Gas Industry Standard

GIS/PL2-9:2019

Specification for

Polyethylene pipes and fittings for natural gas and suitable manufactured gas

Part 9: Flexible Twin-walled Corrugated Pipes for Use at Pressures up to 75 mbar

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Contents

Foreword

Gas Industry Standards (GIS) are revised, when necessary, by the issue of new editions. Users should ensure that they are in possession of the latest edition. Manufacturers and other users external to Gas Transporters should direct their requests for copies of a GIS to the department or group responsible for the initial issue of their contract documentation.

Comments and queries regarding the technical content of this document should be directed in the first instance to the contract department of the Gas Transporter responsible for the initial issue of their contract documentation.

This standard calls for the use of procedures that may be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

Compliance with this engineering document does not confer immunity from prosecution for breach of statutory or other legal obligations.

The requirements contained within PL5 are not necessarily indicative of all the performance requirements, or the suitability of pipework for the service conditions, likely to be encountered in the UK.

Relationship with other publications

GIS/PL2 *Polyethylene pipes and fittings for natural gas and suitable manufactured gas* consists of the following parts:

Part 1: General and polyethylene compounds for use in polyethylene pipes and fittings.

Part 2: Pipes for use at pressures up to 5.5 bar.

Part 3: Butt fusion machines and ancillary equipment.

Part 4: Fusion fittings with integral heating element(s).

Part 5: Electrofusion ancillary tooling.

Part 6: Spigot end fittings for electrofusion and/or butt fusion purposes.

Part 7: Squeeze-off tools and equipment.

Part 8: Pipes for use at pressures up to 7 bar.

Part 9: PE Flexible Twin-walled Corrugated Pipes for Use at Pressures up to 75 mbar

Mandatory and non-mandatory requirements

For the purposes of a GIS the following auxiliary verbs have the meanings indicated:

can indicates a physical possibility;

may indicates an option that is not mandatory;

shall indicates a GIS requirement;

should indicates best practice and is the preferred option. If an alternative method is used then a suitable and sufficient risk assessment needs to be completed to show that the alternative method delivers the same, or better, level of protection.

Disclaimer

This engineering document is provided for use by Gas Transporters and such of their manufacturers as are obliged by the terms of their contracts to comply with this engineering document. Where this engineering document is used by any other party, it is the responsibility of that party to ensure that the engineering document is correctly applied.

Brief history

First published as T/SP/PL2: Part 2 (to include Flexible pipe)	May 2004
Reference to flexible pipes removed from GIS/PL2 Part 2	June 2008
GIS/PL2-9 published	April 2019
Reviewed by TSF	March 2024

1 Scope

This Part 9 of GIS/PL2 specifies the requirements for flexible twin-walled corrugated pipe. For convenience, they will to be referred to as flexible pipes in this standard. The flexible pipes are for use at operating pressures not greater than 75 mbar and operating temperatures in the range from -20°C to 40°C.

They are used for insertion into steel service pipes (Schedule 40 and/or 80), which may contain bends, in order to rehabilitate them. They shall be capable of insertion into steel pipes at ambient temperatures of -5°C to 30°C. Pipes conforming to this specification shall not be installed directly to ground, for example by open cut excavation.

Flexible pipes shall be composed of two layers of PE material that together constitute the ‘pipe wall’. An ‘inner layer’ forms the pipe bore, and an ‘outer layer’ forms the corrugations, and these two layers shall be bonded one to another.

Pipes may be supplied in discrete lengths with a factory formed integral spigot that shall meet the additional requirements of GIS/PL2-9 Annex B.

This part of GIS/PL2-9 is applicable to pipes for carrying gaseous fuels and in particular natural gas having a composition specified in BS EN ISO 13686 or suitable manufactured gases.

GIS/PL2-9-1 of the specification covers twin walled corrugated pipes made of PE80 or PE100 materials. Suppliers may offer alternative configurations or materials which shall be reviewed by a competent authority and if accepted would form the basis of additional parts to this specification.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Formal standards

BS EN 728, *Plastics piping and ducting systems — Polyolefin pipes and fittings — Determination of oxidation induction time*.

BS EN ISO1167 –1 & 2**,** *Plastics piping systems — Thermoplastics pipes — Determination of resistance to internal pressure at constant temperature*.

BS EN ISO 472, *Plastics — Vocabulary*.

BS EN ISO 1043-1, *Plastics — Symbols and abbreviated terms — Part 1: Basic polymers and their special characteristics.*

BS EN ISO 1133, *Plastics — Determination of the melt mass-flow rate (MFR) and the melt volume-flow rate (MVR) of thermoplastics*.

BS EN ISO 1183-2, *Plastics — Methods for determining the density of non-cellular plastics — Part 2: Density gradient column method.*

BS EN ISO 1872-1, *Plastics — Polyethylene (PE) moulding and extrusion materials — Part 1: Designation system and basis for specifications*.

BS EN ISO 6259-1, *Thermoplastics pipes — Determination of tensile properties — Part 1: General test method.*

ISO 6259-3, *Thermoplastics pipes — Determination of tensile properties — Part 3: Polyolefin pipes*.

BS EN ISO 11357-6, *Plastics differential scanning calorimetry (DSC). Determination of oxidation induction time (isothermal OIT) and oxidation induction temperature (dynamic OIT)*

BS EN ISO 13686, *Natural gas – Quality designation*.

BS EN ISO 9080, Plastics piping and ducting systems. Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation.

BS EN ISO 3126, *Plastics piping systems — Plastics piping components — Measurement and determination of dimensions.*

BS EN ISO 17778:2015 Plastics piping systems. Fittings, valves and ancillaries. Determination of gaseous flow rate/pressure drop relationships.

Gas Industry Standards

GIS/PL2-1, *Specification for polyethylene pipes and fittings for natural gas and suitable manufactured gas — Part 1: General and polyethylene compounds for use in polyethylene pipes and fittings.*

GIS/PL2-2, *Specification for polyethylene pipes and fittings for natural gas and suitable manufactured gas — Part 2: Pipes for use at pressures up to 5.5 bar*

3 Terms and definitions, symbols, abbreviations and units

For the purposes of this standard the terms and definitions, symbols, abbreviations and units given in BS EN ISO 472 and BS EN ISO 1043-1 and the following apply.

