Gas Industry Standard

GIS/PL2-2:2016

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

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Foreword

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

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.

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

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Brief history

Edited by BSI in accordance with BS 0-3:1997	August 2006
Substantial review – refer to Annex J	June 2008
Revision – Addition of Multilayer Pipes - refer to Annex K	June 2013
Revision - increase in pipe size up to 800mm - refer to Annex L	December 2014
Revision – Extend size range for multilayer PE80 pipes to 16-500mm and the use of rework of co-extruded pipe - refer to Annex M Revision to modify NPT to cover multimodal PE80 pipes - refer to Annex N	December 2016

1 Scope

This part of the GIS/PL2 suite of documents specifies requirements for nominally yellow polyethylene pipes, with a strength classification of PE80 [1)] in the nominal size range 16 mm to 800 mm inclusive for use at operating pressures not greater than 5.5 bar and operating temperatures in the range −20 °C to 40 °C.

It is applicable to black PE80 pipe with yellow stripes in sizes 16-225mm (inclusive) SDR 11, 13.6, 17.6, 21 & 26 for use at pressures not greater than 5.5 bar and operating temperatures in the range -20 °C to 40 °C.

It is applicable to Multilayer PE pipes consisting of a black PE80 co-extruded inner and yellow PE80 outer layer in the sizes 16-500mm SDR 11, 13.6, 17.6, 21 & 26 for use at pressures not greater than 5.5 bar and operating temperatures in the range -20 °C to 40 °C.

It is applicable to Peelable pipes in sizes 225mm to 800mm SDR 21 & 26, which are produced from natural or black polyethylene core material with a strength classification of PE100 and are covered by a propriety peelable skin. These are intended for use at a maximum operating pressure of 2 bar for the operating temperature range of 0 °C to 40 °C.

It is applicable to black PE100 pipe with yellow stripes in sizes 225-800mm (inclusive) SDR 21 & 26 for use at pressures not greater than 2 bar and operating temperatures in the range 0 °C to 40 °C.

It is applicable to Multilayer PE pipes consisting of a black PE100 co-extruded inner and yellow PE80 outer layer in the sizes 225-800mm SDR 21 & 26 for use at pressures not exceeding 2 bar and operating temperatures in the range 0 °C to 40 °C. The *additional or modified* requirements are included in **Annex G**, though reference is made to other sections in this specification.

It 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.

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 5252, *Framework for colour co-ordination for building purposes*.

BS EN ISO 2505, *Plastics piping and ducting systems — Thermoplastics pipes — Determination of the longitudinal reversion*.

BS EN 1056, *Plastics piping and ducting systems — Plastics pipes and fittings — Method for exposure to direct (natural) weathering*.

BS EN 12099, *Plastics piping systems — Polyethylene piping materials and components — Determination of volatile content*.

BS EN 12106, *Plastics piping systems — Polyethylene (PE) pipes — Test method for the resistance to internal pressure after application of squeeze off.*

BS EN ISO 472, *Plastics — Vocabulary*.

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

[1)] PE80 and PE100 are material strength classifications as determined by BS EN ISO 9080 & ISO12162.

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 1167 –1 & 2, *Plastics piping systems — Thermoplastics pipes — Determination of resistance to internal pressure at constant temperature*.

BS EN ISO 1183-1, *Plastics – Methods for determining the density and relative density of non-cellular plastics — Part 1: Immersion method, liquid pyknometer method and titration method.*

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

BS EN ISO 1183-3, *Plastics — Methods for determining the density of non-cellular plastics — Part 3: Gas pyknometer method.*

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

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

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

BS EN ISO 9969, Thermoplastics pipes. Determination of ring stiffness

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

BS EN ISO 13478, *Thermoplastics pipes for the conveyance of fluids — Determination of resistance to rapid crack propagation (RCP) — Full scale test (FST).*

BS EN ISO 13479, *Polyolefin pipes for the conveyance of fluids — Determination of resistance to crack propagation — Test method for slow crack growth on notched pipes (notch test).*

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

BS EN ISO 13968, *Plastics piping and ducting systems. Thermoplastics pipes. Determination of ring flexibility*

BS ISO 11414, *Plastics pipes and fittings — Preparation of polyethylene (PE) pipe/pipe or pipe/fitting test piece assemblies by butt fusion.*

BS ISO 13953*, Polyethylene (PE) pipes and fittings — Determination of the tensile strength and failure mode of test pieces from a butt-fused joint.*

BS ISO 18553, *Method for the assessment of the degree of pigment or carbon black dispersion in polyolefin pipes, fittings and compounds*.

ISO 2859-1, *Sampling procedures for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection.*

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

ISO 6964, Polyolefin pipes and fittings -- Determination of carbon black content by calcination and pyrolysis -- Test method and basic specification

ISO 13477, *Thermoplastics pipes for the conveyance of fluids — Determination of resistance to rapid crack propagation (RCP) — Small-scale steady-state test (S4) test.*

ISO 13954*, Plastics pipes and fittings— Peel decohesion test for polyethylene (PE) electrofusion assemblies of nominal outside diameter greater than or equal to 90 mm.*

Gas Industry Standards

GIS/ECE 1, *Specification for electrofusion control boxes*.

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/PL2-3, *Specification for polyethylene pipes and fittings for natural gas and suitable manufactured gas — Part 3: Butt fusion machines and ancillary equipment.*

GIS/PL2-4, *Specification for polyethylene pipes and fittings for natural gas and suitable manufactured gas — Part 4: Fusion fittings with integral heating element(s).*

GIS/PL2-7, *Specification for polyethylene pipes and fittings for natural gas and suitable manufactured gas — Part 7: Squeeze-off tools and equipment.*

GIS/PL2-8, *Specification for polyethylene pipes and fittings for natural gas and suitable manufactured gas — Part 8: Pipes for use at pressures up to 7 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 Geometrical definitions

3.1.1 nominal size (DN)
numerical designation of the size of a component, other than a component designated by thread size, which is a convenient round number, approximately equal to the manufacturing dimension in millimetres (mm)

3.1.2 nominal size (DN/OD)
nominal size, related to the outside diameter

3.1.3 nominal outside diameter, dn
specified outside diameter, in millimetres, assigned to a nominal size DN/OD

3.1.4 outside diameter (at any point), de
value of the measurement of the outside diameter through its cross-section at any point of the pipe, rounded to the next greater 0.1 mm

3.1.5 mean outside diameter, dem
value of the measurement of the outer circumference of the pipe or spigot end of a fitting in any cross-section divided by π (= 3.142), rounded to the next greater 0.1 mm

3.1.6 minimum mean outside diameter, dem, min
minimum value for the mean outside diameter as specified for a given nominal size

3.1.7 maximum mean outside diameter, dem, max
maximum value for the mean outside diameter as specified for a given nominal size

3.1.8 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

3.1.9 loss of roundness
loss of pipe diameter, not caused by distortion (ovality), normally caused by surface damage and abrasion

3.1.10 circumferential reversion
reduction in pipe diameter near the pipe ends produced by internal axial stresses in the pipe wall and caused by variations in cooling rates

3.1.11 nominal wall thickness, e_n
numerical designation of the wall thickness of a component, which is a convenient round number, approximately equal to the manufacturing dimension in millimetres (mm)

NOTE For thermoplastics components, the value of the nominal wall thickness, e_n, is identical to the specified minimum wall thickness, e_{min}.

3.1.12 wall thickness (at any point), e
wall thickness at any point around the circumference of a component

3.1.13 minimum wall thickness (at any point), e_{min}
minimum value for the wall thickness around the circumference of a component, as specified

3.1.14 maximum wall thickness (at any point), e_{max}
maximum value for the wall thickness around the circumference of a component, as specified

3.1.15 mean wall thickness, e_m
arithmetical mean of a number of measurements of the wall thickness, regularly spaced around the circumference and in the same cross-section of a component, including the measured minimum and the measured maximum values of the wall thickness in that cross-section

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

3.1.17 wall thickness tolerance
permitted difference between the wall thickness at any point, e, and the nominal wall thickness, e_n

NOTE $e_n = e_{min}$.

3.1.18 standard dimension ratio (SDR)
numerical designation of a pipe series, which is a convenient round number, approximately equal to the dimension ratio of the nominal outside diameter, d_n, and the nominal wall thickness, e_n

3.2 Material Definitions

3.2.1 virgin material
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

3.2.2 own reprocessable (rework) material
material prepared from clean rejected unused pipes, fittings or valves, including trimmings from the production of pipes, fittings or valves, that will be reprocessed in a manufacturer's plant after having been previously processed by the same manufacturer in the production of components by, for example injection moulding or extrusion

3.2.3 compound
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

3.2.4 campaign batch
uninterrupted base polymer production run by the resin manufacturer

NOTE: It should not exceed 1 month’s production.

3.2.5 compound batch
clearly identifiable quantity of a given homogeneous compound manufactured under uniform conditions

NOTE: The compound batch is defined and identified by the compound manufacturer. It should not exceed 700 tonnes.

3.2.6 pipe batch
number of pipes, all of them of the same nominal outside diameter, wall thickness and marking, 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.

3.2.7 peelable pipe
pipe made with polyethylene (PE100) core material over which is an outer skin, which is removed locally with the aid of simple tools, prior to fusion jointing

NOTE The skin allows protection of the core pipe during installation, but does not contribute to the specified wall thickness or to the mechanical strength of the pipe. The skin carries all marking and colour identification of the pipe.

3.2.8 core pipe
polyethylene peelable pipe (PE100) without skin

NOTE: The core pipe meets all the dimensional requirements of GIS/PL2-2 with the exception of colour.

3.2.9 layer
one or more windings of pipe having the same coil diameter

3.2.10 inner layer
layer in contact with the conveyed fluid

3.2.11 outer layer
layer exposed to the outer environment

3.2.12 multilayer PE pipe
pipes consisting of a co-extruded PE inner layer and a PE outer layer. Each layer is stress designed

3.2.13 BRT
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.

3.2.14 PVT
process verification test (PVT) testing performed by the manufacturer on material, components, and assemblies at specific intervals to confirm that the process continues to be capable of producing components conforming to the requirements given in the relevant standard.

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

3.3 Material properties

3.3.1 lower predicted limit (LPL), σ_{LPL}
quantity, with the dimensions of stress in megapascals (MPa), which can be considered as a property of the material, and represents the 97.5 % lower predicted limit of the mean long term strength at 20 °C for 50 years with internal water pressure

3.3.2 minimum required strength (MRS)
value of σ_{LPL}, rounded down to the next smaller value of the R10 series or of the R20 series depending on the value of σ_{LPL}

NOTE R10 and R20 series are the Renard number series according to ISO 3 and ISO 497.

3.3.3 overall service (design) coefficient or safety factor, *C*
Allowable hoop or circumferential stress C should have a minimum value/safety factor of 2.9 which takes into consideration service conditions as well as properties of the components of a piping system other than those represented in the lower confident limit.

3.3.4 design stress, σ_s
allowable stress in megapascals (MPa) for a given application

NOTE: It is derived from the MRS by dividing it by the coefficient *C,* i.e.:

$$\sigma_s = \frac{\mathrm{MRS}}{C}$$

3.3.5 melt-mass flow rate (MFR)
value relating to the viscosity of the molten material at a specified temperature and load, expressed in grams per 10 min (g/10 min)

3.4 Service conditions

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

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

NOTE It is calculated using the following equation:

$$\mathrm{MOP} = \frac{20 \times \mathrm{MRS}}{C \times (\mathrm{SDR} - 1)}$$

3.4.3 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.

3.5 Joints

3.5.1 butt fusion joint (using heated tool)
joint made by heating the planed ends of pipes or spigot end fittings

NOTE The surfaces of the joint match by holding them against a flat heating plate until the polyethylene material reaches fusion temperature, removing the heating plate quickly and pushing the two softened ends against one another.

3.5.2 fusion compatibility
ability of two similar or dissimilar polyethylene materials to be fused together to form a joint which conforms to the performance requirements of this standard

3.6 Packaging

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

3.6.2 drummed pipe
pipe extruded on to a rigid framed reel, with a supporting centre core to which the pipe is anchored

NOTE The drummed pipe shall be dispensed from a trailer or low loader.

