -                           | -       |
| 25      | +                            | -       | -                     | -       | -                           | -       |
| 32      | +                            | -       | -                     | -       | -                           | -       |
| 40      | +                            | -       | -                     | -       | +                           | -       |
| 50      | +                            | -       | -                     | -       | +                           | -       |
| 63      | +                            | -       | -                     | -       | +                           | -       |
| 75      | +                            | -       | -                     | -       | +                           | -       |
| 90      | +                            | +       | +                     | +       | +                           | +       |
| 110     | +                            | +       | +                     | +       | +                           | +       |
| 125     | +                            | +       | +                     | +       | +                           | +       |
| 140     | +                            | +       | +                     | +       | +                           | +       |
| 160     | +                            | +       | +                     | +       | +                           | +       |
| 180     | +                            | +       | +                     | +       | +                           | +       |
| 200     | +                            | +       | +                     | +       | +                           | +       |
| 225     | +                            | +       | +                     | +       | +                           | +       |
| 250     | +                            | +       | +                     | +       | +                           | +       |
| 280     | +                            | +       | +                     | +       | +                           | +       |
| 315     | +                            | +       | +                     | +       | +                           | +       |
| 355     | +                            | +       | +                     | +       | +                           | +       |
| 400     | +                            | +       | +                     | +       | +                           | +       |
| 450     | +                            | +       | +                     | +       | +                           | +       |
| 500     | +                            | +       | +                     | +       | +                           | +       |
| 560     | +                            | +       | +                     | +       | +                           | +       |
| 630     | +                            | +       | +                     | +       | +                           | +       |

where: + corresponds to suitable and – corresponds to unsuitable

**Consultation with the fitting supplier or manufacturer is advised for confirmation of fusion compatibility.**

## 7 PIPE AND TUBING EXTRUSION

### Electrofusion socket jointing

Electrofusion socket jointing incorporates an electrical resistance element in the socket of the fitting which, when connected to an appropriate power supply, melts and fuses the materials of the pipe and fitting together.

The effectiveness of this technique depends on attention to preparation of the jointing surfaces, in particular the removal of the oxidised surface of the pipe over the socket depth, ensuring the jointing surfaces are clean and free

from contamination, and that the assembly and clamping instructions are correctly followed.

The pipe is prepared for jointing by removing a layer, maximum of 0.2 mm for pipes up to DN25, 0.2 mm to 0.3 mm for pipes up to DN75 and 0.2 mm to 0.4 mm for pipes larger than DN75. The minimum allowable outside diameter of the prepared pipe is shown below (see Table 12).

**Table 12: DN of Pipe Versus Minimum Outside Diameter of Prepared Pipe**

| DN of Pipe | Minimum outside diameter (OD) of prepared pipe (mm) | DN of Pipe | Minimum outside diameter (OD) of prepared pipe (mm) |
|------------|---|------------|---|
| 16         | 15.6  | 200        | 199.2   |
| 20         | 19.6  | 225        | 224.2   |
| 25         | 24.6  | 250        | 249.2   |
| 32         | 31.4  | 280        | 279.2   |
| 40         | 39.4  | 315        | 314.2   |
| 50         | 49.4  | 355        | 354.2   |
| 63         | 62.4  | 400        | 399.2   |
| 75         | 74.4  | 450        | 449.2   |
| 90         | 89.2  | 500        | 499.2   |
| 110        | 109.2   | 560        | 559.2   |
| 125        | 124.2   | 630        | 629.2   |
| 140        | 139.2   | 710        | 709.2   |
| 160        | 159.2   | 800        | 799.2   |
| 180        | 179.2   |            |   |

If entry of the pipe or fitting spigot into an electrofusion coupling is still restricted after the oxidised layer has been removed, the pipe can be scraped down to the permissible minimum outside pipe diameter as in the above table. In this case, the thickness removed may be greater than the thickness stated above.

Pipe should also be checked for out-of-roundness (ovality). Some coiled pipes may be too oval to fit into electrofusion sockets and must be re-rounded with rounding tools or clamps to enable sockets to be fitted.

The equipment and procedures described below relate to fittings with centre stops. If fittings without centre stops are used, the maximum insertion depth should be clearly marked on the pipe ends after the pipe surface has been prepared and cleaned prior to jointing.

### Equipment

#### 1. Control Box

The control box input supply should be from a nominal 240V generator suitable to drive inductive loads and phase cut systems, commonly of about 5kVA capacity. Some fitting suppliers may consider smaller capacity generators acceptable for small diameter fittings. The nominal output of the generator should be 240V  $\pm$  10%, between no load and full load.

It should be noted that electrofusion control boxes may generate considerable heat. Refer to the supplier of the controller to ensure the box has an integrated cooling system.

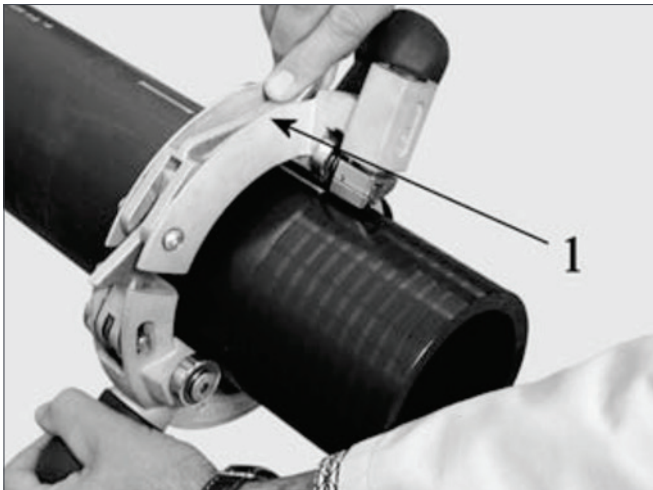


Control boxes should include safety devices to prevent voltages greater than 42V AC for a 40V system being present at the control box output. The safety device should operate in less than 0.5 sec.

### 2. Peeling Tools

Rotational peeling tools must be capable of removing a continuous and uniform chip thickness from the outer oxidised surface, over the required insertion depth, when preparing the fusion zone.

Hand scrapers are difficult to use, and effective preparation is time consuming, physically demanding and in most cases does not produce uniform scraping. Therefore rotational scrapers or peeling tools are preferred when welding occurs at pipe ends (see Figure 34).



**Figure 34:** Rotational Peeling Tool Used to Prepare Pipe Ends

### 3. Re-rounding and Alignment Clamps

Re-rounding and alignment clamps or other approved methods have to be used for restraining, aligning and re-rounding pipes during the fusion cycle (see Figure 35a and b).