3.1 Material Definitions

<u>3.1.1 virgin material</u>
material in a form such as granules/pellets that has not been subjected to use or processing other than that required for its manufacture and to which no reprocessable or recyclable materials have been added

<u>3.1.2 compound</u>
homogenous mixture of base polymer (polyethylene) and additives, i.e. antioxidants, pigments, UV-stabilizers and others, at a dosage level necessary for the processing and use of components conforming to the requirements of this standard

3.2 Pipe Type Definitions

<u>3.2.1 flexible twin-walled corrugated pipes</u>
flexible pipes consisting of two layers of PE, with the inner layer forming the bore of the pipe and the outer layer giving an outer corrugated layer. The inner layer may form a bore of non-uniform diameter.

<u>3.2.2 factory formed pipe spigot</u>

A process undertaken by the pipe manufacturer to form an integral spigot end to the flexible pipe that may be used in conjunction with mechanical or electrofusion jointing systems

<u>3.2.3 corrugator</u>
a corrugator consisting of a number of short moulding blocks on a caterpillar track which continuously mould the flexible pipe.

<u>3.2.4 total manufacturing variability (TMV)</u>
to obtain a fully representative test sample of pipe, a TMV pipe has to be long enough to use all the moulding blocks during a complete rotation of the corrugator.

3.3 Geometrical definitions

3.3.1 nominal outside diameter, d_{On}
specified outside diameter at the crown of the corrugations, in millimetres.

3.3.2 outside mean diameter at peak of corrugation, d_{Op}
value of the measurement of the mean diameter through its cross-section at the peak of the outer layer corrugations of the pipe.

3.3.3 outside mean diameter at trough of corrugation, d_{Ot}
value of the measurement of the mean diameter through its cross-section at the tough of the outer layer corrugations.

3.3.4 inside mean diameter at peak of corrugation, d_{Ip}
value for the measurement of the mean diameter through its cross-section at the peak of the inside layer corrugations.

3.3.5 inside mean diameter at trough of corrugation, d_{It}
value for the measurement of the mean diameter through its cross-section at the trough of the inside layer corrugations.

3.3.6 nominal inside diameter, d_{In}
specified inside diameter, in millimetres, assigned to a nominal size DN/OD

3.3.7 ovality
difference between the maximum and the minimum outside diameter in the same cross-section of a pipe or spigot, rounded off to the nearest 0.1 mm.

3.3.8 nominal thickness of the inner layer, e_{In}
numerical designation of the thickness of the inner layer that forms the inner corrugated layer.

3.3.9 nominal thickness of the outer layer, e_{On}
numerical designation of the thickness of the outer layer that forms the outer corrugated layer.

3.3.10 thickness of the outer layer, e_{O}
value for the measurement of the thickness of the outer layer, obtained from four regularly spaced measurements in that cross-section (around the circumference and in the same cross-section).

3.3.11 thickness of the inner layer, e_{I}
value for the measurement of the thickness of the inner layer, obtained from four regularly spaced (around the circumference and in the same cross-section) measurements in that cross-section

NOTE (Clauses 3.3.8 to 3.3.11) for these flexible corrugated pipes the measurement of the layer thicknesses shall be away from any joint or weld of the inner layer to the outer layer

3.3.12 tolerance
permitted variation of the specified value of a quantity, expressed as the difference between the permitted maximum and the permitted minimum value

3.4 Pipe Quality Assessment and Pipe Strength Definitions

3.4.1 coiled pipe
pipe extruded in a multi-layer coiled configuration with the layers strapped together to provide a stable and self-supporting unit

3.4.2 pipe batch
number of pipes, all of them of the same geometry, nominal outside diameter and layer thickness, extruded from the same compound on the same machine. A batch of pipe should not exceed 7 days continuous production.

NOTE: An extrusion equipment breakdown lasting >14hrs constitutes a new pipe batch.

3.4.3 type testing (TT)
testing performed to prove that the material, component, assembly is capable of conforming to the requirements given in the relevant standard

3.4.4 batch release test (BRT)
testing performed by the manufacturer on a batch of material or components, which has to be satisfactorily completed before the batch can be released.

3.4.5 lower predicted limit (LPL) of pressure strength, P_{LPL}
quantity, with the dimensions of pressure in bar gauge, which can be considered as a property of the flexible pipe, and represents the 97.5 % lower predicted limit of the mean long term pressure strength (see **clause 8.6.1**) at 20 °C for 50 years with internal water pressure,

3.5 Service conditions

3.5.1 gaseous fuel
any fuel which is in gaseous state at a temperature of 15 °C, at atmospheric pressure

3.5.2 maximum operating pressure (MOP)
maximum effective pressure of the fluid in the piping system, expressed in mbar, which is allowed in continuous use. It takes into account the physical and the mechanical characteristics of the components of a piping system.

3.5.3 reference temperature
temperature for which the piping system is designed

NOTE It is used as the base for further calculation when designing a piping system or parts of a piping system for operating temperatures different from the reference temperature.

3.6 Abbreviations

MFR melt mass-flow rate
OIT oxidation induction time
MRS minimum required strength
TMV total manufacturing variability

4 Materials

4.1 Materials for Pipe Manufacture

Flexible twin-walled corrugated pipes can be manufactured from compounded PE80, compounded PE100 materials or both. Such materials shall be suitable for carrying gaseous fuels and in particular natural gas having a composition specified in BS EN ISO 13686 or suitable manufactured gases.

PE80 or PE100 materials for the manufacture of flexible pipes shall have undergone tests as solid wall pipes following the requirements and procedures in BS EN ISO 9080, and shall conform to the requirements of GIS/PL2-1.

4.2 Colour

Pipes manufactured from PE80 compounds may be coloured yellow (see GIS/PL2-1). As permitted in GIS/PL2-1, black PE80 or black PE100 materials may be used to manufacture flexible pipes for either the internal or external layer or both. There is no requirement for a yellow axial stripe on externally black pipes (see also **11 Marking**).

4.3 PE Material Property Requirements

Compounds received from the PE compound manufacturers shall be tested in accordance with PL2-2, which is reproduced in **Table 1**.