3.7 Symbols

C	overall service (design) coefficient
d_e	outside diameter (at any point)
d_{em}	mean outside diameter
$d_{em,max}$	maximum mean outside diameter
$d_{em,min}$	minimum mean outside diameter
d_n	nominal outside diameter
e	wall thickness (at any point) of a pipe
e_m	mean wall thickness
e_{max}	maximum wall thickness (at any point)
e_{min}	minimum wall thickness (at any point)
e_n	nominal wall thickness
σ_{LPL}	lower predicted limit (MPa)
σ_s	design stress
T_{min}	minimum butt joint fusion temperature
T_{max}	maximum butt joint fusion temperature
P_c	critical pressure
$P_{C_{FS}}$	critical pressure measured in full-scale test, BS EN ISO 13478
$P_{C_{S4}}$	critical pressure measured in S4 test, ISO 13477

3.8 Abbreviations

BRT	batch release testing
DN	nominal size
DN/OD	nominal size, outside diameter related
LPL	lower predicted limit
MFR	melt mass-flow rate

MOP maximum operating pressure

MRS minimum required strength

PVT process verification testing

RCP rapid crack propagation

SDR standard dimension ratio

TT type testing

4 Material

4.1 The polyethylene gas pipe systems 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.

4.2 The pipes shall be made from: -

a) virgin compound

b) the manufacturer's own clean rework (reprocessable) material, including material from striped pipes, and used to make pipe of the same PE compound

c) Own rework (reprocessed) material from the inner layer of peelable pipes and used to make pipe with the same inner layer PE compound.

d) Rework (reprocessed) material from multilayer co-extruded pipes shall be blended only with virgin inner layer compound and used to make the same type of co-extruded pipe
Note - Explanatory Example - Rework from a PE80 multilayer coextruded pipe, which comprises of a mixture of Compound A from the inner layer and Compound B from the outer layer, has to be blended with virgin Compound A to produce more PE80 co-extruded pipe (Compound A - inner layer and Compound B - outer layer)

e) All rework (reprocessable) material may be blended with the same virgin compound

The virgin compound from which the pipes are made shall conform to GIS/PL2-1 and be classified PE80 or PE100.

Once a multilayer co-extruded pipe has been approved to this standard, then any other compound, previously used by the manufacturer to make PL2-2 or PL2-8 pipes, and approved to PL2-1 may be substituted for either of the two compounds.

The compound used for coloured stripes on the pipe shall be from one of the unpigmented pipe compounds for which fusion compatibility has been proven when normally pigmented.

Clean rework (reprocessable) compound, including material from striped pipes and multilayer co-extruded pipes, which has been generated from a manufacturer's own production of pipe to this standard, may be used provided it has not left the manufacturer's premises (re-grinding and pelletisation may be done outside the manufacturer's premises provided it is under the manufacturer's supervision).

Pipe produced from rework (reprocessable) compound shall be identifiable and/or traceable throughout the manufacturer's production records.

Pipe produced from rework (reprocessable) compound from multilayer pipes (PE80/PE80 & PE80/PE100) shall be Type Approval Tested in accordance with the requirements of Annex F of this standard. Testing pipes produced from 100% rework is viewed as "worst case", thus Annex F approves any blend of virgin compound & rework (reprocessable) compound, from 1% to 100%. All PE compounds used for rework (reprocessable) shall be from European sources and of grades with a previous supply history to the UK Gas Industry.

NOTE: There are no compound requirements for the propriety skins as these are additional peelable skins on the outside of standard pipe.

5 Compound

Compounds received from the compound manufacturers shall be tested in accordance with Table 1.

NOTE: The requirements are based upon tests in GIS/PL2-1, which have been conducted previously by the compound manufacturers.

6 General

6.1 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. The ends of the pipe shall be cut cleanly and square to the axis of the pipe.

6.2 Colour

Pipes shall be coloured yellow or black with yellow axial stripes (see GIS/PL2-1).

The core of peelable pipes may be natural or black, provided the external skin is yellow with axial stripes in the colours defined in GIS/PL2-1 – Black Stripes for SDR11, Red for SDR17.6, Brown for SDR21, Green for SDR26 and Blue for SDR33.

The inner layer of co-extruded Multilayer PE pipes shall be black with a yellow external layer.

6.3 Pipe construction

Pipes may be constructed of: -

- Yellow PE80 pipe (16 - 800mm, All SDRs)
- Black PE80 pipe with yellow stripes (16 - 225mm, All SDRs)
- Black PE80 inner layer with co-extruded PE80 yellow outer layer 16 - 500mm, All SDRs

- Peelable pipes with PE100 core (natural or black) and yellow skin 225 - 800mm, SDR21 & 26
- Black PE100 pipe with yellow stripes (225 - 800mm, SDR21 & 26)
- Black PE100 inner layer with co-extruded PE80 yellow outer layer 225 - 800mm, SDR 21 & 26

Table 1 — Compound properties

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

[a)] Minimum sampling frequency.

[b)] Detailed test requirements and methods are given in GIS/PL2-1.

[c)] The acceptable MFR range depends on pipes being able to make butt fusion joints with a bead shape and size that meets the requirements of the gas transporter as these beads are used in the field for joint quality control.

7 Geometry

7.1 Measurement of dimensions

Dimensions shall be measured in accordance with BS EN ISO 3126 at 23 °C ± 2 °C, after being conditioned for at least 6 h. The minimum conditioning period depending on wall thickness shall be in accordance with Table 2. Peelable pipes shall be conditioned with the skin intact. In case of dispute, measurements shall be made not less than 24 h after manufacture.

Table 2 — Minimum conditioning period

Minimum wall thickness (mm)	Minimum conditioning period (hours)			
	In air 23°C (± 2°C)	In liquid at 20°C (± 1°C)	In liquid at 80°C (± 2°C)	In liquid at 80°C (± 2°C)[a]
≤12	6	1	6	3 [a)]
>12 and ≤25	10	2	10	5 [a)]
>25 and <60	24	3	24	12 [a)]

[a)] These conditioning times in liquid at 80 °C shall apply only if the specimen, instead of being cold-filled with liquid, is initially pre-filled with liquid at the same temperature as the hot tank.

7.2 Mean outside diameters, wall thicknesses and tolerances

The mean outside diameters of the pipe, d_{em} and wall thicknesses, e shall conform to Table 3. Peelable pipes shall have the skin removed before measuring dimensions.

7.3 Loss of roundness (flats)

The pipe shall not show any loss of roundness (i.e. flats) for more than 0.05 d_n around the circumference of the pipe. At the point of maximum loss of roundness, the true diameter at that point shall not be less than the minimum value specified in Table 3. Peelable pipes shall have the skin removed.

Table 3 — Outside diameter and wall thicknesses of standard PE80, Peelable and Multilayer pipes

Dimensions in millimetres

Nominal outside diameter, d_n	Mean outside diameter, d_{em}		Wall thickness, e							
	Min.	Max.	SDR11		SDR17.6		SDR21		SDR26	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
16 [a]	16	16.3	2.3	2.7	—	—	—	—	—	—
20 [a]	20	20.3	2.3	2.7	—	—	—	—	—	—
25	25	25.3	2.3	2.7	—	—	—	—	—	—
32	32	32.3	3.0	3.4	—	—	—	—	—	—
40	40	40.4	3.7	4.2	—	—	—	—	—	—
50	50	50.4	4.6	5.2	2.9	3.3	—	—	—	—
55	55	55.4	5.1	5.8	—	—	—	—	—	—
63 [b]	63	63.4	5.8	6.5	3.6	4.1	3.0	3.4	—	—
75 [b]	75	75.5	6.8	7.6	4.3	4.9	3.6	4.1	—	—
90	90	90.6	8.2	9.2	5.2	5.9	4.3	4.9	—	—
110	110	110.7	10.0	11.1	6.3	7.1	5.2	5.9	—	—
125	125	125.8	11.4	12.7	7.1	8.0	6.0	6.7	—	—
140	140	140.9	12.7	14.1	8.0	8.9	6.7	7.5	5.4	6.1
160	160	161.0	—	—	9.1	10.1	7.6	8.5	6.2	7.0
180	180	181.1	16.4	18.2	10.3	11.5	8.6	9.6	7.0	7.8
200	200	201.2	18.2	20.2	11.4	12.7	9.5	10.6	7.7	8.6
213	213	214.3	—	—	—	—	10.1	11.2	8.2	9.2
225	225	226.4	—	—	12.8	14.2	10.7	11.9	8.6	9.6
250	250	251.5	22.7	25.1	14.2	15.8	11.9	13.2	9.6	10.7
268	268	269.6	—	—	—	—	—	—	10.3	11.5
280	280	281.7	25.4	28.1	15.9	17.6	13.3	14.8	10.7	11.9
315	315	316.9	28.6	31.6	17.9	19.8	15.0	16.6	12.1	13.5
355	355	357.2	32.3	35.7	20.2	22.4	16.9	18.7	13.7	15.2
400	400	402.4	36.4	40.2	22.8	25.2	19.0	21.0	15.4	17.1
450	450	452.7	40.9	45.1	25.6	28.3	21.4	23.7	17.3	19.2
469	469	471.8	—	—	—	—	22.3	24.7	—	—
500	500	503.0	45.5	50.2	28.4	31.4	23.8	26.3	19.2	21.3
560	560	563.4	50.9	56.1	31.9	35.2	26.7	29.5	21.5	23.9
630	630	633.8	57.3	63.2	35.8	39.5	30.0	33.1	24.2	26.8
710	710	716.4	64.5	71.1	40.3	44.5	33.9	37.4	27.2	30.1
800	800	807.2	72.6	80.0	45.4	50.1	38.1	42.1	30.6	33.8

a) For pipe sizes 16 mm and 20 mm, the actual values are SDR7 and SDR9 respectively due to minimum wall thickness considerations.

b) PE pipes in sizes 63mm SDR13.6 & 75mm SDR13.6 are also permitted
63mm wall thicknesses – 4.7mm minimum; 5.4mm maximum
75mm wall thicknesses – 5.6mm minimum; 6.4mm maximum

Note: Other SDR's may be allowed at the discretion of the gas transporter.

7.4 Ovality

7.4.1 General

Peelable pipes shall have the skin removed before measuring ovality.

7.4.2 Straight pipe (all sizes)

For straight pipes, the maximum ovality shall conform to Table 4.

Table 4 — Maximum ovality

Dimensions in millimetres		
Form	**Nominal outside diameter,** d_n	**Maximum ovality**
Straight pipe	≤75 >75 to ≤250 >250	$1 + 0.008d_n$ $0.02d_n$ $0.025d_n$
Coiled pipe	≤180	$0.06d_n$ for SDR11 & 13.6 $0.15d_n$ for SDR17.6, 21 and 26

7.4.3 Type testing: coiled pipe ovality (16 mm to 180 mm)

7.4.3.1 Ovality

The maximum ovality measured from the test section shall not exceed the applicable limit specified in Table 4.

7.4.3.2 Specimen preparation

For type testing (TT), coiled or drummed pipe (50 m minimum length) shall be stored at ambient temperature for seven days prior to testing. The winding temperature at the time of coiling of each size and SDR shall be recorded and shall not exceed 35 °C, see Table 6.

7.4.3.3 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 1 h and then measure the ovality.

7.4.4 Batch release testing: coiled pipe ovality (≥ 90 mm)

7.4.4.1 Ovality

The maximum ovality measured from the test section shall not exceed the applicable limit given in Table 4.

7.4.4.2 Procedure

For batch release testing (BRT) either:

a) measure the ovality of 90 mm pipes and above (approximately 10 m from the pipe end) annually on each size and SDR produced, provided the winding temperatures during production do not exceed the winding temperatures measured during type testing; or

b) measure ovality on every five hundredth coil/drum of each size and SDR produced.

NOTE: Ovality BRT of coiled pipe sizes less than 90 mm is not required.

7.5 Pipe Peelability Check

Every 4hrs a sample length of peelable pipe taken from each extrusion line shall be checked to ensure that the skin can successfully be peeled off pipes that are in manufacture The skin shall be peeled away completely from the core pipe for a minimum distance of 1 pipe diameter.

The pipe shall be deemed a “pass” if as a result of exerting reasonable force, the skin peels away from the core pipe in one piece without breaking, to leave a clean surface on the outside of the core pipe.

Peeling the skin from the core pipe shall be done by hand in all cases.

Should the pipe fail to meet the pass criteria, then those pipes manufactured subsequent to the last pass result shall be quarantined for further inspection.

The Skin Thickness along with the wall thickness and outside diameter of the core pipe shall also be measured. The Skin Thickness shall be in accordance with Table 5, the core pipe wall thickness and outside diameter shall be in accordance with Table 3.