The benefits of alignment clamps are that they:

- Allow for re-rounding of pipes, particularly coiled pipes that are oval
- Provide correct assembly and alignment of the pipe with the fitting
- Enable the joint to be stabilised during the welding heating and cooling cycle
- Are stress free joints
- Have uniform melt pressure within the joint



**Figure 35a:** Re-rounding and Alignment Clamp Assembly used for Wide Bore Pipe



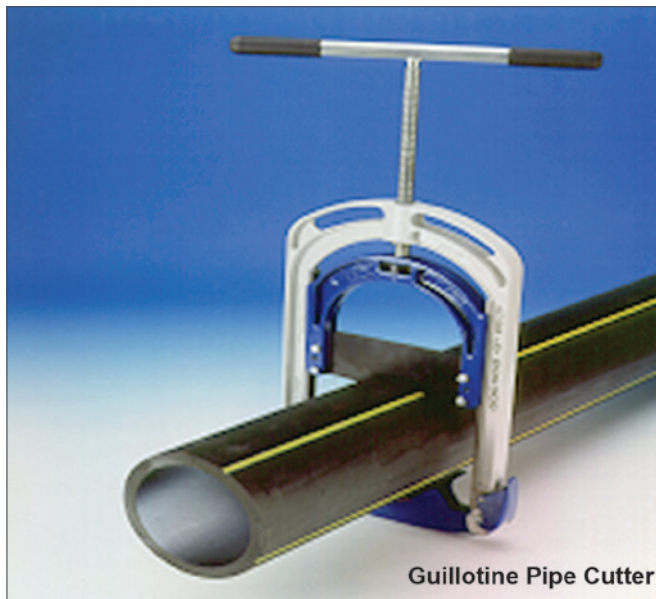
**Figure 35b:** In-field Laying of Multi-Jointed Pipe



## 7 PIPE AND TUBING EXTRUSION

### 4. Pipe Cutters

Pipe cutters are mounted instruments that are used for the accurate cutting of pipes to ensure uniform and perpendicular pipe end. Such cutting devices should include the saw and saw guide (see Figures 36a and b).



**Figure 36a:** Examples of a Guillotine



**Figure 36b:** Motorised Hand Circular Saw Cutter

### 5. Weather Shelter

Suitable shelter should be used to provide shade and protection for the pipe, fittings and equipment against adverse weather conditions and contamination of the jointing surfaces by dust and/or moisture, which can result in unsatisfactory joints. Fittings should only be removed from their original packaging immediately before using for jointing.

### Electrofusion Jointing Method

#### Preparation of Pipe Ends

- i. Ensure hands and tools are free from surface contaminants, such as barrier hand cream, sun screen, detergent and surfactant used in horizontal directional drilling.
- ii. Check equipment is complete, clean, undamaged, in working order and protected by shelter.
- iii. Ensure there is sufficient space to permit access to the jointing area. In a trench, a minimum clearance of 150 mm is required all round. Larger clearances may be needed for large nominal pipe sizes, depending on the tool used.
- iv. Check that the pipe ends to be jointed are cut square to the axis and any burrs and swarf are removed.
- v. Clean the fitting bore, followed by the pipe surface with a new approved alcohol wipe to remove traces of dirt, mud and other contamination. When using slip couplings clean the entire area where the fitting will pass over the pipe. The area of the pipe to be fusion jointed may be washed with clean water if necessary and dried with lint free material prior to peeling. Ensure the fusion area is completely dry before proceeding (see Figure 37). Do not use detergent or surfactants to clean pipe surfaces.

*NOTE: Refer to fitting supplier for recommended alcohol wipes. Personal cleaning wipes may contain lanolin and detergent and are not to be used in electrofusion.*

- vi. Check ovality as described above and use re-rounding tools as appropriate.

With the fittings still in the bag, place alongside the pipe end and put a witness mark on the pipe at half the fitting length plus about 40 mm to enable visual checking of the scraped area after jointing is complete.

*NOTE: Do not remove the fitting from its packaging at this stage.*

- vii. Check that the pipe clamps are of the correct size for the pipes to be jointed. Only use the correct size pipe clamps.

- viii. Check the peeling tools are clean of dirt or other contaminants prior to use.

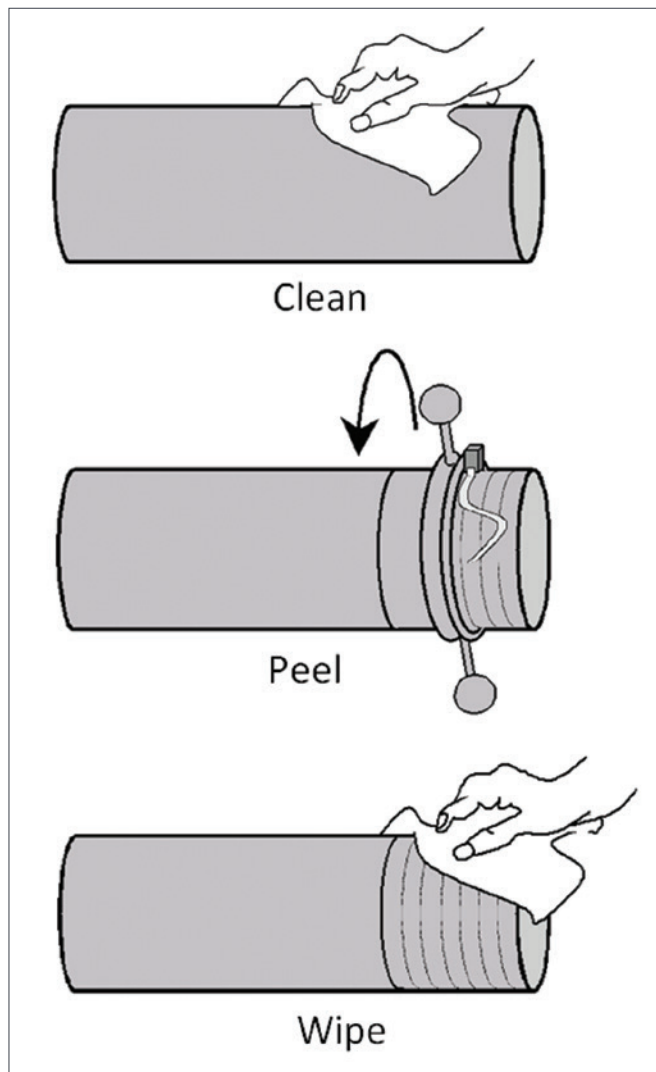
- x. Using an appropriate peeling tool, remove the entire surface of the pipe to the depth of the witness mark. Metal files, rasps, emery paper, etc. are not suitable end preparation tools and should not be used.

- xi. Mechanical peeling tools are strongly preferred, as they achieve a consistent pipe surface preparation. Hand scraping, particularly for larger diameter pipes, is time consuming and onerous to adequately prepare a complete pipe end.

xii. It is important in Australia that pipe and fittings are stored in the shade. If left in the sun, pipe and fittings become very hot which may affect weld conditions, particularly with thin pipe. When jointing in high ambient temperature, it is important that the pipe jointing area is shaded by an appropriate shelter. Some fittings do not require adjustment to the heat cycle time for ambient temperatures in the range  $-10^{\circ}\text{C}$  to  $+45^{\circ}\text{C}$ , whereas others require heat cycle time variation to compensate for ambient temperature within this range.