4.4 Rework Materials

Reworked materials are not permitted. The pipes shall be made from virgin compound only.

Table 1 — PE Compound Properties

Properties	Sampling frequency [a)]	Requirements	Test method
Compound density	Per Compound Batch	Compound density shall be declared by the manufacturer. Max deviation ±3 kg/m^3 of nominated value of compound.	(BS EN ISO 1872-1). Method BS EN ISO 1183-1, -2 and -3
Melt flow rate (MFR)	Per Compound Batch	Compound MFR shall be declared by manufacturer [b] Max deviation ±20 % of nominated value	BS EN ISO 1133 (Condition T)
OIT	Per Compound Batch	>20 min at 200 °C [c)]	BS EN ISO 11357-6
Pellet geometry	Per Compound Batch	Compare with sample from compound manufacturer	

[a)] Minimum sampling frequency.

[b)] The acceptable MFR range depends on pipes being able to make butt fusion joints.

[c)] Test may be carried out at 210 °C providing that there is a clear correlation with the results at 200 °C. In case of dispute the reference temperature shall be 200 °C.

5 Product Design and Pipe Geometry

5.1 General

The flexible pipe dimensions shall be designed to achieve minimum pressure losses but also the pipe shall be able to be inserted through a length of steel piping containing two 90° elbow screwed joints (see **8.3**). Steel pipes encountered are most likely to be Schedule 40, or Schedule 80. The bore dimensions of Schedule 40 & 80 steel pipes given in **Table 2**.

Table 2 – Nominal dimensions of steel pipes encountered in LP gas service installations

Nominal Size	Outside Diameter	Schedule 40		Schedule 80	
		Wall Thickness	Nominal Bore	Wall Thickness	Nominal Bore
¾”	26.7	2.9	20.9	3.9	18.9
1”	33.4	3.4	26.6	4.5	24.4
1¼”	42.2	3.6	35.0	4.9	32.4
1½”	48.3	3.7	40.9	5.1	38.1
2”	60.3	3.9	52.5	5.5	49.3

5.2 Pipe Diameter, Layer Thicknesses and Tolerances

The manufacturer should define the shape of layers, and specify critical dimensions and tolerances for each flexible pipe size, **Figure 1**. These shall be supplied in a data folder to the Gas Transporter and shall include, but not be limited to:

- Outside mean diameter at peak of corrugation (d_{Op})
- Outside mean diameter at trough of corrugation (d_{Ot})
- Inside mean diameter at peak of corrugation (d_{Ip})
- Inside mean diameter at trough of corrugation (d_{It})
- Outer layer thickness (e_O)
- Inner layer thickness (e_I)
- Corrugation pitch (cp)

The tolerances on these dimensions shall also be supplied in a data folder to the Gas Transporter.

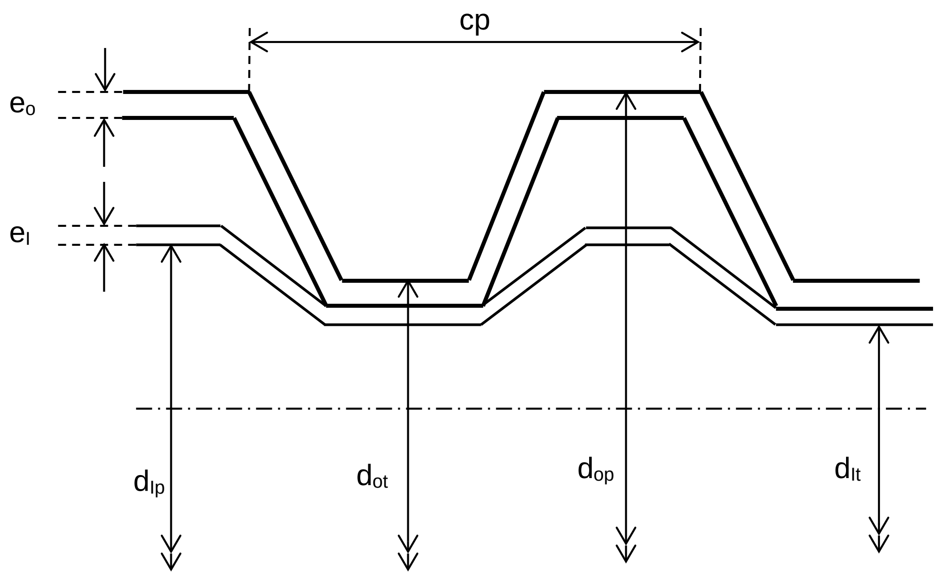


Figure 1 – Schematic Section through Flexible Pipe - Critical Dimensions

6 Sample Selection and Conditioning

6.1 Pipe Samples & Pipe Samples of Total Manufacturing Variability, TMV

Pipe samples are to have a minimum length of 10 x outside pipe diameter (10D).

Pipes that are supplied with an integral spigot end to PL2-6 (standard pipe dimensions) shall always be pressure tested with the spigot end at least on one end.

For flexible pipe tests as identified in **Table 6**, selected samples shall be long enough to use all the moulding blocks during a complete rotation of the corrugator. Such samples are termed total manufacturing variability (TMV) test samples.

Samples shall be conditioned at 23° ± 2°C unless specified. They shall be conditioned for the minimum period in accordance with **Table 3**. In case of dispute, measurements shall be made not less than 24 h after manufacture.

Table 3 — Minimum conditioning periods

Minimum conditioning period (h)			
In air 23°C (± 2°C)	In water at 20°C (± 1°C)	In water at 80°C (± 2°C)	In water at 80°C (± 2°C) [a]
6	1	6	3 [a]
a) Reduced conditioning time if the specimen is also filled with water at 80°C.			

7 Pipe Dimensions

7.1 General

Dimensions shall be measured in accordance with BS EN ISO 3126 at 23° ± 2°C, except the diameters shall be rounded to the next greater 0.1mm and the layer thicknesses to the next greater 0.01mm. For integral spigots the requirements of Annex B shall be met.

7.2 Diameters and Wall Thicknesses

The mean peak outer diameter ($\mathbf{d}_{Op}$), the mean peak inner diameter ($\mathbf{d}_{Ip}$) and the mean trough inner diameter ($\mathbf{d}_{It}$) of the pipes, and the inner skin thickness ($\mathbf{e}_{I}$) and the outer skin thickness ($\mathbf{e}_{O}$) shall be measured (see **Figure 1**).