NOTE: Some pipe sizes (highlighted in Table 5) are specifically for breakout moling, so the minimum skin thickness has been increased.

Table 5 — Peelable pipes skin/stripe requirements & Black pipe stripe requirements

Dimensions in millimetres				
Nominal outside diameter, d_n	**Skin thickness**		**Stripe**	
	Minimum	**Maximum**	**Width**	**Number**
63	0.6	1.2	6 ± 2	4
75	0.6	1.2	6 ± 2	4
75	1.0	1.5	6 ± 2	4
90	0.6	1.2	6 ± 2	4
90	1.0	1.5	6 ± 2	4
110	0.6	1.2	10 ± 3	4
110	1.0	1.5	10 ± 3	4
125	0.6	1.2	10 ± 3	4
140	1.0	1.5	15 ± 5	4
160	1.0	1.5	15 ± 5	4
160	0.6	1.2	15 ± 5	4
180	0.6	1.2	15 ± 5	4
200	0.6	1.2	15 ± 5	4
225	0.6	1.2	15 ± 5	8
250	0.6	1.5	20 ± 6	8
280	0.6	1.5	20 ± 6	8
315	0.6	1.5	20 ± 6	8
355	0.6	1.5	20 ± 6	8
400	0.6	1.5	20 ± 6	8
450	0.6	1.5	20 ± 6	8
500	0.6	1.5	20 ± 6	8
560	0.6	1.5	20 ± 6	8
630	0.6	1.5	20 ± 6	8
710	0.6	1.5	20 ± 6	8
800	0.6	1.5	20 ± 6	8
Other pipes sizes e.g. 213mm, 268mm & 469mm should use the values of the next largest pipe size Refer to Clause 6.2 for Stripe Colours				

7.6 Dimensions of pipe coils

Coiled pipe shall be deemed acceptable provided that the dimensions of the coil are in accordance with Table 6 and that the maximum surface temperature of the pipe during coiling conforms to Table 6.

The width of any coil shall be not greater than 1 m, and all coils shall be labelled in accordance with **15.4**.

Table 6 — Coil dimensions and winding temperatures

Nominal outside diameter, d_n	Minimum internal coil diameter		Maximum external coil diameter
	SDR11 & 13.6	SDR17.6, 21 & 26	SDR11, 13.6, 17.6, 21 & 26
mm	m	m	m
16 [a)]	0.6	—	4.0
20 [a)]	0.6	—	4.0
25	0.6	—	4.0
32	0.7	—	4.0
40	1.0	—	4.0
50	1.0	1.0	4.0
55	1.3	—	4.0
63	1.3	1.3	4.0
75	1.5	1.5	4.0
90	1.8	1.8	4.0
110	2.0	2.5	4.0
125	2.5	2.5	4.0
140	2.5	2.5	4.0
160	2.5	2.5	4.0
180	3.0	3.0	4.0
Maximum external coil temperature at time of winding shall be 35 °C. For peelable pipes, the maximum external coil temperature refers to the skin.			
a) For pipe sizes 16 mm and 20 mm, the actual values are SDR7 and SDR9 respectively, due to minimum wall thickness considerations.			

7.7 Circumferential reversion

The circumferential reversion of pipes with d_n equal to or greater than 180 mm shall be determined after a conditioning in water at 80 °C, in accordance with ISO1167. The pipe test pieces shall be a minimum of $3d_n$ in length. With the test piece at 23 °C ± 2 °C, circumferential measurement shall be made to establish d_{em}.

The difference between the d_{em} measurement made at distance of 1.0 d_n and 0.1d_n respectively from the end of the test piece shall not be greater than the d_{em} tolerance range specified in Table 3.

8 Mechanical properties

8.1 Conditioning

Unless otherwise specified by the applicable test method, the test pieces shall be conditioned at 23 °C ± 2 °C according to Table 2, before testing in accordance with Table 7.

8.2 Requirements

When tested in accordance with the test methods as specified in Table 7, the pipe shall conform to the performance requirements specified in Table 7 for each compound.

Table 7 — Mechanical properties

Properties	Performance requirements	Test parameters		Test method
		Parameter	Value	
20°C Long-term hydrostatic strength [a, e] 1000h on Weathered Peelable Pipes 100h & 5000h on Non-Weathered Pipes (all types)	No failure during the test period of any test piece	End caps	Type a	BS EN ISO 1167
		Conditioning time	Shall conform to BS EN ISO 1167	
		Type of test	Water-in-water	
		Circumferential (hoop) stress for:		
		PE 80/ PE80 core	Stress taken from the appropriate regression curves [a]	
		PE100 core		
		Number of test pieces [b]	3	
		Test periods	100 h and 5000 h	
		Test temperature	20 °C	
80 °C Hydrostatic strength [e] d_n < 63 mm (un-notched)	No failure during the test period of any test piece [c]	End caps	Type a	BS EN ISO 1167
		Conditioning time	Shall conform to ISO1167	
		Number of test pieces [b]	3	
		Type of test	Water-in-water	
		Internal test pressure:		
		PE 80/ PE80 core PE80/PE100 rework PE80/PE80 rework	Select from Table 8 [c]	
		PE100 core	Select from Table 8 [c]	
		Test period	Select from Table 8 [c]	
		Test temperature	80 °C	
80 °C Hydrostatic strength after squeeze off. Sizes: PE80 ≤ 500 mm Peelable ≤ 500 mm Multilayer ≤ 500 mm	Squeeze off pipe to conditions in BS EN 12106 except using squeeze-off equipment to GIS/PL2-7 [h]	Test temperature	0 °C	BS EN 12106 GIS/PL2-7
		Number of test pieces [b]	2	
	No failure during the test period of any test piece [c]	As above for 80 °C hydrostatic strength	As above for 80 °C hydrostatic strength	BS EN ISO 1167
80 °C Hydrostatic strength after offset butt fusion. Sizes ≥ 90 mm [d, e]	Produce butt weld to conditions in Annex A.	Number of test pieces [b]	2	Annex A
	No failure during the test period of any test piece [c]	As above for 80 °C hydrostatic strength	As above for 80 °C hydrostatic strength	BS EN ISO 1167

(Table 7 continued overleaf)

Table 7 — Mechanical properties (*continued*)

Properties	Performance requirements	Test parameters		Test method
		Parameter	Value	
Yield strength and elongation at break [g, h]	PE80 & PE80 core Yield stress ≥ 15 MPa Elongation ≥ 500% [f] PE100 core Yield strength ≥ 20 MPa Elongation ≥ 500% [f]	Speed of testing: *e* <13mm *e* ≥13mm	 100mm/min 25mm/min	BS EN ISO 6259-1 and ISO 6259-3
		Test piece dimensions	Shall conform to ISO 6259-3 [i]	
		Number of test pieces [b]	Shall conform to BS EN ISO 6259-1	
Skin Peel Adhesion Test - Peelable Pipes	Peel Strength ≥ 0.1N/mm ≤ 2.0N/mm	Speed of Testing:	50mm/min	Annex I
		Test Temperature:	-5°C & 30°C (TT) 23°C (BRT)	
		Number of Test Pieces [b]	2	
Resistance to slow crack growth d_n ≥ 63 mm Notch pipe test [e]	No failure during the test period [c]	Test temperature	80 °C	BS EN ISO 13479
		Internal test pressure		
		PE80 / PE80 core	Select from Table 9 [c]	
		PE100 core	Select from Table 9 [c]	
		PE80 / PE100 rework PE80 / PE80 rework	Select from Table 9 [c]	
		Test period	Select from Table 9 [c]	
		Type of test	Water-in-water	
		Number of test pieces [b]	Shall conform to BS EN ISO 13479	
Resistance to rapid crack propagation *e* ≥ 15 mm Critical pressure, P_c [e, l]	P_{cFS} ≥ 2.0 MOP [j] with $P_{cFS} = 3.6\ P_{cS4} + 2.6$	Test temperature	0 °C	ISO 13477 or BS EN ISO 13478
		Number of test pieces [b]	Shall conform to ISO 13477 or BS EN ISO 13478	

a) Tests at 100 h and 5000 h shall be conducted on non-weathered pipes of all types. Tests at 1000hrs shall be conducted on weathered peelable pipes. From the material classification in GIS/PL2-1, the 20 °C long-term hydrostatic tests shall be conducted using the appropriate hoop stresses obtained from the lower predicted limit applicable to 100 h, 1000 h, and 5 000 h. For co-extruded pipes see Annex G.

For mature / approved UK suppliers and at the gas transporters discretion, new suppliers using European approved resins with a proven track record (at the discretion of the gas transporter) of supply to gas transporters within the European Commission may substitute the 5000 h test period by a test for 100 h. Approved European resins to include those manufactured outside of Europe.

b) The numbers of test pieces given indicate the numbers required to establish a value for the property described in the table.

c) Only brittle failures shall be taken into account. If a ductile failure occurs, the test shall be repeated. The pressures and the associated test periods shall be selected from Table 8 or Table 9 (as appropriate) or from a line based on the pressure/time points.

d) Skin shall be peeled back from the pipe end, so that the skin does not later contact the joint or weld bead.

e) All pipes shall be tested, including peelable pipes (PE100) with the skins intact.

f) Where the rupture takes place outside the gauge marks, the test shall be accepted if the value conforms to the requirements.

(Table 7 continued overleaf)

Table 7 — Mechanical properties (*continued*)

g) The test can be terminated when the requirement is met, without necessarily carrying out the test up to the rupture of the test piece

h) The skin on peelable pipe shall be removed before squeeze-off (locally), tensile testing, including after weathering.

i) Where practicable, machined type 2 test pieces may be used for pipe wall thickness ≤ to 25mm.

j) The maximum operating pressures (MOP) are given in Annex B. The RCP testing conditions and requirements for all pipes are detailed in clause 12 and Annex D of this standard.

k) If the S4 requirement is not met or S4 test equipment not available, then (re)testing by using the full-scale test shall be performed in accordance with BS EN ISO 13478 in which case the full-scale test shall take preference. In this case: $P_c = P_{cFS}$.

l) Test pipes shall have a wall thickness of 15 mm or greater and shall be produced under commercial extrusion conditions. If the pipe is to operate at temperatures below 0 °C, then testing at the appropriate temperature may be required.

Table 8 — 80°C hydrostatic strength (un-notched) - Test pressures at 80 °C and associated test periods for all PE pipes

PE type	**Stress** MPa	**Pressure** bar					**Time** h
		SDR11	**SDR13.6**	**SDR17.6**	**SDR21**	**SDR26**	
PE80 & PE80 core/inner layer.	4.5	9.00	7.14	5.42	4.50	3.60	165
	4.4	8.80	6.98	5.30	4.40	3.52	233
	4.3	8.60	6.83	5.18	4.30	3.44	331
	4.2	8.40	6.67	5.06	4.20	3.36	474
	4.1	8.20	6.50	4.94	4.10	3.28	685
	4.0	8.00	6.35	4.82	4.00	3.20	1000
PE100 & PE100 core/inner layer	5.4	10.8	8.57	6.51	5.40	4.32	165
	5.3	10.6	8.41	6.39	5.30	4.24	256
	5.2	10.4	8.25	6.27	5.20	4.16	399
	5.1	10.2	8.10	6.14	5.10	4.08	629
	5.0	10.0	7.94	6.02	5.00	4.00	1000

Table 9 — Resistance to slow crack growth (notched pipe test) – Test pressures at 80 °C and associated test periods for all PE pipes (d_n ≥ 63 mm)

Stress MPa	**Pressure** bar					**Time** h
	SDR11	**SDR13.6**	**SDR17.6**	**SDR21**	**SDR26**	
4.2	8.40	6.67	5.06	4.20	3.36	474
4.1	8.20	6.50	4.94	4.10	3.28	685
4.0	8.00	6.35	4.82	4.00	3.20	1 000

9 Physical Properties

9.1 Conditioning
Unless otherwise specified by the applicable test method, the test pieces shall be conditioned at 23 °C ± 2 °C according to Table 2, before testing in accordance with Table 10.

9.2 Performance
When tested in accordance with the test methods specified in Table 10, the pipe shall conform to the performance requirements specified in Table 10.

10 Butt fusion jointing compatibility: fitness-for-purpose

10.1 General
Polyethylene pipes intended to be used for jointing by butt fusion shall be prepared and assembled in accordance with BS EN ISO 11414 except using butt fusion welding procedures and equipment in accordance with GIS/PL2-3. Joints shall be assessed for fitness-for-purpose under normal conditions in accordance with **10.2.**

Manufacturers making more than one pipe grade but of the same classification or substituting a new grade for an old one of the same classification, shall conduct the compatibility tests in accordance with **10.2** on all the possible pipe combinations between the same grades.