**ENSURE THE PREPARED SURFACES ARE COMPLETELY DRY BEFORE PROCEEDING**

**DO NOT TOUCH THE PREPARED PIPE SURFACE**



**Figure 37:** Illustration of Pipe End Preparation Prior to Welding

### Jointing Procedure

- i. Wipe the prepared pipe surface only with a recommended alcohol wipe to remove any dust residue and other contaminants. For larger diameter pipes use a multiple number of alcohol wipes.

*NOTE: Cleaning of the prepared surface is a critical step and one that has the potential to introduce contaminants if not done correctly – remember this is the surface that is about to be welded and the presence of contaminants can readily result in a poorly welded joint. To avoid contamination, ONLY wipe the peeled fusion zone area.*

**Do not under any circumstances use methylated spirits, acetone, methyl ethyl ketone (MEK) or other solvents to clean the fusion area. Rags are not recommended for use with any alcohol solvent to clean the fusion area given the possibility of dirt, detergent or fabric conditioner being transferred into the fusion zone.**

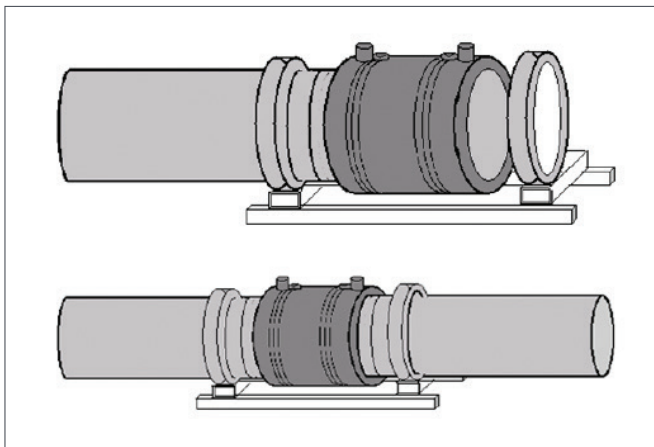
Other important factors relating to this procedure:

- Ensure wipes are saturated with alcohol i.e. have not dried out.
  - To avoid contamination ONLY wipe the peeled fusion zone area.
  - Only use the wipe once.
  - Do not touch the prepared pipe surface – sweat, sunscreen, barrier cream, dirt and skin oils are all potential sources of contamination. Disposable latex or nitrile gloves are recommended when handling the wipes for preparation of the surface.
  - Ensure alcohol left by the wipe on the cleaned surface has evaporated and the prepared surfaces are completely dry before assembling the joint.
  - Refer to the electrofusion fitting supplier for the correct selection of alcohol wipes.
- ii. Remove the fitting from its packaging and check that the bore of the fitting is clean. The bore of the fitting may be wiped with an approved isopropyl wipe if necessary.
 

*NOTE: Ensure the cleaned bore is completely dry before proceeding.*
  - iii. It is good practice to install the fitting to both pipe ends at the same time. However if this is not possible, open only one end of the fitting package and install the fitting to the pipe end. The package can then be fixed in place to enclose the exposed end of the fitting to keep the fitting bore free from contamination.

## 7 PIPE AND TUBING EXTRUSION

- iv. Inscribe an accurate witness mark or insertion depth onto the pipe and then insert the pipe ends into the fitting so that they are in contact with the centre stop and witness mark. It is critical that the pipe be fully inserted, particularly for larger pipes or when there is no centre stop. Ensure an aligned pipe arrangement in order to avoid any stress during the jointing process, especially when using coiled pipes.
- v. The pipe end(s) and the fitting must be correctly aligned and free of any bending stress. Use pipe clamps, or other suitable means, to secure the pipe(s) so they cannot move and ensure that the fitting is satisfactorily supported to prevent it sagging during the fusion procedure (see Figure 38).

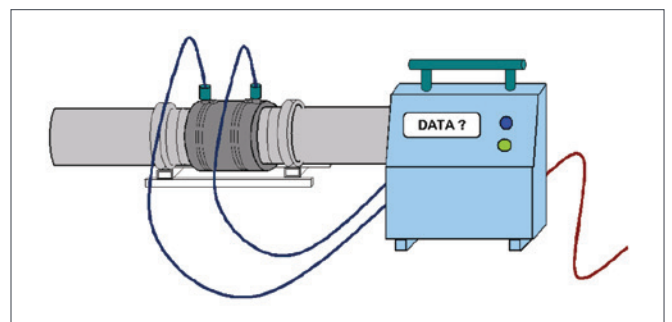


**Figure 38:** Illustration of Pipe Clamps and Fitting Attached to Pipe Ends Prior to Welding

- vi. Check that there is sufficient fuel for the generator to complete the joint. Start the generator and check that it is functioning correctly.  
*NOTE: Ensure the generator is switched on and running satisfactorily before connecting the electrofusion control box to the power source.*
- vii. Switch on the control box. Check that the reset button, if fitted, is in the correct mode.
- viii. Connect the control box output leads to the fitting terminals and check that they have been fully inserted (see Figure 39).
- ix. The jointing time is generally indicated either on the fitting or on a data carrier supplied with the fitting. Check that the correct time is shown on the control box display. If required for the control box, enter the fusion jointing time into the control box timer.

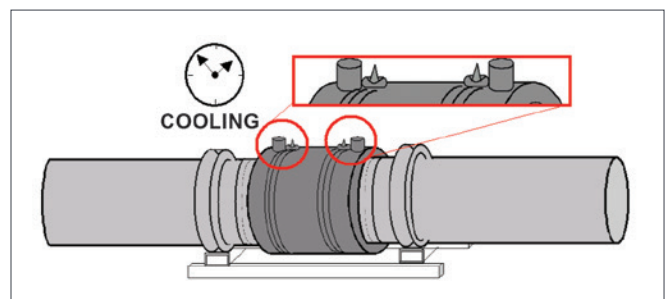
*NOTE: Automatic control boxes are available which obviate the need to enter the fusion time.*

- x. If the control box is equipped with a barcode reader or barcode scanner, scan the fusion data barcode into the machine to ensure a fully automated and controlled data entry. Barcode reading control boxes automatically adjust for variable temperature conditions. For manual input of the heat fusion time into the control box, refer to the manufacturer's parameters, supplied with the fitting.



**Figure 39:** Attachment of Control Box Leads to Pipe Fitting

- xi. Press the start button on the control box and check that the heating cycle is proceeding as indicated by the display.
- xii. On completion of the heating cycle, both melt indicators within the processed part of the fitting should have risen. If there is no apparent movement of either indicator the joint could be unsatisfactory (see Figure 40) – refer to discussion on electrofusion indicator pins below.



**Figure 40:** Diagram illustrating Locating of Melt indicators

- xiii. If the fusion cycle terminates before completion of the countdown, check for faults as indicated by the control box warning lights or display. Check for a possible cause of the break, e.g. inadequate fuel in the generator, or power supply failure, etc.

NOTE: *Do not attempt a second fusion cycle until the entire fitting has cooled to less than 45°C. Some manufacturers recommend replacement of the fitting rather than a second fusion cycle. Refer to the fitting manufacturer for details.*

- xiv. The completed joint should be left in the clamps for cooling. The time needed will be specified on the fitting, or by its data carrier, or in the display of the automatic control box.
- xiv. When the joint has cooled, remove it from the clamps and inspect.