For Type Testing approval, the diameters and layer thicknesses shall be measured at a minimum of 15 locations evenly spread along each TMV pipe sample length.

For Type Testing and Batch Release Testing, the measured diameters ($\mathbf{d}_{Op}$, $\mathbf{d}_{Ip}$, $\mathbf{d}_{It}$) and layer thicknesses ($\mathbf{e}_{I}$ and $\mathbf{e}_{O}$) shall be within the tolerances declared in **5.2**.

In case of dispute measurement shall not be made until 24h after production, and not until the pipe has conditioned for 6h at 23° ± 2 °C

7.3 Ovality

7.3.1 Specimen preparation

For Type Testing (TT), coiled pipe shall be stored at ambient temperature for seven days prior to testing. The winding temperature at the time of coiling shall be recorded and shall not exceed 35 °C.

7.3.2 Procedure

Immediately after unwinding, cut a 1 m long section 20 m from the pipe end of the innermost layer. Condition the test section at 23 °C ± 2 °C for 1h and then measure the ovality.

7.3.3 Requirement

The maximum ovality measured from the test section shall not exceed ($1 + 0.008\mathbf{d}_{On}$)

8 Pipe Physical and Mechanical Properties

8.1 Appearance

When viewed without magnification, the internal and external surfaces of pipes shall be smooth and clean and shall have no scoring, cavities and other surface defects to an extent that would prevent conformity to this standard.

8.2 Physical Requirements for PE Materials

When tested in accordance with the test methods as specified in PL2-2 **Table 4**, the pipe shall conform to the performance requirements specified in **Table 4** for each compound.

Table 4 — Physical Properties of Flexible PE Pipes

Properties	Performance requirements	Test parameters		Test method
		Parameter	Value	
Melt mass flow rate (MFR)	MFR of resin from pipe to be ±20% of MFR measured for resin batch used to manufacture pipe	Loading mass	5 kg	BS EN ISO 1133 (Condition T)
		Test temperature	190 °C	
		Time	10 min	
		5 test pieces shall use inner & outer layers	Shall conform to BS EN ISO 1133	
Oxidation induction time (OIT)	> 20 min	Test temperature	200 °C [a)]	BS EN ISO 11357-6
		No. of samples	3	
[a)] Test may be carried out at 210 °C providing that there is a clear correlation with the results at 200 °C. In case of dispute the reference temperature shall be 200 °C.				

8.3 Flow Rate Pressure Drop

Flexible pipes shall be subjected to the pressure drop tests as specified in **Annex A**.

The pressure drop measurements of straight flexible pipe shall be supplied in a data folder to the Gas Transporter (see **Table 5)**.

The pressure drop measurements of the flexible pipe inserted into a steel pipe with two 90° elbows shall be supplied in a data folder to the Gas Transporter (see **Table 5**).

Table 5 –Pressure Drop

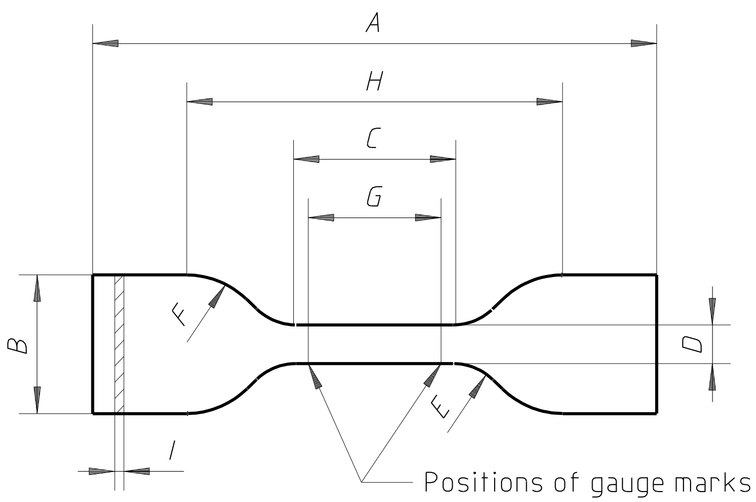
Steel Pipe Nominal Size	Flexible Pipe Size Designation	Maximum Flowrate (SCMH methane gas)	Maximum Pressure Loss (straight pipe) mbar/m	Measured Pressure Loss (inserted pipe with two 90° bends)
¾"	#¾	4	To be supplied by manufacturer in a data folder	To be supplied by manufacturer in a data folder
1"	#1	4		
1¼"	#1¼	8		
1½"	#1½	12		
2 "	#2	24		

8.4 Tensile Yield Stress and Failure Strain

Five tensile dumbbell samples (from different corrugators as appropriate), of the type and the dimensions shown in **Figure 2**, shall be taken from a length of flexible pipe and pulled at a separation rate of 25 mm/min generally according to BS EN ISO 6259-3. Record the maximum load and the elongation. Flexible pipes shall have yield stress calculated from the maximum load, the gauge length width and the sum of the measured thicknesses of the inner and outer layers of the pipe.

The yield stress shall not be less than 15MPa for PE80 and PE100 materials or pipes with a combination of both materials.

The nominal failure elongation of the gauge section shall not be less than 350% for PE80 and PE100 materials or pipes with a combination of both materials.



Symbol	Description	Dimensions mm
A	Overall length (min.)	115
B	Width of ends	25 ± 1
C	Length of narrow, parallel-sided portion	33 ± 2
D	Width of narrow, parallel-sided portion	$6^{+0,4}_{0}$
E	Small radius	14 ± 1
F	Large radius	25 ± 2
G	Gauge length	25 ± 1
H	Initial distance between grips	80 ± 5
I	Thickness	that of the pipe

Figure 2 — Type 2 test piece and dimensions

The use of the Type 2 test piece is known to be problematical with smaller diameter flexible pipes. Manufacturers may propose an alternative test protocol (sample form, e.g. whole pipe testing) but only on the basis that when pulled at the specified strain rate of 25mm/min it demonstrates the specified elongation and stress at yield.