10.2 Normal conditions (23 °C)
For the assessment of fitness-for-purpose under normal conditions, butt fusion joints shall be produced between pipes of the same material grade and type at an ambient temperature of 23 °C ± 2 °C, using the parameters specified in BS EN ISO 11414:1996, Annex A except using butt welding procedures and butt fusion equipment in accordance with GIS/PL2-3.

The tensile strength and 80 °C hydrostatic strength (un-notched) of butt joints shall conform to **Table 11**.

Note Butt jointing will be between the same grade and type e.g. co-extruded PE80 core with PE80 outer layer with pipe of exactly the same type and coloured layers but not with similar pipe but with a PE100 outer layer

Table 10 — Physical properties

Properties	Performance requirements	Test parameters		Test method
		Parameter	Value	
Oxidation induction time (OIT) (thermal stability)	> 20 min	Test temperature	200 °C [a]	BS EN ISO 11357-6
		No. of test pieces [b] [c]	3	
Melt mass flow rate (MFR)	After processing, maximum deviation of ±20% of the value measured on the batch used to manufacture the pipe	Loading mass	5 kg	BS EN ISO 1133
		Test temperature	190 °C	
		Time	10 min	
		No. of test pieces [b]	Shall conform to BS EN ISO 1133	
Longitudinal reversion	≤ 3 % Original appearance of the pipe must remain	Test temperature	110 °C	BS EN ISO 2505
		Length of test piece	200 mm	
		Immersion time	1 h	
		No. of test pieces [b]	Shall conform to BS EN ISO 2505	
Resistance to weathering [d] Peelable pipes – SDR21 only one size in range 75mm to 250mm	The weathered test pieces must fulfil the requirements of the following characteristics: -	Weathering: Cumulative solar radiation	≥ 3.5 GJ/m^2	BS EN 1056
		No. of test pieces [b]	See below	
Hydrostatic strength 20 °C, 1000 h	Shall conform to Table 7			BS EN ISO 1167
80 °C hydrostatic strength after squeeze off	Shall conform to Table 7			BS EN 12106 GIS/PL2-7 ISO1167
80 °C hydrostatic strength after offset butt fusion [e]	Shall conform to Table 7			Annex A
Yield Strength and elongation	Shall conform to Table 7			BS EN ISO 6259-1 and ISO 6259-3
Electrofusion joint fusibility. Assemble joints to Annex C Decohesive resistance (Peel test) [f]	>66.7 % ductile failure	Test temperature	23 °C	Annex C ISO13954 [g]
		No. of test pieces [b]	2	

(Table 10 continued overleaf)

Table 10 — Physical properties *(continued)*

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.
b) The numbers of test pieces given indicate the numbers required to establish a value for the characteristic described in the table.
c) Samples shall be taken from the outer and inner pipe surfaces as well as from mid wall position.
d) As soon as possible after the completion of the weathering, the five tests shall be carried out.
e) Skin shall be peeled back from the pipe end, so that the skin does not later contact the joint or weld bead.
f) For black pipe with yellow stripes, samples shall be cut from the fusion areas containing both stripe material as well as from areas fused to the black pipe for decohesion (peel) testing.
g) ISO 13954 requires that each sample be cut into 4 test pieces for measurement.

Table 11 — Fitness-for-purpose properties of the butt joint

Properties	**Performance requirements**	**Test parameters**		**Test method**
		Parameter	**Value**	
80 °C hydrostatic strength (un-notched)	No failure during the test period of any test piece [a]	End caps	Type a	BS EN ISO 1167
		Conditioning time	Shall conform to ISO1167	
		No. of test pieces [b]	3	
		Type of test	Water-in-water	
		Circumferential (hoop) stress for: PE 80 & PE80 core PE100 core	 Select from Table 8 [a] Select from Table 8 [a]	
		Test period	Select from Table 8 [a]	
		Test temperature	80 °C	
Tensile strength for butt fusion	Test to failure: ductile: pass brittle: failure	Speed of testing	5 mm/min	BS ISO 13953
		Test temperature:	23 °C	
		No. of test pieces [b]	Shall conform to BS ISO 13953	
[a] Only brittle failures shall be taken into account. If a ductile failure occurs, the test may be repeated at a lower pressure. The pressures and the associated test periods shall be selected from Table 8 or from a line based on the pressure/time points.				
[b] The numbers of test pieces given indicate the numbers required to establish a value for the characteristic described in the table.				

11 Maximum operating pressures (MOP), overall service (design) coefficient and design stress

PE80 yellow pipes shall be able to operate at temperatures down to -20°C at pressures up to: -

- 5.5 bar for SDR11
- 3 bar for SDR17.6
- 2 bar for SDR21/26

Due to RCP considerations, the MOPs of conventional PE80 yellow pipes in the larger sizes and lower temperatures have been reduced (see Annex B).

All other PE pipes shall be able to operate at temperatures down to 0°C and at operational pressures up to a MOP of 5.5 bar, depending on the SDRs. (see Table 12 & Annex B).

NOTE 1 – The relationships between the pipe's SDR, maximum operating pressure (MOP), minimum required strength (MRS), overall service (design) coefficient (C) and the design stress (σ_S) are given in Table 12 below. For Multilayer pipes see Annex G.

Table 12 – Relationships between Design Parameters

Polyethylene Designation	SDR	MOP bar	MRS MPa	Service Design Coefficient, C	Design Stress, σ_S MPa
PE80 & PE80 (striped)	11	5.5	8.0	2.9	2.75
	17.6	3.0		3.2	2.5
	21	2.0		4.0	2.0
	26	2.0		3.2	2.5
PE100 (striped)	21	2.0	10.0	5.0	2.0
	26	2.0		4.0	2.5
Peelable (PE100 core)	21	2.0	10.0	5.0	2.0
	26	2.0		4.0	2.5
Co-extruded Multilayer (PE80 inner)	11	5.5	8.0	See Annex G.6	
	17.6	3.0			
	21	2.0			
	26	2.0			
Co-extruded Multilayer (PE100 inner)	21	2.0	10.0		
	26	2.0			
see clause 3 for symbols and definitions					

where: -

$$\sigma_S = \frac{MRS}{C}, \quad \text{MPa}$$

$$MOP = \frac{20 \times MRS}{C \times (SDR - 1)} = \frac{20\,\sigma_S}{(SDR - 1)}, \quad \text{bar}$$

12 Rapid crack propagation requirements for PE80, PE100 and peelable pipes

Conventional yellow PE80 pipes operate at temperatures down to -20 °C but the RCP tests are conducted at the reference temperature of 0 °C. The derating of the pipe's MOPs for the larger sizes and operation below 0 °C allows the pipes to be used at these temperatures provided the RCP performance is first demonstrated at 0 °C.

All other PE pipes are only permitted to be operated at temperatures down to 0 °C. The RCP performance of the peelable pipes has to be tested at this temperature by the pipe manufacturer as per GIS/PL2-2. In this specification, the RCP performances of the PE100 and also the PE80 compound for multilayer pipes have to be tested as pipe by the compound manufacturer at a temperature of 0 °C.

The RCP performance of all pipes shall be conducted at the relevant temperature and demonstrate crack arrest at a test pressure of 2 x MOP i.e. a safety factor of 2.

Details of the full-scale and S4 RCP testing procedures and requirements for PE80, peelable PE100 pipes are given in Annex D with further information in Annex H.

13 Type testing of pipe

13.1 General

The test programme in accordance with Table 13 shall be carried out on each size of pipe, except where a range of pipe sizes in a size group permits a reduced number of test sizes (see **13.2**).

NOTE: Users of this standard are advised to consider the desirability of third-party certification of product conformity with this standard or testing by an independent laboratory accredited to BS EN ISO/IEC 17025.

Pipes, when tested in accordance with Table 13, shall conform to the performance requirements specified in Table 13.

Table 13 — Properties of pipes that require type testing (TT) per compound

Properties		**Shall conform to:**	**Sampling procedure** [a]	**No. of test pieces** [b]	**No. of measurements per test piece**
Appearance		**6.1**	Two diameters/ size group	1	1
Colour		**6.2**	Two diameters/ size group	1	1
Geometrical properties	d_{em}, e	**7.2**	Two diameters/ size group	2	1 + 1
	Ovality	**7.4**	Two diameters/ size group	2	1
	Dimensions of pipe coils	**7. 6**	All sizes	1	1
	Circumferential reversion	**7.7**	Two diameters/ size group	2	1
Mechanical properties (non- weathered pipes – all types)	20 °C Long-term hydrostatic strength 100 h and 5 000 h	**8.2**	Two diameters/ size group	3 + 3	1
	Peelable Pipe - Skin Peel Adhesion Test	**8.2**	Two diameters/ size group	2	1
	80°C Hydrostatic strength d_n < 63mm (un-notched)	**8.2**	One diameter/ size group	3	1
	80°C Hydrostatic strength after squeeze-off $d_n \leq 500$ mm	**8.2**	Two diameters/ size group	2 a)	1
	80°C Hydrostatic strength after offset butt fusion $d_n \geq 90$ mm	**8.2**	Two diameters/ size group	2 a)	1
	Yield strength and elongation at break	**8.2**	Two diameters/ size group	Shall conform to BS EN ISO 6259-1	1
	Resistance to slow crack growth $d_n \geq 63$ mm Notch pipe test	**8.2**	Two diameters/ size group	3	1
	Resistance to rapid crack propagation [c), d), e)] (RCP) e ≥ 15mm Critical pressure, P_c	**8.2**	Test at 0 °C: Maximum pipe size and maximum wall thickness of that size in the manufacturer's range [c)]	Shall conform to ISO 13477 or BS EN ISO 13478	Shall conform to ISO 13477 or BS EN ISO 13478

(Table 13 continued overleaf)

Table 13 — Properties of pipes that require type testing (TT) per compound (*continued*)

Properties			**Shall conform to:**	**Sampling procedure** [a)]	**No. of test pieces** [b)]	**No. of measurements per test piece**
Physical properties	De-cohesion of an electrofusion joint % ductile failure		**9.2**	Two diameters/ size group	3	4
	Melt mass-flow rate (MFR)		**9.2**	Two diameters/ size group	3	1
	Longitudinal reversion		**9.2**	Two diameters/ size group	1	1
	Resistance to weathering of Peelable Pipes	Skin Peel Adhesion	**8.2**	One diameter	3	4
		20 °C Long-term hydrostatic strength 1000 h	**9.2**	One diameter	3	1
		80 °C Hydrostatic strength after squeeze-off	**9.2**	One diameter	3	1
		80 °C Hydrostatic strength after offset butt fusion	**9.2**	One diameter	3	1
		Yield strength and elongation at break	**9.2**	One diameter	Shall conform to BS EN ISO 6259-1	1
		Electrofusion joint fusibility	**9.2**	One diameter	2	1
Strength of butt fusion joint	Normal Conditions	Tensile strength ductility	**10.2**	Two diameters/ size groups 2 and 3 only.	1	Shall conform to BS ISO 13953
		80°C Hydrostatic strength (un-notched)	**10.2**	Two diameters/ size group 3	1	1
Marking			**14**	Two diameters /size group	1	1

(Table 13 continued overleaf)

Table 13 — Properties of pipes that require type testing (TT) per compound (*continued*)

[a)] Evenly distributed diameters over the product range shall be chosen, except for weathered Squeeze off and Offset Butt joint, were the largest size shall be tested in the manufacturer's product range. The product range in each size group shall be defined by the manufacturer.

Samples shall comprise the smallest and largest diameter of the range manufactured. The successful testing will validate pipe, with the same d_n, at a higher SDR, i.e. thinner wall thickness.

Where a manufacturer extends his production beyond his approval, additional relevant type testing shall be carried out.

[b)] The number of test pieces given in the table shall be the minimum. All test pieces shall pass the relevant test(s).

[c)] For peelable pipes, testing of sizes, 250 mm, 315 mm and maximum size e.g. 630 mm (all SDR21) shall be conducted to demonstrate that the skin does not significantly affect the RCP performance.

For full-scale testing of PE100 cored pipes, the use of a PE80 initiation pipe and, if necessary, reducing the full-scale test temperature below zero in order to achieve the correct initiation conditions is acceptable. The RCP test shall then be conducted at this lower temperature with the normal full-scale test pressure of 2 x MOP.