## Electrofusion Indicator Pins

The fusion indicator protrusion following the completion of the fusion process indicates that fusion pressure has developed but does not guarantee the quality of the joint. The height of the extended pin is dependent upon the fitting in use, component tolerances and the pipe material.

The pins are used as a pointer to whether a more detailed inspection of the joint is required so in the event that the pin does not rise, the supervisor or operator must investigate the following to determine if the joint is satisfactory.

- Dimensional check and compliance of the pipe spigot OD and ovality.
- The fitting socket internal diameter by measurement or batch traceability.
- In the case where the pipe and socket are concentric, the maximum gap between the two should not exceed 1% of the nominal diameter. If the socket and spigot are eccentric the gap should not exceed 2%.
- That there is no disruption to the input power supply from the fusion box with no control box error messages.
- That the heat fusion parameters are correct.
- The pipe to fitting alignment is correct with no visible plastic extruded out from the fitting.

## Maintenance, Servicing and Calibration

All equipment should be well maintained and kept in a clean condition at all times.

The equipment should be serviced and calibrated regularly. The frequency at which this is carried out will be different for individual items of equipment and will also depend on usage, but should be at least once every 12 months. Guidance should be sought from the equipment manufacturer and a scheme of calibration and servicing should be implemented. Particular attention should be given to the control box, the generator and the scraping (or peeling) tools. The sharpness of the cutter head of the tools should be checked at least on a monthly base.

## Records

### 1. Job Supervision

Electronic or written records of appropriate fusion procedure for each joint should be kept as required.

### 2. Equipment Servicing and Calibration

Electronic or written records of appropriate servicing and calibration should be kept. The minimum information to be recorded is given in Appendix 1.

### 3. Training

Instructions should be provided by Registered Training Organisations (RTO's) that are accredited by State/Territory Training Authorities under the Australian National Training Authority (ANTA) guidelines and complying with PMB 01–Competency Standards prepared by Manufacturing Learning Australia, Qualification Framework for the plastics, rubber and cable making industry.

The RTO's providing training in all forms of welding plastics pipeline systems must have staff qualified in presenting courses that meet competency standards covered by sections PMBWELD301A through to PMBWELD311A in PMB 01.

The RTO's normally issue an accreditation certificate to successful candidates completing the training course and maintain a register of accredited welders.



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### Electrofusion Saddle Jointing

Electrofusion saddle jointing incorporates an electrical resistance element in the base of the saddle which, when connected to an appropriate power supply, melts and fuses the materials of the pipe and fitting together (see Figure 41).



**Figure 41:** Polymer Fitting that can be Welded onto a Pipe by Electrofusion Saddle Jointing

The effectiveness of this technique depends on attention to preparation of the jointing surfaces, in particular the removal of the oxidised surface of the pipe over an area equivalent to the saddle base, and the cleaning of the jointing surfaces and freedom from contamination. Although PE is comparatively inert, the outer surface of the pipe will become oxidised when exposed to the atmosphere. This oxidised outer layer will interfere with the bond between the pipe and fitting and must therefore be removed before joint assembly.

Electrofusion tapping saddles are available to fit all commonly used main sizes from DN40 to DN560 with service connection outlet sizes from DN20 to DN63 and branch saddle spigot off-takes from DN32 to DN125.

*NOTE: Some saddle type fittings are limited to SDR11. Refer to the fitting manufacturer for further details.*

Tapping tee saddles are usually supplied complete with the manufacturer's recommended installation procedure. Generally recommended installation parameters are similar to the procedure described here, which refers to fittings supplied with an underpart with bolts for assembling the two parts on the pipe.

The nominal pipe diameter should be within the tolerances specified in AS/NZS 4130. Pipe ovality in excess of 1.5% of the nominal pipe diameter (DN) will require re-rounding tools to allow satisfactory contact between tapping saddle and pipe. Some full circle tapping saddles may effectively re-round pipe when correctly fitted but a constant and reliable joint quality can always be achieved by using re-rounding tools. If in doubt, refer to the fitting supplier.

### Equipment

- i. The control box input supply should be from a nominal 240V generator suitable to drive inductive loads and phase cut systems, commonly of about 5kVA capacity. Some fitting suppliers may consider smaller capacity generators acceptable for small diameter fittings. The nominal output of the generator should be 240V +15%, -15% between no load and full load. It should be noted that electrofusion control boxes may generate considerable heat. Refer to the supplier of the controller for details. Control boxes should include safety devices to prevent voltages greater than 42V AC for a 40V system being present at the control box output. The safety device should operate in less than 0.5 sec.
- ii. Pipe surface preparation tool (scraper or peeler) has to be capable of removing the oxidised surface of the pipe over the full area of the saddle base. The tool should remove a surface layer of between 0.2 mm and 0.4 mm. Hand scrapers can be difficult to use in trench conditions, and effective preparation by hand may be time consuming and physically demanding. Therefore rotational scrapers or peeling tools are preferred.
- iii. Re-rounding clamps or other approved methods of re-rounding pipes should be used, particularly if pipe out of roundness exceeds 1.5%.

- iv. A pipe clamp of suitable dimensions for making the service or branch connection is needed.
- v. Pipe cutters should include a saw and saw guide.
- vi. Suitable shelter should be used to provide adequate protection for pipe, fittings and equipment against adverse weather conditions and contamination of the jointing surfaces by dust and/or moisture, which can result in unsatisfactory joints. Fittings should only be removed from their original packaging immediately before using for jointing.

### Preparation

- i. Ensure hands and tools are free from surface contaminants, such as barrier hand cream, sun screen, detergent and surfactant used in horizontal directional drilling.
- ii. Expose the pipe onto which the tapping tee or saddle is to be assembled, ensuring there is clear space around the pipe. In a trench a minimum clearance of 150 mm is required all round. Larger clearances may be needed for larger nominal sizes, depending on the tool used.
- iii. Wipe the joint area, where the saddle is to be fitted, with alcohol wipes to remove traces of dirt, mud and other contamination. The joint area may be washed with clean water if necessary and dried with lint free material prior to scraping. Ensure the joint surface is completely dry before proceeding. Do not use detergent or surfactants to clean pipe surfaces.  
*NOTE: Refer to fitting supplier for recommended alcohol wipes. Personal cleaning wipes may contain lanolin and detergent and are not suitable for use in electrofusion.*
- iv. Without removing the fitting from its packaging, place it over the required position on the pipe. Mark the pipe surface outlining the saddle base area plus about 20 mm with a suitable marker pen to allow for visual checking of the scraped area after jointing is complete.
- v. Check ovality as described above and use re-rounding tools as appropriate.
- vi. Using an appropriate preparation tool remove the entire surface of the pipe over the full area marked. If hand scraping, ensure long even scrapes starting outside the marked area to ensure craters do not occur in the fusion zone, which can produce an excessive gap leading to a brittle weld. Remove the swarf. Metal files, rasps, emery paper, etc. are not suitable scraping tools and should not be used.