8.5 Resistance to External Collapse Pressure

A sample of flexible pipe shall be mounted in a test jig to permit an external hydrostatic pressure of 2 bar to be applied around the pipe. The pipe shall be open to atmosphere at one end (or both ends). The test shall be a conducted at 23°C, and the pipe subjected to pressure for a period of 1 hour minimum.

The pipe shall not collapse and the internal diameter of the pipe shall not change by more than 2.5%.

8.6 Long-Term Pressure Strength.

8.6.1 General

BS EN ISO 9080 data generated by resin manufacturers using solid wall pipes cannot be used to identify the pressure capability of flexible (structured wall) pipes. For each pipe design, size and manufacturing route, flexible pipes shall have the pressure capability assessed by undertaking a BS EN ISO 9080 style regression analysis, but with pipe lifetime recorded as a function of the internal pressure (normally pipe lifetime is recorded as a function of pipe hoop stress). Tests shall be water-in-water at 20°C and 80°C, and shall conform to BS EN ISO 1167 using Type A end caps.

Normally the minimum sample length of the test samples shall be 10 times the pipe outside diameter, except for TMV samples (see **6.1**). TMV samples may be held in a loose coil to fit inside the test tanks.

The regression curves generated at 20°C and 80°C shall be used to identify the test pressures for the Batch Release Testing of flexible pipes **(see 8.6 & 8.7)**

Manufacturers may be permitted to offer pipe to this specification for sale to Gas Transporters after 5000h of testing provided 80% of all tests (at 20° and 80°C) have been completed, all failures have been ductile and the predicted LPL strength at 20°C is 1 bar or greater (**see 8.6.2**).

Note: Pipes that are supplied with an integral spigot end to PL2-6 (standard pipe dimensions) shall always be pressure tested with the spigot end at least on one end (**see 6.1**).

8.6.2 Determination of the Hydrostatic Pressure Strength at 20°C

At 20°C, a minimum of 18 pressure strength tests shall be made using at least five different pressure levels, and selected to give at least three observations above 7000h and one above 9000h. For two of the pressure tests (one of which shall be at a pressure to give a lifetime of above 7000h) the sample lengths shall meet the TMV requirement specified in **6.1.**

The slope of the 20°C mean regression curve shall not change beyond 100h of testing.

The calculated LPL pipe pressure strength at 20°C and 50 years shall not be less than 1 bar.

All pipe sample failures shall be ductile.

Determine the pressures equal to 80% of the value at 165h (BRT) and 1000h (TT) from the mean regression curve.

8.6.3 Determination of the Hydrostatic Pressure Strength at 80°C

At 80°C, a minimum of 12 pressure strength tests shall be made using at least four different pressure levels, and selected to give at least four observations above 2000h and one above 5000h.

For two pressure tests (using a pressure to give a lifetime of above 2000h) the sample length shall meet the TMV requirement specified in **6.1**.

The slope of the 80°C mean regression curve shall not change beyond 100h of testing.

All the pipe sample failures shall be ductile.

Determine the pressures equal to 80% of the value at 165h (BRT) and 1000h (BRT retest) from the mean regression curve.

8.7 Determination of Hydrostatic Pressure Strength under Bending at 80°C

Five pipe samples shall be bent and held to a radius of 1 x the appropriate steel service pipe inside diameter (1d) and then subjected to pressure at 80°C for 1000h, using a pressure equal to 80% of the value at 1000h for the mean regression curve constructed from the 80°C pressure tests specified in clause **8.6.3**. Tests shall be water-in-water, and shall conform to BS EN ISO 1167 using Type A end caps.

The pipe samples shall not fail.

8.8 Hydrostatic Pressure Strength of Crushed Flexible Pipe at 80°C

Flexible pipe shall be crushed flat between two parallel metal plates, over a minimum length of 100mm, using stops equivalent to twice the sum of the nominal thicknesses of the inner and outer layers. Pipe shall be held in this crush test at 20°C for 24h, and the crush load then released, followed by the pressure test within 24h.

Five crushed pipes shall be subjected to pressure at 80°C for 1000h, using a pressure equal to 80% of the value at 1000h for the mean regression curve constructed from the 80°C pressure tests specified in clause **8.6.3**. Tests shall be water-in-water, and shall conform to BS EN ISO 1167 using Type A end caps.

The pipe samples shall not fail.

8.9 Hydrostatic Pressure Strength of Inner Pipe Layer at 80°C

Pipe shall have the crown of the external corrugations removed, or cut through with a knife, for a minimum length of 100mm, leaving the internal layer intact, **Figure 3**.

Five cut pipes shall be subjected to pressure at 80°C for 1000h, using a pressure equal to 80% of the value at 1000h for the mean regression curve constructed from the 80°C pressure tests specified in clause **8.6.3**. Tests shall be water-in-water, and shall conform to BS EN ISO 1167 using Type A end caps.

The pipe samples shall not fail.

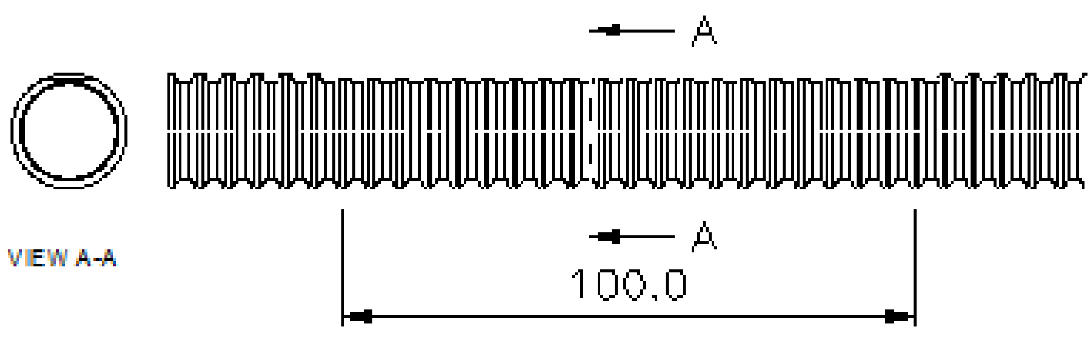


Figure 3 – Schematic presentation of external layer partially removed

9 Type Testing (TT) Approval

The test programme in accordance with **Table 6** shall be carried out to gain approval for flexible pipes to GIS/PL2-9 for each pipe size, design and PE material.