If the S4 test temperature of PE100 cored pipes is reduced to below zero, in order to achieve the correct initiation conditions of a crack length of $1d_n$ with zero pressure, then the RCP test shall then be conducted at this temperature with the P_{cS4} test pressure calculated from the equations in Table 7.

[d)] If RCP test(s) are successful, approval given to any smaller pipe sizes, provided the wall thickness is not greater than that tested. For peelable pipes see footnote c.

[e)] If necessary for ordinary PE80 and PE80 cored pipes, the S4 test temperature can be reduced below zero in order to achieve the correct initiation conditions of a crack length of $1d_n$ with zero pressure. The RCP test shall then be conducted at this lower temperature with the P_{cS4} test pressure calculated from the pipe's 2 × MOP.

[f)] Test sample shall be un-notched.

NOTE: Test pieces used for tests for geometrical properties may be subsequently used in the destructive tests listed in this table.

13.2 Selection of test pipe sizes

Pipe size groups shall be in accordance with Table 14.

Table 14 — Size groups for pipes

			Dimensions in millimetres
Size group	**1**	**2**	**3**
Nominal outside diameter, d_n, for pipes	$d_n < 75$	$75 \leq d_n < 250$	$250 \leq d_n \leq 800$

The manufacturer shall define the product range in each size group and choose for testing evenly distributed diameters over the product range. Samples shall comprise of the smallest and largest of the range manufactured.

The successful testing will validate pipe with the same diameter but with thinner wall thickness.

Where a manufacturer extends his production beyond his approval, additional relevant type testing shall be carried out.

14 Batch release testing (BRT)

Checks shall be carried out as follows:

The checks shown in Table 15 shall be carried out at the stated frequency on production from each pipe extrusion line, except where the PVT testing shall be carried out on compounds using Table 16.

Table 15 — Properties and minimum sampling frequencies for BRT by Pipe Batch

Properties		Shall conform to:	Min. sampling frequency per extruder	No. of samples [a)]	No. of measurements per sample
Appearance		**6.1**	Every 4 h	1	1
Colour		**6.2**	Every 6 months	1	1
Geometrical properties	Outside diameter	**7.1, 7.2**	Continuously or every 4 h	1	1
	Wall thickness [b)]	**7.1, 7.2**		1	1
	Ovality	**7.4.4**	Daily	1	1
	Loss of roundness (flats)	**7.3**	Daily	1	1
	Pipe Peelability check	**7.5**	Every 4 h	1	1
	Circumferential reversion	**7.7**	One sample/ size/ week	1	1
Mechanical properties	Peelable pipe – Skin Peel Adhesion Test	**8.2**	Weekly	1	As defined in Annex I
	80°C Hydrostatic strength d_n < 63 mm (un-notched)	**8.2**	One sample/ size/week	1	1
	Yield strength and elongation at break	**8.2**	One sample/ size/ week	Shall conform to BS EN ISO 6259-1	1
	Rapid crack propagation resistance (RCP) PE80 pipe: S4 or [full-scale] Peelable pipe: S4 or [full-scale] [c)]	**8.2**	One sample/ year	3[1]	3[1]
Physical properties	Oxidation induction time (thermal stability)	**9.2**	One sample/ size/week	1	1 (inside surface only)
	Melt mass-flow rate (MFR)	**9.2**	Weekly	1	1
Marking		**14**	Every 4 h	1	1

[a)] The number of test pieces given in the table shall be the minimum. All test pieces shall pass the relevant test(s).

[b)] Continuous wall thickness monitoring shall also be used.

[c)] The peelable, co-extruded and multilayer pipe samples shall have a wall thickness of 15mm or more.

NOTE 1 Minimum frequency of sampling shall be as follows. Continuously: on-line monitoring of pipe dimensions. Every 4 h: one sample at the start of production then every 4 h. One sample/size/week: one sample at the start of production of each size then again every week.

NOTE 2: Ovality BRT of coiled pipe in sizes less than 90 mm is not required.

Table 16 – Properties for minimum sampling frequencies PVT by Pipe Compound

Properties	**Shall conform to:**	**Min. sampling Frequency per <u>Compound</u>**	**No. of Samples a)**	**No. of measurements Per sample**
Resistance to slow crack growth $d_n \geq 63$mm Notch pipe test	8.2	One sample/ compound/month a	1	1

a) One sample tested for every pipe compound used by the manufacturer to make PE pipes to PL2-2 in the previous month. If possible, select different pipe sizes each month from current production.

b) For pipes manufactured with large percentage of rework, material containing more than 80% rework would be classified as another pipe compound and so be subjected to PVT testing.

15 Marking

15.1 General

The marking elements shall be printed or formed directly on the pipe in such a way that after storage, weathering, handling and installation, legibility is maintained during the use of the pipe. Marking shall not initiate cracks or other types of defects, which adversely influence the performance of the pipe.

15.2 Mark colour and size

All pipes shall be permanently and legibly marked along their length with a legend, which shall be indented to a depth of between 0.02 mm and 0.15 mm. Pipe not greater than 75mm nominal size shall be marked with a single “non-inked” indented strip plus an inkjet print line. Larger pipe sizes shall be marked with two “non-inked” indented strips on opposite sides of the pipe, plus an inkjet print line.

The height of the characters shall be uniform and at least the following:

a) 3 mm for pipe 90 mm nominal size or less;

b) 5 mm for pipe greater than 90 mm nominal size.

15.3 Minimum required marking

Pipe conforming to GIS/PL2-2 [2)] shall be permanently marked at 1 m intervals in accordance with Table 17 and where authorized, the product conformity mark of a third party certification body, e.g. BSI Kitemark.

Table 17 — Minimum required marking

Legend	**Mark or symbol examples**
Number and date of this pipe standard	GIS/PL2-2:2014
The name and/or trademark of the manufacturer or their appointed agent	Name or symbol
For pipes $d_n \leq 32$ mm: Nominal outside diameter x nominal wall thickness (d_n x e_n)	 32 × 3.0
For pipes $d_n > 32$ mm: –nominal outside diameter, d_n –SDR.	 200 or 200 mm SDR17.6
Material and designation	PE80
Manufacturer’s traceability: Production site & Extrusion line Date of manufacture	 DD/MM/YY
Internal fluid	GAS
Weight per metre for $d_n \geq 125$ mm	20 kg/m
Sequential number in metres [a]	000 to 999
[a)] The sequential number shall be required for coiled pipe and preferable for straight pipe.	

2) Marking GIS/PL2-2 on or in relation to a product represents a manufacturer’s declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the specification. The accuracy of the claim is therefore solely the responsibility of the person making the claim. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

15.4 Marking of coils and drums

Each coil and drum of pipe shall be clearly and indelibly labelled in accordance with Table 18.

Table 18 — Marking of coils and drums [a]

Legend	Mark or symbol examples
Weight of coil or drum	50 kg
Length	100 m
Nominal outside diameter, d_n and SDR	180 mm SDR17.6
Start and finish sequential number in metres	050 - 150
[a)] Drummed pipe shall not be banded, as both ends shall be secured to the drum.	

For pipe sizes equal to or greater than 90 mm, the label shall also carry the following warning:

“Before un-strapping, ensure that both pipe ends and coil/drum are firmly mechanically restrained.”

A label attached to the lead end of the pipe, or a directional arrow printed on the surface of the pipe shall be used to define which end of the coiled pipe should be dispensed *first.*

15.5 Marking of pipe bundles

When straight pipe lengths are supplied in bundles, the manufacturer shall affix a label on both sides of the bundle indicating:

a) weight (kg)

b) correct orientation of the bundle (e.g. “THIS WAY UP”) to assist in the safe loading, unloading and stacking of the bundle.

16 Delivery conditions

The lengths of straight pipe shall be 6 m or 12 m, and coiled pipe shall be supplied in a minimum length of 50 m. The pipe shall not contain any swarf within the cut pipe. If the lengths of individual pipes are specified, such lengths shall be not less than that specified when determined at 23° ± 2°C.

Pipe supplied in coils or on drums shall be packaged in accordance with Annex E.

Annex A Method for jointing by offset butt fusion (normative)

A.1 Principle

The adjacent ends of two longitudinally-aligned pipes are fused by contact with a heated plate and then jointed whilst subject to a specified amount of radial misalignment.

A.2 Apparatus

Apparatus shall conform to GIS/PL2-3.

A.3 Procedure

A.3.1 *Hot plate temperature*

Raise the temperature of the hot plate until it lies in the range 230 °C to 236 °C and maintain the temperature between those limits for 15 min before each joint is made.

A.3.2 *Misalignment*

Mount and axially align the two lengths of pipe to be joined in the butt fusion machine and then adjust the positions of the clamps to introduce a radial misalignment as follows:

a) for pipes not greater than 180 mm nominal outside diameter, a minimum offset of 1 mm at any point around the circumference;

b) for pipes greater than 180 mm nominal outside diameter, an offset of not less than 10 % of the actual wall thickness of the pipe.

NOTE The misalignment is applied to serve as a feature of the test condition. For installation purposes, misalignment should always be minimized and may be subject to a different limit.

A.3.3 *Fusion*

Using the procedure specified in GIS/PL2-3, apply the mutually opposed ends to the heated plate and then to one another to form a fused butt joint.

A.3.4 *Inspection*

Inspect the joint and ensure that the bead conforms to the gas transporter's required shape and size, otherwise discard the jointed test piece and adjust the welding conditions or procedure within the prescribed limits until such a joint is obtained.

A.3.5 *Report*

The report of the jointing operation shall include the following:

a) the identification of the test pieces;

b) a reference to this standard, i.e. GIS/PL2-2;

c) the jointing procedure used;

d) the amount of offset obtained;

e) the date of jointing.

Annex B Maximum operating pressures (MOP) for PE80 pipes (normative)

TABLE B.1 - Diameters and maximum operating pressures for PE80 polyethylene pipes (yellow PE80, black PE80 with yellow stripes, black PE80 inner layer and co-extruded yellow PE80 outer layer)

Pipe Outside Diameter	Maximum operating pressure bar															
	Pipe SDR (class)															
	11				17.6				21				26			
mm	-20ºC to -10ºC	-10ºC to -5ºC	-5ºC to 0ºC	0ºC to 40ºC	-20ºC to -10ºC	-10ºC to -5ºC	-5ºC to 0ºC	0ºC to 40ºC	-20ºC to -10ºC	-10ºC to -5ºC	-5ºC to 0ºC	0ºC to 40ºC	-20ºC to -10ºC	-10ºC to -5ºC	-5ºC to 0ºC	0ºC to 40ºC
16	5.5	5.5	5.5	5.5	-	-	-	-	-	-	-	-	-	-	-	-
20	5.5	5.5	5.5	5.5	-	-	-	-	-	-	-	-	-	-	-	-
25	5.5	5.5	5.5	5.5	-	-	-	-	-	-	-	-	-	-	-	-
32	5.5	5.5	5.5	5.5	-	-	-	-	-	-	-	-	-	-	-	-
40	5.5	5.5	5.5	5.5	-	-	-		-	-	-	-	-	-	-	-
55	5.5	5.5	5.5	5.5	-	-	-	-	-	-	-	-	-	-	-	-
63	5.5	5.5	5.5	5.5	-	-	-	-	-	-	-	-	-	-	-	-
75	5.5	5.5	5.5	5.5	-	-	-	-	-	-	-	-	-	-	-	-
90	5.5	5.5	5.5	5.5	3	3	3	3	-	-	-	-	-	-	-	-
110	-	-	-	-	3	3	3	3	-	-	-	-	-	-	-	-
125	4.4	4.7	5.1	5.5	3	3	3	3	-	-	-	-	-	-	-	-
140	4.1	4.4	4.8	5.5	3	3	3	3	-	-	-	-	2	2	2	2
160/162	-	-	-	-	3	3	3	3	-	-	-	-	2	2	2	2
180	3.5	3.7	4.1	4.7	2.9	3	3	3	-	-	-	-	2	2	2	2
200	3.3	3.5	3.8	4.4	2.7	2.8	3	3	-	-	-	-	2	2	2	2
213	-	-	-	-	-	-	-	-	-	-	-	-	2	2	2	2
225	-	-	-	-	-	-	-	-	-	-	-	-	2	2	2	2

TABLE B.1 - (concluded)