- vii. It is important in Australia that pipe and fittings are stored in the shade. If left in the sun the pipe and fittings become very hot which may affect weld conditions, particularly with thin pipe. When jointing in high ambient temperature, it is important that the pipe jointing area is shaded by an appropriate shelter. Some fittings do not require adjustment to the heat cycle time for ambient temperatures in the range -10°C to +45°C, whereas others require heat cycle time variations to compensate for ambient temperature variation within this range.

### Jointing Procedure

- i. Wipe the prepared surface only with the manufacturer's approved alcohol wipe to remove any dust residue and other contaminants. For larger diameter pipes a multiple number of alcohol wipes shall be used.

*NOTE: Cleaning of the prepared surface is a critical step and one that has the potential to introduce contaminants if not done correctly – remember this is the surface that is about to be welded and the presence of contaminants can readily result in a poorly welded joint (see Figure 42).*

**Do not under any circumstances use methylated spirits, acetone, methyl ethyl ketone (MEK) or other solvents. Do not use rags or other cloth soaked in these materials to wipe the prepared fusion surface as they have the potential to contaminate the surface with dirt, grease and fabric conditioner. These are not suitable options for wiping the prepared surface.**

Other important factors relating to this procedure:

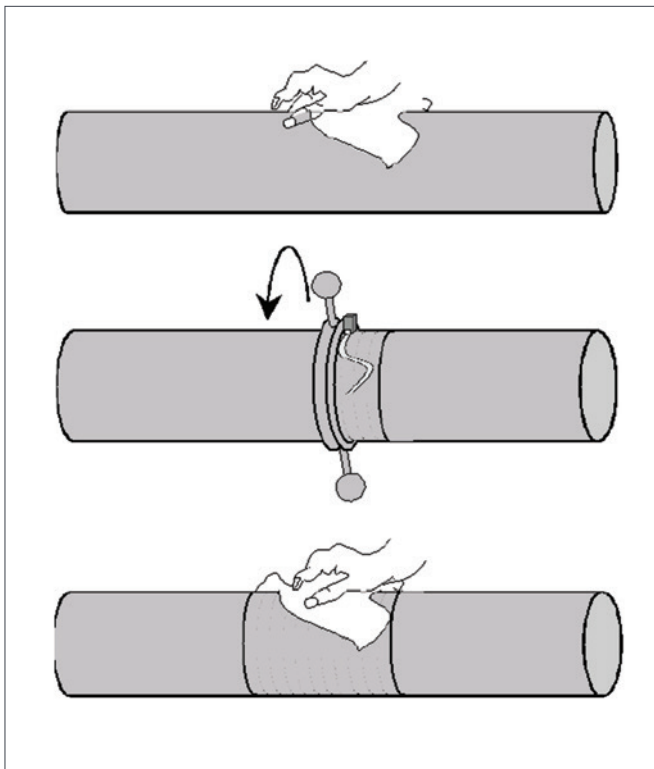
- Ensure wipes are saturated with alcohol i.e. have not dried out.
- When using the wipe work from the prepared (peeled) surface towards the unprepared area and discard the wipe after it has come in contact with any unprepared areas. Wiping from unprepared areas towards the prepared surface can contaminate the fusion surface and similarly using a wipe which has been used on an unprepared can also introduce contaminants.
- Only use the wipe once.
- Do not wipe over the witness mark.
- Do not touch the prepared pipe surface – sweat, sunscreen, barrier cream, soap, detergent, dirt and skin oils are all potential sources of contamination. Disposable latex or nitrile gloves are recommended when handling the wipes for preparation of the surface.

## 7 PIPE AND TUBING EXTRUSION

- Ensure alcohol left by the wipe on the cleaned surface has evaporated and the prepared surfaces are completely dry before assembling the joint.
- Refer to the electrofusion fitting supplier for the correct selection of alcohol wipes.

**ENSURE THE PREPARED SURFACES ARE COMPLETELY DRY BEFORE PROCEEDING**

**DO NOT TOUCH THE PREPARED PIPE SURFACE**

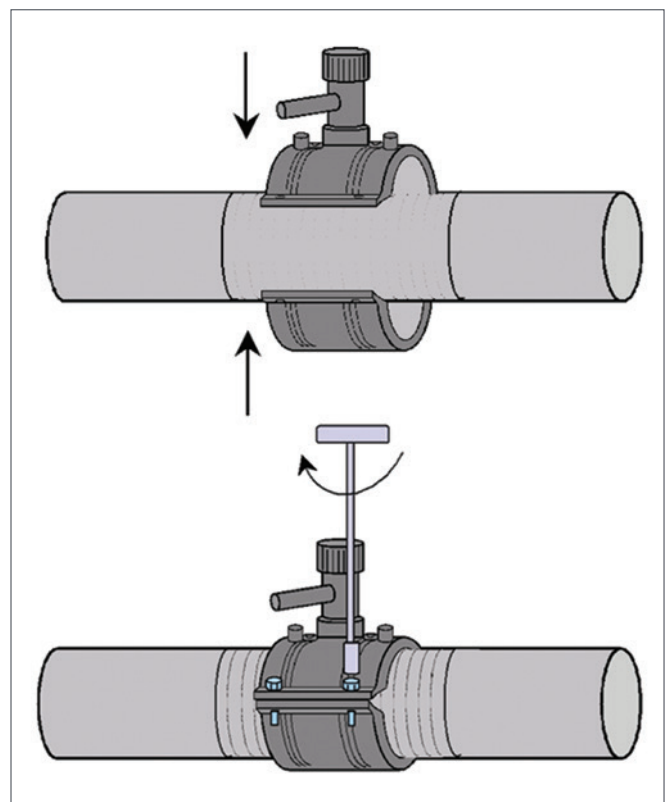


**Figure 42:** Illustration of Pipe Preparation Required Prior to Welding of Pipe Fitting

Remove the fitting from its packaging and check that the jointing surface of the saddle fitting is clean. The bore of the fitting may be wiped with a recommended alcohol wipe if necessary.

**NOTE:** *Ensure that the bore is completely dry before proceeding.*

- ii. Position the fitting base onto the prepared pipe surface. Bring the lower saddle into position. Then gradually and equally tighten the bolts and nuts until the upper saddle makes firm contact with the prepared surface of the pipe (see Figure 43). Carefully inspect the fitting to ensure a firm contact with the pipe is achieved over the entire upper saddle contact area. Install re-rounding tools if pipe out of roundness exceeds 1.5% or if a firm contact is not achieved over the entire upper saddle contact area.



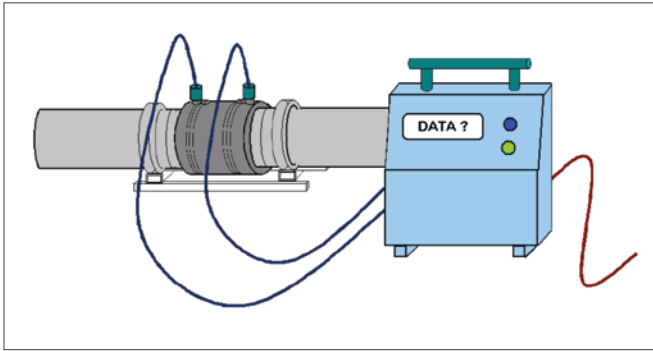
**Figure 43:** Installation of Saddle Fitting onto Pipe Prior to Welding

- iii. Check that there is sufficient fuel for the generator to complete the joint. Start the generator and check that it is functioning correctly.