The Manufacturer shall compile a signed and dated data folder to include details of all type approval tests made and the results, and all critical information including, materials, source of materials, manufacturing technique and site(s), and detailed pipe dimensions.

Type Testing data shall be presented to show clearly compliance with the requirements of this specification; all tests listed in **Table 6** shall be annotated and data and results included.

The data folder shall be available for review by the Gas Transporter or their agents.

9.1 Design changes

Any proposed changes in design, materials, source of materials and manufacturing site to approved pipes shall be proposed by the manufacturer for consideration as a variant by the Gas Transporter.

The manufacturer shall submit details of the changes with a copy of the original signed data folder and a copy of the new completed data folder appropriately signed and dated.

The relevant Type Testing approval tests shall be repeated when performance is considered to be affected; tests to be made to be agreed by the Gas Transporter or their agents.

On approval of the variant, the new data shall be countersigned and returned to the manufacturer to replace the superseded data in the data folder.

Table 6 — Performance of pipes for Type Testing (TT) for each compound per size and pipe design

Properties		**Shall conform to:**	**Minimum No. of samples**
Geometrical properties	Outside mean Ø at peak, $\mathbf{d_{Op}}$	5.2	All samples used for TT tests. 2 TMV samples - 15 measurements evenly spread along each TMV pipe sample length
	Outside mean Ø at trough, $\mathbf{d_{Ot}}$	5.2	
	Inside mean Ø at peak, $\mathbf{d_{Ip}}$	5.2	
	Inside mean Ø at trough, $\mathbf{d_{It}}$	5.2	
	Outer layer wall thickness, $\mathbf{e_O}$	5.2	
	Inner layer wall thickness, $\mathbf{e_I}$	5.2	
	Ovality	7.3.3	2 TMV samples
Appearance		8.1	All samples used for TT tests
Melt Mass Flow Rate (MFR)		8.2 Table 4	5
Oxidation Induction Time (OIT)		8.2 Table 4	3
Gas Pressure Drop		8.3 Table 5	4
Mechanical properties	Tensile Yield Stress & Failure Strain	8.4	5
	External Collapse Pressure Strength (1h)	8.5	3
	20°C Long-term Pressure Strength (1000h)	8.6.1 & 8.6.2	18, of which 2 shall be TMV samples
	80°C Long-term Pressure Strength (165h)	8.6.1 & 8.6.3	12 of which 2 shall be TMV samples at each temperature
	80°C Long-term Pressure Strength in Bending (1000h)	8.7	5
	80°C Hydrostatic Pressure Strength after Pipe Crushed (1000h)	8.8	5
	80°C Hydrostatic Pressure Strength of Inner Pipe Layer (1000h)	8.9	3

10 Batch Release Testing (BRT)

The BRT shown in **Table 7** shall be carried out at the stated frequency on production from each pipe extrusion line.

Table 7 — Properties and Minimum Sampling Frequencies for BRT by Pipe Batch

Properties	Shall conform to:	Min sampling frequency per production line	Minimum No. of samples
Appearance	8.1	Every 4 h	1
Outside diameters, $\mathbf{d}_{Op}$, $\mathbf{d}_{Ip}$, $\mathbf{d}_{It}$	5.2 & 7.2	Every 2h	2 (rotate corrugator production units)
Outer and Inner layer thickness, $\mathbf{e}_{O}$, $\mathbf{e}_{I}$	5.2 & 7.2	Every 2h	2 (rotate corrugator production units)
Oxidation Induction Time	7.3	Start and end of pipe batch [b)]	1 (inner layer) 1 (outer layer)
Tensile Yield Stress and Failure Strain	8.4	Every 12h	2 (rotate corrugator production units)
20°C Hydrostatic Pressure Strength (165h)	8.6.1 & 8.6.2	Start and end of pipe batch [b)]	1 (rotate corrugator production units)
80°C Hydrostatic Pressure Resistance (165h) [a)]	8.6.1 & 8.6.3	Start and end of pipe batch [b)]	1 (rotate corrugator production units)
Marking	11	Every 2 h	1
Marking	11	Every 12 h	1 (record by dated photography)

a) If a sample fails, re-test for 1000h at 80°C but at a pressure equal to 80% of the value of the pressure found at 1000h on the mean regression curve constructed from the 80°C pressure tests.

b) Where production of the next batch is continuous and without interruption, the start test for the following batch would be deemed the end test for the preceding batch.

11 Marking

11.1 General

The marking elements shall be printed on the pipe in such a way that after storage, handling and installation, legibility is maintained in service.

Pipe shall be marked with a single strip using a technique that shall not put any depression into the wall of the pipe nor initiate cracks or other types of defects, which adversely influence the performance of the pipe; ink jets are acceptable (other techniques may be proposed by the manufacturer for consideration as a variant)

The height of the characters must be uniform and at least 3mm high using black marking on yellow pipes and yellow marking on black pipes.

Pipe conforming to GIS/PL2-9 shall be marked at 1 m intervals in accordance with **Table 8** and where authorized, the product conformity mark of a third party certification body, e.g. BSI Kitemark.

11.2 Information Required on Product Marking

Flexible pipe legend shall contain the information listed in **Table 8**:

Table 8 — Minimum Required Marking for Pipes

Legend	**Mark or symbol examples**
Number and date of this pipe standard	GIS/PL2-9:2019
The name and/or trademark of the manufacturer or their appointed agent	Name or symbol
Pipe Size Designation	#1½ (alternative methods may be proposed)
Material and designation	PE80 or PE100
Manufacturer's traceability for the Production site; Extrusion line; Date of manufacture	DD/MM/YY
Internal fluid	GAS
Sequential number in metres [a)]	00 to 50
[a)] The sequential number shall be required for coiled pipe and preferable for straight pipe.	

11.3 Marking of coils and drums

Each coil of pipe shall be clearly and indelibly labelled in accordance with **Table 9**.