Pipe Outside Diameter	Maximum operating pressure bar															
	Pipe SDR (class)															
	11				17.6				21				26			
mm	-20°C to -10°C	-10°C to -5°C	-5°C to 0°C	0°C to 40°C	-20°C to -10°C	-10°C to -5°C	-5°C to 0°C	0°C to 40°C	-20°C to -10°C	-10°C to -5°C	-5°C to 0°C	0°C to 40°C	-20°C to -10°C	-10°C to -5°C	-5°C to 0°C	0°C to 40°C
250	2.9	3	3.3	4	2.3	2.5	2.7	3	-	-	-	-	2	2	2	2
268	-	-	-	-	-	-	-	-	-	-	-	-	1.9	2	2	2
280	2.7	2.8	3.1	3.8	2.2	2.3	2.5	2.9	-	-	-	-	1.8	2	2	2
315	2.5	2.6	2.9	3.4	2	2.1	2.3	2.7	-	-	-	-	1.7	1.8	2	2
355	2.3	2.4	2.7	3.1	1.9	2	2.2	2.5	1.7	1.8	2	2	-	-	-	-
400	2.1	2.3	2.5	2.9	1.7	1.8	2	2.3	1.6	1.7	1.9	2	-	-	-	-
450	2	2.1	2.3	2.7	1.6	1.7	1.9	2.2	1.5	1.6	1.7	2	-	-	-	-
469	-	-	-	-	1.6	1.7	1.8	2.1	1.5	1.6	1.7	2	-	-	-	-
500	1.9	2	2.2	2.5	1.5	1.6	1.8	2	1.4	1.5	1.6	2	-	-	-	-
560	-	-	-	2.3	-	-	-	1.9	-	-	-	1.8	-	-	-	-
630	-	-	-	2.2	-	-	-	1.8	-	-	-	1.6	-	-	-	-
710	-	-	-	2.0	-	-	-	1.6	-	-	-	1.5	-	-	-	-
800	-	-	-	1.9	-	-	-	1.5	-	-	-	1.4	-	-	-	-

Notes

1. SDR 21 and SDR 26 pipe for traditional insertion/close fit insertion only.
2. Pipe sizes of 355mm and above use SDR 21 instead of SDR 26, as the thicker wall gives additional support from ground loading.
3. Pipe sizes indicated by a dash (-) are not normally available.
4. The higher operating pressures apply to the overlapping temperatures of -10°C, -5°C and 0°C.
5. The operating temperature range for the UK under normal conditions is in the range of 0°C to 20°C.
6. The maximum test pressure for PE is 1.5 times the maximum operating pressure.

TABLE B.2 - Diameters and maximum operating pressures for PE100 pipes (Black PE100 with yellow stripes, yellow peelable skin with natural or black PE100 core, black PE100 inner layer with co-extruded yellow PE80 outer layer)

Pipe Outside Diameter	Maximum operating pressure bar			
	Pipe SDR (class)			
mm		17.6	21	26
	0°C to 40°C			
63	-	3	2	2
75	-	3	2	2
90	-	3	2	2
110	-	3	2	2
125	-	3	2	2
140	-	3	2	2
160/162	-	-	2	2
180	-	3	2	2
200	-	3	2	2
213	-	-	2	2
225	-	3	2	2
250	-	3	2	2
280	-	3	2	2
315	-	3	2	2
355	-	3	2	2
400	-	3	2	2
450	-	3	2	2
500	-	3	2	2
560	-	3	2	2
630	-	3	2	2
710	-	3	2	2
800	-	3	2	2

Notes

The operating temperature range for the UK is 0°C to 40°C.

The test pressure for PE pipes is 1.5 times the maximum operating pressure.

Pipe size indicated by a dash (-) are not normally available.

Annex C Method for electrofusion socket joint strength with weathered peelable pipe & with un-weathered 100% rework pipe (normative)

C.1 Principle

The capability of weathered pipe to produce good electrofusion joints is determined by ensuring that the weathered surface of the pipe is not degraded significantly. The test applies to peelable pipes.

The electrofusion socket joint test is also required for pipes manufactured with 100% rework (reprocessable). These have not been weathered.

C.2 Test specimen preparation

The test specimen shall consist of two pipes, each of minimum length $5d_n$, and, if appropriate, previously weathered in accordance with BS EN 1056, fused to an approved electrofusion coupler in accordance with GIS/PL2-4. The test pipe shall be one size in range 75mm to 250mm and for peelable pipes SDR21.

C.3 Test procedure

Remove the surface of 100% rework pipe to a depth up to 0.2 mm using tooling in accordance with GIS/PL2-5, before conditioning and subsequent fusion.

Only remove the skin from weathered peelable pipes, before conditioning and subsequent fusion.

Condition the pipes for 8 h at -5 °C ± 2 °C, and condition the fitting for 8 h at 23°C ± 2 °C.

Fuse the coupler to the pipes within the cold storage, or within 1 min of removal from the cold storage, at 39 V or 78 V for the manufacturer's specified fusion time.

Test the specimen for decohesive resistance (peel test) in accordance with ISO 13954.

Annex D RCP Testing Procedures (normative)

D.1 RCP testing of yellow PE80 Pipes

PE80 yellow pipes have to be able to operate at temperatures down to -20 °C at pressures up to: -

- 5.5 bar for SDR11
- 3 bar for SDR17.6
- 2 bar for SDR21 and SDR26

Due to RCP considerations, the maximum operating pressures (MOPs) of PE80 pipes in the larger sizes and lower temperatures have already been reduced (see Table B.1 of this standard). Consequently, RCP tests are conducted at a temperature of 0 °C.

The correlation equation proposed by the ISO TC138/SC4 committee in producing ISO 13477 is: -

$$P_{FS} = 3.6P_{S4} + 2.6 \quad bar \qquad (1)$$

where

P_{FS} – full-scale pressure, bar

P_{S4} – S4 pressure, bar

For GIS/PL2 Part 2, the RCP test shall be conducted on the manufacture's maximum pipe size provided the wall thickness is 15mm or greater.

A full-scale RCP test (BS EN ISO 13478) or an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and test pressure of 2 x MOP for the appropriate pipe size, SDR and 0°C temperature.

The S4 test shall be conducted at a temperature of 0°C and a test pressure (P_{S4}) calculated from equation 1 using a full-scale pressure (P_{FS}) of 2 x MOP for the appropriate pipe size, SDR and 0°C temperature.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedent, as the full-scale test is the reference test.

If successful, approval is given to any smaller pipe size, provided the wall thickness is not greater than that tested.

D.2 RCP testing Peelable (PE100) Pipes

All peelable pipes (SDR21 and SDR26) with a PE100 core shall be able to operate at temperatures down to 0 °C and at operational pressures up to a MOP of 2 bar (see Table B.2 in this standard).

For GIS/PL2 Part 2, the RCP test shall be conducted on 250mm, 315mm and the manufacturer's maximum pipe size.

A full-scale RCP test (BS EN ISO 13478) or an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 4 bar.

The S4 test shall be conducted at a temperature of 0°C and a pressure (P_{S4}) of 0.4 bar

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedent, as the full-scale test is the reference test.

If successful, approval is given to any smaller and intermediate pipe sizes and further to any SDR26 pipe if the SDR21 pipe has RCP approval.

D.3 RCP testing Multilayer Co-extruded Pipes

See Annex G, Clause G.11

D.4 RCP testing of black (PE80 & PE100) pipes with yellow stripes

All black PE80 pipes with yellow stripes shall be able to operate at temperatures down to -20 °C.

All black PE100 pipes with yellow stripes shall be able to operate at temperatures only down to 0 °C.

For both PE80 and PE100 pipes operate at pressures (see Tables B1 & B.2) up to a MOP of:

5.5 bar SDR11
3 bar SDR17.6
2 bar SDR21 & 26

For GIS/PL2 Part 2, the RCP test shall be conducted on the maximum size and thickest wall in the manufacturer's range.

A full-scale RCP test (BS EN ISO 13478) or an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 2 x MOP.

The S4 test shall be conducted at a temperature of 0°C and a pressure (P_{S4}) calculated from the equations in Table 7.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedent, as the full-scale test is the reference test.

If successful, approval is given to any smaller pipe size, provided the wall thickness is not greater than that tested.

Annex E Packaging of coiled and drummed pipe (Minimum Requirements) (normative)

E.1 General

All pipes shall be constrained in a stable configuration, to ensure the safe and controlled dispensing of the pipe without damage or kinks. Any exposed ends of pipes on coils or drums shall be suitably protected from damage (e.g. by means of end caps/plugs).

The maximum external surface temperature of the pipe at time of coiling shall not exceed 35°C. The temperature shall be measured using a contact thermometer probe or agreed alternative at a distance as near as practicable to the point where the pipe enters the coiler.

E.2 Coiled Pipe

E.2.1 General

The dimensions of the pipe coils shall be in accordance with 7.6, Table 6. The maximum width of any coil shall be 1m.

E.2.2 Pipe not greater than 32mm

Coiled pipe not greater than 32mm diameter shall be restrained using an outer covering of “shrink wrap” or equivalent material to enable pipe to be drawn from the centre of the coil.

E.2.3 Pipe greater than 32mm

Coiled pipe greater than 32mm in diameter shall be constrained in a stable configuration by applying a minimum of 2 bands per layer for pipes ≤125mm, and 3 bands per layer for pipes >125mm. The bands shall be equally spaced and staggered on each layer.

Each band shall have a minimum width of 12mm if manufactured from polypropylene material, and 50mm if adhesive tape is used. The breaking load of the banding or adhesive tape supplied as new, shall be >1.5 Tonnes. It shall be possible to remove one layer of the coil without the remainder of the coil being unravelled, and individual layers shall be clearly discriminated by the banding.

For all pipe diameters ≥75mm, 2 security bands shall be applied to the coil, (see Figure E.1) one to retain the inner tail and one to retain the outer tail. These shall be positioned no less than 2 pipe diameters, and no greater than 1metre, from each end. The security bands shall be a minimum of 12.5mm wide, and shall be either plastic coated steel, or steel covered in a protective sleeve.

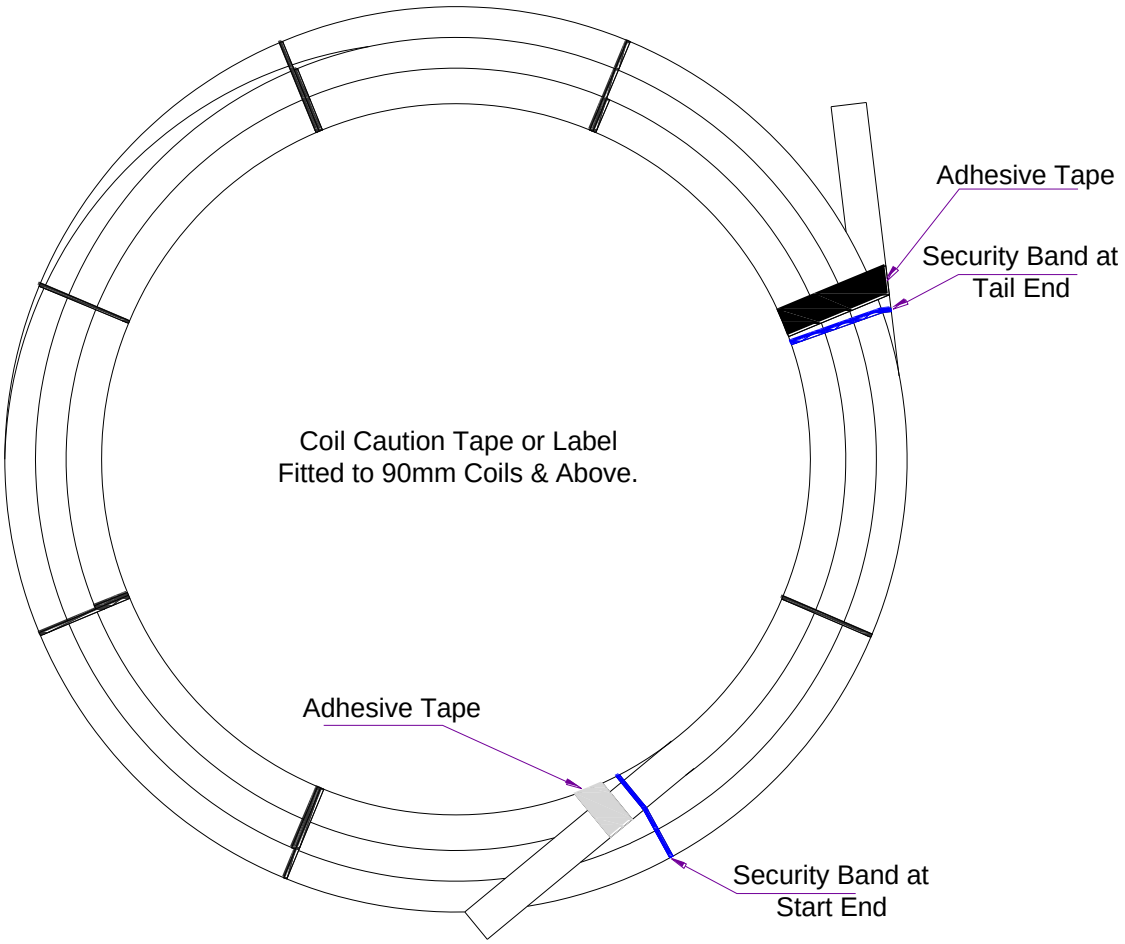
Adhesive tape may be applied to the security bands to minimise slippage and maximise safety.