**NOTE:** *Ensure the generator is switched on and running satisfactorily before connecting the electrofusion control box to the power source.*

- iv. Switch on the control box. Check that the reset button, if fitted, is in the correct mode.
- v. Connect the control box output leads to the fitting terminals and check that they have been fully inserted (see Figure 44).



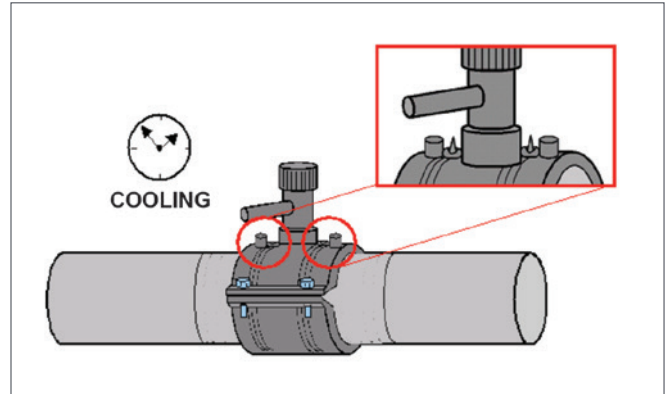


**Figure 44:** Attachment of Control Box Leads to Pipe Fitting

- vi. The jointing time is indicated either on the fitting label or on a data carrier supplied with the fitting. Check that the correct time is shown on the control box display. If required enter the fusion jointing time into the control box timer.

NOTE: Automatic control boxes are available which obviate the need to enter fusion time.

- vii. If the control box is equipped with a barcode reader or barcode scanner, scan the fusion data barcode into the machine to ensure a fully automated and controlled data entry. Barcode reading control boxes automatically adjust for variable temperature conditions. For manual input of the heat fusion time into the control box, refer to the manufacturer's or supplier's parameters, which should be supplied with the fitting.
- viii. Press the start button on the control box and check that the heating cycle is proceeding as indicated by the display.
- ix. On completion of the heating cycle, the melt indicator on the fitting should have risen (see Figure 45). If there is no apparent movement the joint could be unsatisfactory – refer to the manufacturer's instructions for further information.



**Figure 45:** Diagram illustrating Locating of Melt indicators on Fitting

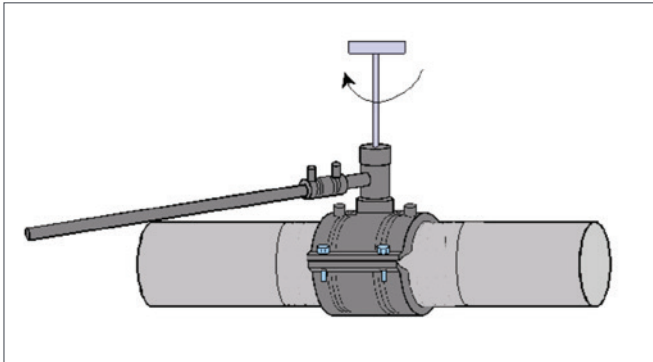
**Refer to the fitting supplier or manufacturer for details on branch outlets and specific installation instructions.**

- x. If the fusion cycle terminates before completion of the countdown, check for faults as indicated by the control box warning lights or display. Check for a possible cause of the break, e.g. inadequate fuel in the generator, or power supply failure, etc.

NOTE: *DO NOT attempt a second fusion cycle until the entire saddle fitting has cooled to less than 45°C. Some manufacturers recommend replacement of the fitting rather than a second fusion cycle. Refer to manufacturer for details.*

- xi. The completed joint should be left in the clamps for cooling. The time needed will be specified on the fitting label, or by its data carrier, or in the display of the automatic control box.
- xii. The connection of the service pipe to the spigot outlet should be carried out in accordance with the procedure of the appropriate section of these guidelines (see Figure 46).

## 7 PIPE AND TUBING EXTRUSION



**Figure 46:** Illustration of Tapping Process used to Connect Spigot Outlet to Main Service Pipe

- xiii. DO NOT attempt to tap the main with the integral cutter before the completion of the required cooling cycle as specified by the supplier.

Additional cooling time is recommended before tapping if the pipeline is to be field pressure tested as soon as practical:

- DN40 saddle minimum 10 minutes for field test pressure  $\leq 6$  bar and minimum 30 minutes for field test pressure  $> 6$  bar  $\leq 24$  bar
- DN63 - DN560 saddle minimum 20 minutes for field test pressure  $\leq 6$  bar and minimum 60 minutes for field test pressure  $> 6$  bar  $\leq 24$  bar

### Top load Electrofusion Branch Saddle Jointing

Top load electrofusion branch saddles are typically used for large diameter branch connections  $\rightarrow 90$  mm.

Applications include: new installations, renovation, repair and under pressure live branch connections on existing PE mains for sizes to DN630 mm.

Typical installation instructions are detailed below:

- Ensure hands and tools are free from surface contaminants, such as barrier hand cream, sun screen, detergent and surfactant used in horizontal directional drilling.
- Clean pipe in the fusion area with an approved alcohol wipe as detailed above in the Jointing Procedure, then remove the oxidised layer with a rotary peeler (see Figure 47).



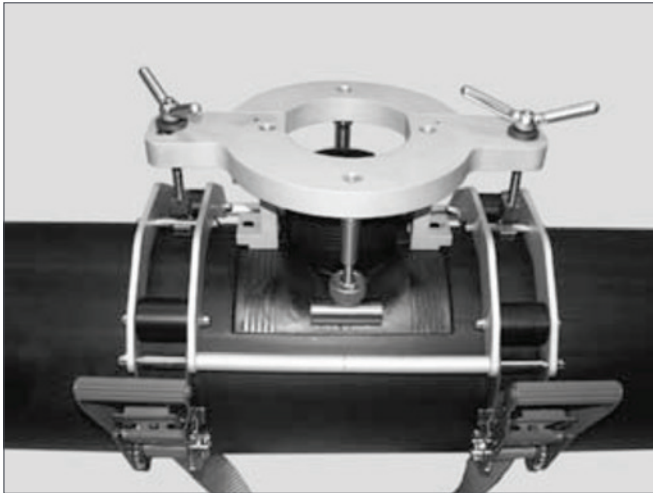
**Figure 47:** Installation of Detachable Rotary Peeler to Service Pipe

- Clean pipe in the fusion zone with an approved alcohol wipe (see Figure 48).



**Figure 48:** Illustration of Prescribed Cleaning of Pipe Fusion Zone

- Mount the fitting to the pipe using a top-load tool and tightening clamp device to ensure a positive contact is made between the pipe and saddle. The joint gap should not exceed 0.5 mm (see Figure 49).