Table 9 — Marking of coils

Legend	**Mark or symbol examples**
Weight of coil or drum	2 kg
Length	50 m
Pipe Size Designation	#1½ (alternative methods may be proposed)
Start and finish sequential number in metres	00 - 50

12 Packaging of Flexible Pipe

12.1 Coils

For a given pipe diameter, Manufacturers shall agree with the Gas Transporter the length of pipe to be provided, or range of lengths to be provided, the dimensions of the coil and the number of coils to be included on a bulk package such as a pallet.

Individual coils shall be wound at a coiling diameter which results in minimal ovalisation or damage of the pipe. The suitability of any pipe shall be judged against the resulting head loss when uncoiled and be within the values declared in **8.3**

Individual coils shall be capped at both ends and a label affixed to the end which should be dispensed initially (e.g. a direction arrow). Individual coils shall be labelled with the product details in accordance with **11.3**

13 Annex A – Pressure Drop Test Method

13.1 General

Pipe used for the assessment of pressure loss shall be manufactured close to the worst case tolerances that influence pressure head loss (i.e. maximum inside mean diameter at peak ($\mathbf{d}_{lp}$) and minimum inside diameter at trough ($\mathbf{d}_{lt}$) (minimum pipe bore)).

The manufacturer shall declare the pipe dimensions and geometry used for pressure drop testing in their data folder.

Test 1 is designed to measure the pressure drop along a straight pipe to determine the pressure drop per metre (mbar/m)

Test 2 is to measure the total pressure drop along a length of flexible pipe that has been inserted into an appropriate steel pipe that contains two 90° screwed elbow joints.

For each test, suitable pressure loss charts shall be plotted in mbar from 0 SCMH up to the maximum flowrates as defined in **8.3**, **Table 5**, in 0.5 SCMH intervals.

13.2 Test A

The length of flexible pipe shall be a minimum of 4m long and shall be long enough to use all the moulding blocks during a complete rotation of the corrugator.

Measure the pressure drop according to BS EN ISO 17778 and calculate the pressure drop per metre (mbar/m) at the maximum flow rate.

The pressure drop per metre shall be declared in the data folder.

13.3 Test B

Insert the flexible pipe using the manufacturer's written procedure into the 5.5m steel pipe layout, which includes two steel screwed 90° elbows, **Figure A.1**.

It is acceptable to extend straight flexible pipe beyond the steel pipe. After measuring the total pressure drop, the pressure drop due to the additional straight lengths of flexible pipe may be subtracted.

Measure the total pressure drop in mbar according to BS EN ISO 17778. These pressure drop values shall be declared in the data folder.

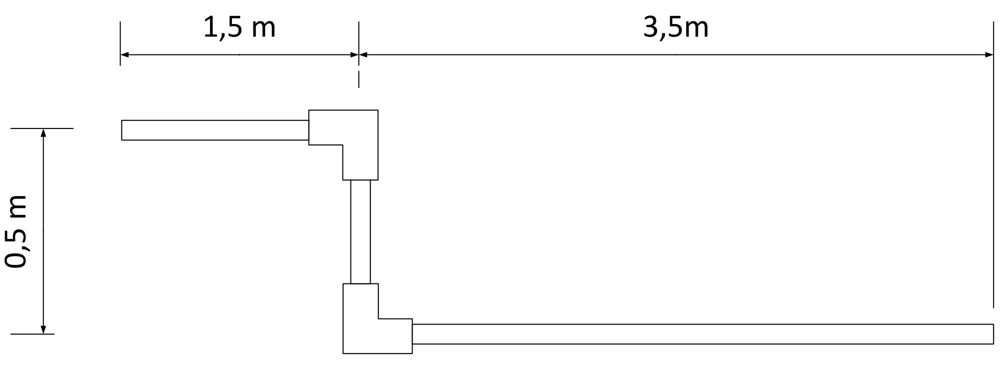


Figure A.1: Insertion test -Schematic pipe layout

14 Annex B – Additional Requirements for Factory Formed Spigot Ends

14.1 General

Acceptable forms for an integral spigot end for flexible twin walled corrugated pipes can be made either within the extrusion process or by a secondary welding operation of parts in compatible materials. This Annex B details the additional test requirements that shall apply where a secondary weld process is used to form an integral spigot.

It is permissible to include assembly parts and inserts which may cooperate with the integral spigot end for the purpose of jointing. The suitability of such parts are the responsibility of the fitting designer and users of this specification shall conduct a failure modes & effects analysis (FMEA) to identify and eliminate risks in their unique/proprietary jointing design solutions.

Tests defined in an FMEA shall be undertaken. The FMEA and the results of testing shall be documented and reference included in any first or third party accreditation to this standard GIS/PL2-9 to guide users to their existence.

Manufacturers shall provide a suitable marking system to identify each unique batch of spigot component. Each assembly batch of integral spigot formed pipes shall have a unique identification and shall use pipe taken from only one production batch and spigot components taken from one production batch.

14.2 Spigot Component

The manufacturer should define the shape of the spigot end component(s) and specify their critical dimensions and tolerances. These shall be supplied in the data folder to the Gas Transporter.

Materials suitable for the manufacture of the spigot end component(s) shall meet the requirements defined in **4 Materials**.

14.3 Integral Spigot End

The manufacturer should define the shape of the spigot end once it has been welded and formed as an integral part of the flexible twinwall pipe. The critical dimensions and tolerances shall be specified and supplied in the data folder to the Gas Transporter. This should include as a minimum:

14.3.1 nominal outside diameter

specified outside diameter of the integral spigot, in millimetres.

14.3.2 effective length of the spigot

the effective length over which nominal outside diameter and ovality measurements apply, in millimetres.

14.3.3 ovality

difference between the maximum and the minimum outside diameter in the same cross-section of a pipe or spigot, rounded off to the nearest 0.1 mm.

14.3.4 tolerances

permitted variation of the specified value of a quantity, expressed as the difference between the permitted maximum and the permitted minimum value

14.4 Type Testing (TT) Approval

The test programme in accordance with **Table B.1** shall be carried out to gain approval for integral spigot ends on flexible pipes to GIS/PL2-9 for each pipe size, design and PE material.

The Manufacturer shall compile a signed and dated data folder to include details of all type approval tests made and the results, and all critical information including, materials, source of materials, manufacturing technique and site(s), and detailed pipe dimensions.