All banding/adhesive tape shall be sufficiently stable to minimise movement during transport and handling, and shall withstand normal handling loads and stresses.

The ends of the coil shall be nominally straight for a distance greater than two diameters, and both ends shall be free from anchorage holes. If necessary, re-rounding/straightening tools may be used.

For pipe sizes ≥90mm, a label or tape shall also be applied carrying the following warning:

"Before un-strapping, ensure that both pipe ends and coil/drum are firmly mechanically restrained"



NOTE 1 : Banding of individual layers of coils should be in different positions and should be clearly staggered.
NOTE 2 : Position of Security Banding should be not less than 2 pipe diameters, and no greater than 1m from pipe lead and tail ends.

Figure E.1 - Guide to the Banding of individual layers of polyethylene pipe Positions may be subject to variation

E.2.4 Drummed pipe

The pipe shall be dispensed from a trailer or low loader.

Pipe shall be wound on to drums having the principal limiting dimensions as shown in Figure E.2. Drums shall be sufficiently robust to withstand normal site handling, and shall have a permanent indication of unladen weight. The polyethylene pipe shall not stand proud of the drum outer guard rail.

The weight of the drum plus maximum length of polyethylene pipe shall not exceed 2500 kg unless intended for direct use from a low loader; however in this case the system shall incorporate a braking device. The pipe manufacturer shall declare the maximum length of pipe (for a given diameter and SDR) that is compatible with the drum weight and dimension criteria. Security Bands shall be steel.

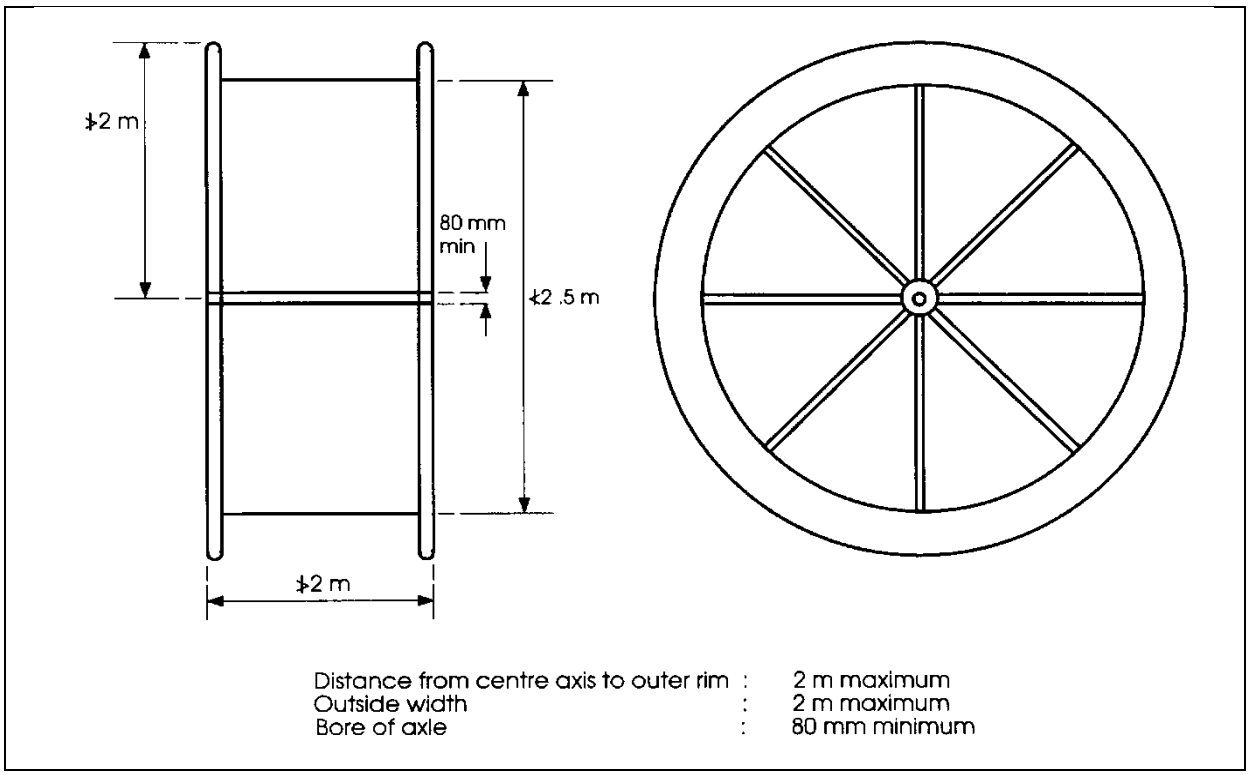


Figure E.2 – Principal limiting dimensions of drums

Annex F Type Approval Testing of Multilayer Pipes produced from 100% Rework (normative)

Pipes produced from re-processable material from multilayer pipes (PE80/PE80 & PE100/PE80) conforming to the requirements in Clause 4.2 of this standard, shall be subject to Type Test as per the Table shown below;

Properties	Performance Requirements	Test Parameters	Test Method
Oxidation induction time (OIT) (thermal stability)	>20 min	3 samples at test temperature of 200 °C 1 set of OIT samples (Outer, Mid, & Inner) per pipe size	BS EN ISO 11357-6
Carbon black content (1)	2.0 % (by mass) to 2.5 % (by mass)	Shall conform to ISO 6964	ISO 6964
Pigment and carbon black dispersion (1)	Grade ≤3.0	Shall conform to BS ISO 18553	BS ISO 18553
Resistance to Slow Crack growth **≥** 63mm (Notched Pipe Test)	No failure during the test period	3 samples as defined in Table 7 (note 2)	BS EN ISO13479
80˚C Hydrostatic Strength after 10% Offset Butt fusion – Sizes **≥** 90mm	Produce Butt Weld to conditions in Annex A No failure during the test period of any test piece.	3 samples as defined in Table 7 (note 2)	Annex A BS EN ISO 1167
Electrofusion joint assemblies - Fusibility @ – 5C, Min Power. De-cohesive resistance (Peel Test)	Ductile over 67% of fusion length	3 samples	Annex C ISO 13954
Yield Strength & Elongation at Break	PE80 Yield Stress / Elongation (2) ≥ 15MPa / ≥ 500% PE100 Peelable pipe ≥ 20MPa / ≥ 500%	1 set of tensile samples per pipe size (note 2)	BS EN ISO6259-1 & ISO 6259-3
Resistance to Rapid Crack Propagation (RCP) S4 Small Scale Test ≥15mm Critical Pressure, Pc	Refer to Table 7 for details of performance requirements.	PE80, Striped & Multilayer – Test pipe size ≥ 180mm SDR11 Peelable pipes PE100 – Test pipe size ≥ 315mm SDR21.	BS EN ISO 13477

Notes
1. Test on carbon black only required if the rework is made into black pipes with yellow stripes or co-extruded pipes with black inner layers.
2. Rework made from a mixture of PE80 / PE100 & PE80 / PE80 materials shall be tested at the PE80 yield stress and hoop stress levels defined in Table 7.

Where a range of pipe sizes is to be tested, the smallest and largest size in the range shall be tested as per the above table. A successful RCP test shall approve smaller pipe diameters.

Annex G Specification for Multilayer co-extruded PE pipes (normative)

G.1 Scope

Annex G to GIS/PL2-2 specifies the ***additional or modified*** requirements for Multilayer co-extruded PE pipe systems in the nominal size range from 16-500mm inclusive SDR11, 13.6, 17.6, 21 & 26 and 225-800mm inclusive SDR21 & 26. The inner layer is to be constructed from black PE80 or black PE100 compound and the outer layer from yellow PE80 compound.

The outer layer shall be less than 45% of the total wall thickness for pipe sizes 16-225mm and less than 15% of the total wall thickness for pipe sizes 250-800mm. The minimum thickness of the outer layer shall be 0.6mm.

The Multilayer PE pipes shall be co-extruded from a single die.
NOTE: separate extrusion of the outer layer over the inner layer is not permitted.

The co-extruded pipes 16-500mm inclusive SDR11, 13.6, 17.6, 21 & 26 pipes are intended for use at a maximum operating pressure up to 5.5 bar. For these pipes with the inner layer of black PE80, the operating temperature range is -20 °C to 40 °C.

The co-extruded pipes 225-800mm inclusive SDR21 & 26 pipes are intended for use at a maximum operating pressure up to 2 bar. For these pipes with the inner layer of black PE100, the operating temperature range is only 0 °C to 40 °C.

The multilayer pipes are designed to be suitable for butt fusion to GIS/PL2-3 and electrofusion fittings to GIS/PL2-4 with ancillary tooling to GIS/PL2-5.

The multilayer pipes are designed to be suitable for squeeze-off using tools to GIS/PL2-7.

G.2 Geometrical definitions

G.2.1
total wall thickness e
measured total wall thickness at any point around the circumference of the component, rounded up to the nearest 0.1 mm.

G.2.2
layer wall thickness e_l
measured wall thickness of the layer at any point around the circumference of the component, rounded up to the nearest 0.1 mm.

G.2.3
minimum layer wall thickness e_{lmin}
minimum value of the measured wall thickness of the layer at any point around the circumference of the component, rounded up to the nearest 0.1 mm.

G.3 Material

G.3.1 Construction

The Multilayer PE pipe shall be made of an outer layer and an inner layer with each layer meeting the requirements of GIS/PL2-1.

G.4 General

G.4.1 Colour

The outer layer shall be coloured yellow (see GIS/PL2-1)
NOTE: There shall be no stripes on the outer layer

G.5 Geometry

G.5.1 Mean outside diameters, wall thicknesses and tolerances

The mean outside diameters, d_{em} and wall thicknesses, *e* shall apply to the entire pipe consisting of both layers and shall conform to **Table 3**.

G.5.2 Declaration of layer dimensions and tolerances

The following information shall be declared by the manufacturer.

- Thickness of the outer layer and tolerances
- Thickness of the inner layer and tolerances

G.5.3 Layer thickness dimensions

The thickness of each layer measured by means of e.g. a microscope shall be within the tolerances declared by the manufacturer.

G.6 Pressure rating design

G.6.1 Long-term hydrostatic strength

For design purposes, the value of the long-term hydrostatic strength of the multilayer pipes at a time 50 years and at a temperature of 20 °C shall be determined to obtain the long-term pressure strength, *P*.

The long-term hydrostatic strength, σ_{LPL}, shall be calculated using the data determined in accordance with ISO 9080 for each individual pressure-bearing polymer layer. The addition rule related to each pressure bearing layer assumes complete interlayer fusion.

The mean of the tolerance range of each stress designed layer, as specified by the pipe producer, shall be used for the calculation.

G.6.2 Pressure strength calculation

The long-term pressure strength of the pipe, *P* expressed in bar, shall be calculated using the following equation:

$$P = 20\left[\frac{\sigma_o\ e_{lo}}{(D_o - e_{lo})} + \frac{\sigma_i\ e_{li}}{D_i - e_{li}}\right] \qquad \text{…… equation 1}$$

where

P is long-term pressure strength of the pipe in bar
σ_o is the lower confidence limit of the predicted hydrostatic strength (σ_{LPL}) of the outer layer in MPa.
e_{lo} is the *mean* wall thickness of the outer layer in mm
D_o is the outside diameter of the outer layer in mm

σ_i is the lower confidence limit of the predicted hydrostatic strength (σ_{LPL}) of the inner layer in MPa.
e_{fi} is the *mean* wall thickness of the inner layer in mm
D_i is the outside diameter of the inner layer in mm

NOTE The equation does not take into account interaction effects between layers. Validation of the use of the equation is necessary for each design of multilayer pipe.