**Figure 49:** Illustration of Top-load Tool Attached to Both the Saddle and Pipe

- v. Connect the terminals and apply the fusion voltage following the method outlined above in Jointing Procedure.
- vi. The completed joint should be left in the clamps for cooling. The time needed will be specified on the fitting label, or by its data carrier, or in the display of the automatic control box.

### Maintenance, servicing and calibration

All equipment should be well maintained and kept in a clean condition at all times.

The equipment should be serviced and calibrated regularly. The frequency at which this is carried out will be different for individual items of equipment and will also depend on usage, but should be at least once every 12 months. Guidance should be sought from the equipment manufacturer and a scheme of calibration and servicing should be implemented. Particular attention should be given to the control box, the generator and the scraping (or peeling) tools. The sharpness of the cutter head of tools should be checked at least on a monthly base.

### Records

#### 1. Job Supervision

Electronic or written records of appropriate fusion procedure for each joint should be kept as required.

#### 2. Equipment Servicing and Calibration

Electronic or written records of appropriate servicing and calibration should be kept. The minimum information to be recorded is given in Appendix 1.

#### 3. Training

Instructions should be provided by Registered Training Organisations (RTO's) that are accredited by State/Territory Training Authorities under the Australian National Training Authority (ANTA) guidelines and complying with PMB 01 - Competency Standards prepared by Manufacturing Learning Australia, Qualification Framework for the plastics, rubber and cable making industry.

The RTO's providing training in all forms of welding plastics pipeline systems must have staff qualified in presenting courses that meet competency standards covered by sections PMBWELD301A through to PMBWELD311A in PMB 01.

The RTO's normally issue an accreditation certificate to successful candidates completing the training course and maintain a register of accredited welders.

### Quality Assurance

To achieve consistently good quality fusion joints as outlined by these guidelines, manufacturers and installers should operate a quality system in accordance with the principles of AS/NZS ISO 9001.

Assessment of the achievement would take the form of an audit against the points below. Independent testing of fusion joints may also be required.

# 7 PIPE AND TUBING EXTRUSION

## Management Responsibility

### 1. Customer Focus

The organisation responsible for the jointing operation should ensure that customer requirements are determined and are met with the aim of enhancing customer satisfaction.

### 2. Planning

The organisation responsible for the jointing operation should ensure that all aspects of the jointing operation are given adequate consideration prior to the commencement of work.

### 3. Responsibility, Authority and Communication

On each site where pipes and fittings are to be jointed in accordance with these guidelines, a person should be nominated to supervise work affecting the jointing quality. The person should:

- Have the responsibility and authority to ensure effective jointing operations
- Ensure that processes needed for jointing operations are established, implemented and maintained
- Be able to communicate the requirements for effective jointing operations

## Control of Documents

Document control should ensure that:

- Documents are approved for adequacy prior to use,
- The relevant versions of applicable documents are available at points of use,
- Documents remain legible and readily identifiable,
- The unintended use of obsolete documents is prevented, and to apply suitable identification to them if they are retained for any purpose.

### 1. Purchasing

The installer should ensure that purchased items including pipe, fittings and fusion jointing equipment conform to specified requirements.

### 2. Fusion Jointing Control

The installer should ensure that fusion jointing procedures as well as servicing and maintenance of fusion jointing equipment are carried out in accordance with the specified guidelines.

### 3. Inspection and Testing

- a. Inspection of goods received and used on site  
The installer should ensure that incoming pipe, fittings and fusion jointing equipment are not used until they have been inspected and confirmed as conforming to specified requirements including appearance and marking. Any non-conforming items should be identified, recorded and segregated.
- b. Final inspection and testing  
At the commencement of each contract, the frequency and type of inspection by the installer should be agreed with the client and documented.
- c. Inspection and test records  
The installer should establish and maintain electronic and/or written records of appropriate fusion jointing procedures, servicing and calibration details in accordance with these guidelines.

### 4. Corrective Action

The installer should establish and maintain procedures to show evidence of:

- Review of non-conformities (including customer complaints) as a result of poor quality joints
- Determining the causes of poor quality joints
- Evaluating the need for action to ensure poor quality joints do not recur
- Determining and implementing action needed
- Recording the results of action taken, and
- Reviewing corrective action taken

### 5. Preservation of Product

The installer should establish and maintain appropriate procedures for handling and storage of pipe, fittings and fusion jointing equipment on site.

*NOTE: Damaged packaging can permit ingress of dirt and moisture, which can adversely affect joint integrity.*

### 6. Control of Records

The installer should establish and maintain procedures for collection, indexing, filing and storage of quality records for a minimum period of 6 years from the date of installation.



### 7. Competence, Awareness and Training

The installer should:

- Determine the necessary competence for personnel performing fusion jointing
- Provide training or take other actions to satisfy these guidelines
- Evaluate the effectiveness of the actions taken
- Ensure that personnel are aware of the relevance and importance of their activities and how they contribute to the achievement of effective fusion jointing, and
- Maintain appropriate records of education, training, skills and experience

## 7 PIPE AND TUBING EXTRUSION

### APPENDIX 1 – RECORD SHEETS

Record sheets should be maintained for all equipment required for all fusion jointing operations. The sheet should be headed:

#### 'SERVICING AND CALIBRATION RECORD SHEET'

Followed by:

#### 'ELECTROFUSION SOCKET EQUIPMENT OR ELECTROFUSION SADDLE EQUIPMENT'

Then the appropriate sub-title from the following list (additional record sheets may be kept if required):

- Electrofusion socket jointing:
  - Generators
  - Electrofusion control box
  - Electrical safety test
- Electrofusion saddle jointing:
  - Generators
  - Electrofusion control box
  - Electrical safety test

The information recorded on the sheet should include, but not be restricted to:

- The date of servicing or maintenance
- The name, address and telephone number of the undertaking or contractor operating the equipment
- The name, address and telephone number of the company conducting the service or maintenance
- The member (or members) of staff responsible for servicing or maintenance
- The serial number of the equipment
- The details of service and/or maintenance carried out. This should include relevant details of test equipment, procedures and/or manuals used, and relevant ambient conditions.
- The signature(s) of the member (or members) of staff responsible for the servicing or maintenance operations conducted