Type Testing data shall be presented to show clearly compliance with the requirements of this specification; all tests listed in **Table B.1** shall be annotated and data and results included.

The data folder shall be available for review by the Gas Transporter or their agents.

Any subsequent design changes shall be in accordance with **9.1 Design Changes**.

Table B.1 — Performance of integral spigot pipe joints for Type Testing (TT) for each compound per size and pipe design

Properties		**Shall conform to:**	**Minimum No. of samples**
Geometrical properties	Outside Ø minimum	7.1	3
	Outside Ø maximum	7.1	
	Effective length	7.1	
	Ovality	7.3.3[a)]	
Appearance		8.1	All samples used for TT tests
Melt Mass Flow Rate (MFR) spigot part(s)		8.2 Table 4[b)]	3
Oxidation Induction Time (OIT) – outside surface spigot end		8.2 Table 4[c)]	3
Oxidation Induction Time (OIT) – inside surface of pipe adjacent weld interface		8.2 Table 4[d)]	3
Mechanical properties	Tensile Yield Stress & Failure Strain	8.4[e)]	5
	20°C Long-term Pressure Strength (1000h)[f)]	8.6.1 & 8.6.2	5
	80°C Long-term Pressure Strength (165h)	8.6.1 & 8.6.3	5
	80°C Long-term Pressure Strength (1000h)	8.6.1 & 8.6.3	5

Notes:

a) Condition integral formed assembly for 7 days at 35°C. Then condition at 23°C ± 2°C for 1 h and measure ovality

b) MFR shall be taken from the spigot subassembly part(s), not the finished assembly

c) Samples for OIT testing are taken from the outside surface of the integral formed spigot at the mid-point along the effective length

d) Samples for OIT testing are taken from the pipe bore adjacent the welded area of the spigot deemed to have received the most heat during the welding process

e) Full pipe sample shall be tested with an integral formed spigot and a minimum free length of pipe of 6D. Elongation at break shall be comparable to Clause 8.4 and failure shall be ductile.

f) The spigot end may require a cap to be fitted, such a cap shall not interfere with, reinforce or otherwise prevent the weld interface between the spigot end and the pipe from being subject to fluid contact and the full hoop stress required for the purpose of the test.

14.5 Batch Release Testing (BRT)

The BRT shown in **Table B.2** shall be carried out at the stated frequency on production from each spigot forming production unit. Pipe shall still meet the BRT testing requirements in **10**.

Table B.2 — Properties and Minimum Sampling Frequencies for BRT by Fitting Batch

Properties	Shall conform to:	Min sampling frequency per production line	Minimum No. of samples
Appearance	8.1	Every 4 h	1
Outside diameter	7.1	Every 1 h	2
Ovality	7.3	Every 1 h	2
Oxidation Induction Time	8.2 Table 4	Start and end of pipe batch [b]	2 [c]
Tensile Yield Stress and Failure Strain	8.4 [d]	Every 12 h	1
20°C Hydrostatic Pressure Strength (165h)	8.6.1 & 8.6.2	Start and end of batch [b]	1
80°C Hydrostatic Pressure Resistance (165h) [a]	8.6.1 & 8.6.3	Start and end of batch [b]	1
Marking	14.1	Every 12 h	1 (record by dated photography)

a) If a sample fails, re-test for 1000h at 80°C but at a pressure equal to 80% of the value of the pressure found at 1000h on the mean regression curve constructed from the 80°C pressure tests.

b) Where production of the next batch is continuous and without interruption, the start test for the following batch would be deemed the end test for the preceding batch.

c) One sample shall be taken from the outside surface of the spigot at the mid-point of the effective length. The second samples shall be taken from the bore of the pipe deemed to have received the most heat during the welding process

d) Full pipe samples shall be tested with an integral formed spigot and a minimum free length of pipe of 6D. Elongation at break shall be comparable to Clause 8.4 and failure shall be ductile.

14.6 Informative Guidance

Informative Guidance has no mandatory bearing on this specification. It is included to provide background information about products existing which informed the intent and/or content that has been included. This will assist those seeking to interpret the specification, particularly where failure modes effects analysis (FMEA) is being undertaken, on those additional tests to be undertaken as innovation is delivered.

Certain situations can be envisaged, for example that the inclusion of an integral spigot end would likely have a purpose involving the jointing of the Flexible Pipe to another part of the gas infrastructure. This means that the intended construction is likely to provide means to add caps to the pipe/spigot combination that permits the pressure testing to be undertaken on samples representative of the final construction.

The spigot end may modify the bore of the pipe and in such a situation it would be reasonable for the Manufacturer to declare the impact on the pressure loss to be experienced as a result of its inclusion together with the data required for conformance to Clause 8.3

This annex was originally written to support the development of trenchless remote connections by robots of the Flexible Pipe to mains pipes. Such a situation required the spigot end to be pulled through the ground and then to be electrofusion jointed. This would mean that for the spigot end the maximum pulling load could be identified and a suitable safety margin applied to this to arrive at a test load to be placed on the spigot end to create worst case damage scenarios for the minimum and maximum installation temperature. Samples made in this way would be subject to lifetime testing, in particular their resistance to environmental stress crack resistance.

Where it is intended that a spigot end is intended to form a below ground transition from a section of Flexible Pipe inside a steel conduit to a length of conventional solid wall PE80 pipe conforming to GIS/PL2-2 laid direct to ground, then aspects of GIS/PL2-6 should be used. In particular, where the spigot component has a substantial section (e.g. long spigot that dimensionally accords with GIS/PL2-6) and can be tested independently of the Flexible Pipe then it would be reasonable to test it independently to the requirements of GIS/PL2-6, and when combined with Flexible Pipe to the requirements of GIS/PL2-9.

In addition, where a spigot end is used to form the below ground transition, then historical metallic fittings for this purpose have included as their design intent that they anchor to the steel pipe to mitigate third party damage risks. The requirements are defined in GIS/PL3 for Class A fittings and the principle is that the connected PE80 pipe shall yield before the transition fitting is pulled from the steel pipe. The intent where the steel pipe condition permits it, is to ensure third party damage occurs at the point of damage to the network and is not transferred to a distal point such as the Flexible Pipe in the gas supply to a dwelling house.