## APPENDIX 2 – PIPE EXTRUSION TROUBLESHOOTING GUIDE

| Problem/ Issue                               | Cause(s)  | Potential Solution(s)/ Action(s)  |
|--|---|---|
| <b>Die (extrudate) lines.</b>                | Damage to the exit edges of the tip or die.   | Refinish tip or die exit edges to sharp and uniform about the diameters.                                  |
|  | Die drool or build-up on the tip or die faces.                                      | Adjust temperature of the die exit accordingly  |
| <b>Extruder surging</b>                      | Too fast extruder throughput relative to OEM Extruder specifications                | Check OEM guaranteed extruder throughput and run extruder within specifications                           |
|  | Improper extruder temperature settings  | Adjust temperature setting according to OEM recommendations   |
|  | Poor resin- extruder design match versus extruder OEM specifications for throughput | Discuss with resin supplier and implement actions to ensure extruder runs within OEM specifications       |
|  | Extruder not set as per OEM design specifications                                   | Check with OEM and ensure compliance with design specifications   |
| <b>Gels and other contaminations in pipe</b> | Resin contains foreign particles/ contaminated with gels etc                        | Check with resin supplier for presence of gels etc.<br>Check regrind for contaminants                     |
|  | Degraded resin coming off the die during extrusion                                  | Follow proper shut-down procedures for extruder to avoid long exposure of resin to excessive temperatures |
| <b>Localised thick spots in pipe wall</b>    | Improper die setting  | Adjust the die setting  |
|  | Hot and cold spots in die profile temp  | Check for uniformity in die heating   |
|  | Uneven pipe drag downstream of the extruder   | Check for spots in cooling baths which could cause pipe drag  |
|  | Haul-off slippage   | Check and adjust haul-off   |
|  | Uneven melt delivery from die -extruder surging                                     | Check remedies for extruder surging   |
| <b>Pipe out of round</b>                     | Sizing device (calibrator) in adequate or out of shape                              | Check the calibrator for concentricity.   |
|  |   | Ensure it is 3–5% larger than the final pipe diameter   |
|  | Pipe is too warm when it reaches the haul off unit                                  | Ensure sufficient downstream cooling length before pipe gets to the haul off unit<br>Decrease throughput  |
|  | Wrong vacuum setting in vacuum tanks  | Ensure proper vacuum setting in vacuum tanks  |
| <b>Pipe tear</b>                             | Haul-off too fast   | Check and adjust the speed of haul off  |
|  | Pipe too hot at the entrance to calibrator  | Check for water flows on calibrator and adjust to avoid hot spots   |
|  |   | Ensure adequate calibrator size   |
| Pipe dragging in cooling tanks               | Check and eliminate drag spots  |   |
| <b>Pipe sag</b>                              | Melt temperature too high   | Adjust extruder temperature setting and throughput to lower melt temperature                              |
|  | Die gap not adjusted to accommodate sag   | Adjust die gap – wider at the top and narrower at the bottom of the die                                   |
|  | Resin's inherent resistance to sag is not adequate for the pipe wall thickness      | Use low-sag resin   |
|  | No enough cooling capability in line  | Ensure adequate water temperature in cooling baths and enough cooling length                              |

## 7 PIPE AND TUBING EXTRUSION

| Problem/ Issue                         | Cause(s)   | Potential Solution(s)/ Action(s)                                  |
|--|--|---|
| Rough surface inside or outside        | Moisture in resin  | Ensure minimum of 1.5 hrs drying of resin at 70–90°C              |
|  | Not adequate water flows setting to the calibrator                     | Adjust water flows to calibrator                                  |
|  | Melt temperature too low   | Increase die/ and or extruder temperatures                        |
| Thermal degradation of pipe-failed OIT | Too high melt temperature  | Adjust extruder/ and or die temperatures accordingly              |
|  | Excessive extruder screw speed   | Lower extruder throughput   |
|  | Die too small for required throughput                                  | Ensure adequate die size  |
|  | Die pin too hot  | Check operation of pin cooling otherwise decrease throughput      |
|  | Extruder surging   | Check remedies for extruder surging                               |
| Uneven pipe cut                        | The saw blade is flexing   | Get thicker/ larger blades  |
|  | The saw blade is lose  | Check and fix   |
|  | Saw arm is entering pipe too quickly and with insufficient revolutions | Adjust as required  |
|  | The saw arm is lose or bushes worn and is 'floating'                   | Check and fix   |
|  | There is wear/slack in slip rings of the saw planetary components      | Check and fix   |
|  | Uneven speed of haul-off or cutting carriage                           | Check uniformity of the speed of haul-off and cutting carriage    |
|  | Saw is not capable of cutting the pipe                                 | Check with OEM for saw specifications                             |
| Uneven wall thickness                  | Uneven melt delivery from the die -extruder surging                    | Check remedies for extruder surging                               |
|  | Uneven take-off speed  | Check haul-off unit   |
|  | Improper alignment of die and haul-off units                           | Check for alignment   |
|  | Die and pin not centred evenly   | Even die gap  |
|  | Excessive sag of a polymer   | Check remedies for pipe sag                                       |
| Voids in pipe                          | Moisture in resin  | Ensure minimum of 1.5 hrs drying of resin at 70–90°C              |
|  | Trapped air  | Adjust extruder temperature setting and back pressure accordingly |

### Disclaimer

The proposed solutions in this guide are based on conditions that are typically encountered in the manufacture of products from polyethylene. Other variables or constraints may impact the ability of the user to apply these solutions. Genos also refers the user to the disclaimer at the beginning of this document.



**BIBLIOGRAPHY/FURTHER READING**

1. Janson, L. E.; *Plastic Pipes for Water Supply and Sewage Disposal* (4<sup>th</sup> Ed.), Borealis, 2003.
2. Brömstrup, H.; *PE100 Pipe Systems* (2<sup>nd</sup> Ed.), Vulkan-Verlag GmbH, 2004.
3. Hensen, F.; *Plastic extrusion Technology*, Hanser Verlag, 1997.
4. Michaeli, W.; *Extrusion Dies*, Hanser Verlag, 2003.
5. *Technical Manual – Materials for Pipe Extrusion*, Hostalen, Lupolen, -Processing and Applications, Basell Polyolefins.
6. *Reliable Pipelines with Hostalen CRP 100*, Properties, Practical Experience and Standards, Hoechst.
7. *Battenfeld Extrusionstechnik – SMS Group, Pipe Extrusion Plant*.
8. AS/NZS 4131:2010, *Polyethylene (PE) compounds for pressure pipes and fittings*.
9. AS/NZS 4130:2009, *Polyethylene (PE) pipes for pressure applications*.
10. ISO 9080:2003, *Plastic piping and ducting systems – Determination of the long-term hydrostatic strength of thermoplastics materials in form by extrapolation*.
11. ISO 13479:2009, *Polyolefin pipes for the conveyance of fluids – Determination of resistance to crack propagation – Test method for slow crack growth on notched pipes (notch test)*.
12. ISO 13477:2008, *Thermoplastic pipes for the conveyance of fluids – Determination of resistance to rapid crack propagation (RCP) – Small-scale steady-state test (S4 test)*.
13. ISO 4437:2007, *Buried polyethylene (PE) pipes for the supply of gaseous fuels – Metric series – Specifications*.
14. ISO 4427 – 1:2007, *Plastics piping systems – Polyethylene (PE) pipes and fittings for water supply. PMBWELD301B Butt Weld PE Pipelines Resource Manual*, Chisholm Institute, 2010
15. Industry Guidelines, *Butt Fusion Jointing of PE Pipes and Fittings*, PIPA, 2011.
16. Industry Guidelines, *Butt Fusion Jointing of PE Pipes and Fittings for Pressure Applications*, PIPA, 2011.
17. Industry Guidelines, *Temperature Rerating of PE Pipes*, PIPA, 2010.
18. Industry Guidelines, *High Stress Crack Resistant PE100*, PIPA, 2018.



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