G.6.3 MOP, overall service (design) coefficient and log-term pressure strength

The maximum operating pressure (MOP) is up to 5.5 bar depending on the pipe's SDR.
The minimum overall service (design) coefficient(C) shall be 2.9.
The minimum long-term pressure strength of the multilayer co-extruded pipes (*P*) shall be derived from the equation 2.

$$MOP \leq \frac{P}{C} \qquad \text{……equation 2}$$

G.6.4 Validation of long-term hydrostatic strength calculation

A pressure test shall be carried out at 80 °C for 3,000 h on *two* pipes. For PE80/PE80 multilayer pipes, the pressure test shall be chosen from sizes in the range 75-225mm, whilst for PE100/PE80 pipes the size range is 225-800mm. This shall include the maximum and minimum size in the manufacturer's range. Extensions to the manufacturer's size range shall require testing at the maximum additional size.

The multilayer pipe shall withstand the pressure, 95% *P* calculated from each layers σ_{LPL} regression characteristic for 3000h at 80 °C, using equation 1.

G.7 Structural performance

When tested in accordance with the test methods as specified in **Table G.1** using the indicated parameters, the pipe shall have the structural performance conforming to the requirements given in **Table G.1**.

Table G.1 Structural performance

Characteristic	**Requirement**	**Test parameters**		**Test method**
Integrity of the structure after deflection	≥ 80 % of the initial stiffness value	Deflection	30% of d_{em}	BS EN ISO 9969 & BS EN ISO 13968
		Position of test piece	at 0°, 120° and 240° from the upper plate.	

For the determination of the integrity of the structure by deflection of Multilayer PE pipes, the following procedure shall be applied:

(a) determine the initial ring stiffness of the pipe according to BS EN ISO 9969;
(b) carry out the ring flexibility test according to BS EN ISO 13968;
(c) after a 1h period for recovery, determine again the ring stiffness of the pipe according to BS EN ISO 9969;
(d) The ring stiffness of the multilayer pipes shall be at least 80 % of the initial ring stiffness.

G.8 Butt fusion jointing compatibility: fitness-for-purpose
The Multilayer PE pipe shall meet the requirements in **10.1, 10.2** and **Table 11**. The 80°C hydrostatic test pressure and time shall be selected from **Table 8**.

G.9 Mechanical properties

G.9.1 General
Unless specified otherwise, the test parameters and requirements for Multi-layered PE pipe shall be as for PE80 or PE100 pipe (without a skin) in **Table 7** as appropriate.

G.9.2 Long-term Hydrostatic Strength at 20 °C
The test shall be as in **Table 7**, except the multilayer pipe shall withstand the pressure, 95%*P* calculated from each layers σ_{LPL} regression characteristic for 100 h and 5000 h at 20 °C using equation 1.

G.9.3 80°C hydrostatic strength after squeeze-off
The Multilayer PE pipe (up to 500mm) shall meet the requirement in **Tables 7 & 8**.
After pressure testing the two areas of maximum compression ("pinch points") shall be sectioned circumferentially and examined for delamination between the layers.

G.9.4 80°C hydrostatic strength after offset butt fusion
The Multilayer PE pipe shall meet the requirement in **Tables 7 & 8**.

G.9.5 Yield strength and elongation at break
The Multilayer PE pipe shall meet the requirement of minimum yield strength of 15 MPa (PE80 core) or 20MPa (PE100 core) and minimum elongation of 500% (**Table 7)**. There shall be no delamination of the layers during testing up to 500% elongation.

G.9.6 Resistance to slow crack growth (notched pipe test)
The Multilayer PE pipe shall meet the requirement in **Table 7** with the test pressure and time selected from **Table 9**.

G.9.7 Rapid crack propagation
The Multilayer PE pipe shall meet the requirement in **Table 7** at 0 °C. This shall be the maximum pipe size and maximum wall thickness of that size in the manufacturer's range. The pipe wall thickness must be 15mm or greater even if this means using a smaller diameter pipe (**see also G.11**).

G.10 Physical properties

G.10.1 Oxidation induction time (OIT)
Each PE layer shall meet the requirements in **Table 10**.

G.10.2 Melt mass flow rate (MFR)
Each PE layer shall meet the requirements in **Table 10**.

G.10.3 Longitudinal reversion
The Multilayer PE pipe shall meet the requirement in **Table 10.** There shall be no delamination between the layers.

G.11 Rapid crack propagation requirements for multilayer pipe

Co-extruded multilayer PE pipes with a black PE80 inner layer shall be able to operate at temperatures down to -20 °C and at operational pressures up to a MOP of 5.5 bar.

Co-extruded multilayer PE pipes (SDR 21 & 26) with a black PE100 inner layer shall be able to operate at temperatures down to 0 °C and at operational pressures up to a MOP of 2 bar.

For GIS/PL2 Part 2, the RCP test shall be conducted on the maximum size and thickest wall in the manufacturer's range (t ≥ 15mm).

A full-scale RCP test (BS EN ISO 13478) or an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 2 x MOP bar.

The S4 test shall be conducted at a temperature of 0°C and a pressure (P_{S4}) calculated from the formula in Table 7 e.g. test at 0.4 bar for a MOP of 2 bar

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedent, as the full-scale test is the reference test.

If successful, approval is given to any smaller pipe size, provided the wall thickness is not greater than that tested. Approval of the thinner SDR26 pipe is granted if the SDR21 has RCP approval.

G.12 Type Testing of multilayer pipe

G.12.1 General

The test programme in accordance with **Table 13** shall be carried out on each size of pipe, except where a range of pipe sizes in a size group permits a reduced number of test sizes (see **13.2**).

Pipes, when tested in accordance with **Table 13 (**modified according to this **Annex G**), shall conform to the performance requirements specified in **Table 13** (modified according to this **Annex G**).

G.12.2 Selection of test pipe sizes

Pipe size groups shall be in accordance with **Table 14**.

The manufacturer shall define the product range in each size group and choose for testing evenly distributed diameters over the product range. Samples shall comprise of the smallest and largest of the range manufactured.

The successful testing will validate pipe with the same diameter but with thinner wall thickness.

Where a manufacturer extends his production beyond his approval, additional relevant type testing shall be carried out.

G.12.3 Additional tests to Table 13 for Multilayer PE pipes

Table G.2 Properties of pipes that require type testing (TT) per compound

Properties			**Shall conform to:**	**Sampling procedure** [a)]	**No. of test pieces** [b)]	**No. of measurements per test piece**
Mechanical properties	Validation of long-term strength calculation	80°C Hydrostatic strength (un-notched)	**G.6.4**	Two diameters/ size group .	1	1
	Structural perfor-mance	Ring stiffness	**G.7**	Two diameters/ size group .	1	1

G.13 Marking

The Multilayer PE pipe shall meet the requirements in clause **15**.

No special requirements are required for Multilayer co-extruded PE pipes except for “Material and designation” in **Table 17**, the pipe shall be marked, PE100-core/PE80, PE80-core/PE80.

G.14 Delivery conditions

The Multilayer PE pipe shall meet the requirements in clause **16**.

Annex H Rapid Crack Propagation (RCP) - Discussion and Requirements (informative)

H.1 Summary

H.1.1 General

Rapid crack propagation (RCP) is the name used to describe a brittle crack travelling down a pipeline at very high speeds. RCP is more likely to occur with large diameter polyethylene (PE) pipes operating at high pressures and low temperatures when crack speeds of up to 1000 km/hr (300 m/s) are produced. Consequently, the PE pipeline system has to be designed to ensure this failure mode cannot occur either during pressure testing or later in service.

The two RCP test methods – full-scale (BS EN ISO 13478) and S4 (BS EN ISO 13477) are described, together with the correlation between the test pressures derived from these two methods.

Conventional yellow PE80 pipes are operated at pressures up to 5.5 bar but the maximum operating pressures (MOP) are derated for larger pipe sizes and lower operating temperatures. They are operated down to -20°C.

Peelable pipes have a yellow skin over a black or natural PE100 core. These are operated down to 0 °C at maximum operating pressures up to 2 bar for all sizes and temperatures.

PE80 black pipes with yellow stripes are to be operated up to 5.5 bar and at a temperature down to -20 °C, whereas PE100 black pipes (SDR21 & 26 only) with similar yellow stripes are to operated up to 2 bar but only down to 0 °C.

Multilayer pipes have a yellow PE80 layer co-extruded over a black PE80 inner layer or a yellow PE80 layer co-extruded over a black PE100 inner layer. The black PE80 inner layer pipes are to be operated down to -20 °C, whereas the black PE100 inner layer pipes (SDR21 & 26 only) are only operated down to 0 °C.

Conventional orange PE100 pipes are operated at pressures up to 7 bar but must also be operated at temperatures of 0 °C and above.

A multilayer pipe with black PE100 inner layer and an orange PE100 outer layer is also produced for up to 7 bar and at temperatures of 0 °C and above.

The detailed RCP testing requirements are given and discussed for Gas Industry Specifications: -

GIS/PL2 Part 1 [General & PE compounds]

GIS/PL2 Part 2 [yellow PE80, yellow striped, peelable and multilayer PE pipes]

GIS/PL2 Part 8 [PE100 yellow-orange pipe and multilayer PE100/PE100 pipes]

The full-scale test at 0 °C and the appropriate pressure should be conducted. Alternatively, the S4 test may be used at the same or lower temperature but with the reduced test pressure calculated from the correlation equation (**H.4.2**). If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful, takes precedence, as the full-scale test is the reference test.

H.1.2 PE80 yellow Pipes – Sizes 16 – 800mm at SDR 11, 17.6, 21 & 26 at up to 5.5 bar

For GIS/PL2-1 compliance, the full-scale RCP test shall be conducted on one pipe size (wall thickness, t ≥15mm) at 0°C and a pressure of 2 x maximum operating pressure (MOP) for the appropriate pipe size and SDR and 0°C temperature.

For GIS/PL2-2, the full-scale RCP test shall be conducted on the manufacturer's maximum pipe size (t ≥15mm) at 0 °C and a pressure of 2 x maximum operating pressure (MOP) for the appropriate pipe size and SDR and 0°C temperature. If successful, approval is also given to any smaller pipe size, provided the wall thickness is not greater than that tested.

In both cases, the S4 test method at 0°C may be used instead and at the reduced test pressure calculated from the correlation equation (**H.4.2**).

H.1.3 Yellow Striped (black PE80) Pipes – Sizes 16 – 225mm at SDR11, 17.6, 21 & 26 at up to 5.5 bar

For GIS/PL2-1, the full-scale RCP test shall be conducted on one pipe size (wall thickness, t ≥15mm) at 0 °C and a pressure of 2 x maximum operating pressure (MOP) for the appropriate pipe size and SDR. and 0°C temperature.

For GIS/PL2-2, the full-scale RCP test shall be conducted on the manufacturer's maximum pipe size (t ≥15mm) at 0°C and a pressure of 2 x maximum operating pressure (MOP) for the appropriate pipe size and SDR and 0°C temperature. If successful, approval is also given to any smaller pipe size, provided the wall thickness is not greater than that tested.

In both cases, the S4 test method at 0°C may be used instead and at the reduced test pressure calculated from the correlation equation (**H.4.2**).

H.1.4 Yellow Striped (black PE100) Pipes – Sizes 225 – 800mm at SDR 21 & 26 at up to 2 bar

For GIS/PL2-1, the full-scale RCP test shall be conducted on one pipe size (wall thickness, t ≥15mm) at 0 °C and a pressure of 2 x maximum operating pressure (MOP) i.e. 14 bar for PE100 SDR11 pipe. For GIS/PL2-2, the full-scale RCP test shall be conducted on the manufacturer's maximum pipe size (t ≥15mm) at 0 °C and a pressure of 4 bar (2 x maximum operating pressure, MOP). If successful, approval is also given to any smaller pipe size, provided the wall thickness is not greater than that tested and further to any SDR26 pipe if the SDR21 pipe has RCP approval.

In both cases, the S4 test method at 0 °C may be used instead and at the reduced test pressure calculated from the correlation equation (**H.4.2**) i.e. GIS/PL2-1 at 3.2 bar; GIS/PL2-2 at 0.4 bar.

H.1.5 Peelable Pipes (natural or black PE100 core) – Sizes 225 – 800mm at SDR 21 & 26 at up to 2 bar

For GIS/PL2-1, the full-scale RCP test shall be conducted on one pipe size (t ≥15mm) ***without the skin*** at 0 °C and a pressure of 2 x maximum operating pressure (MOP) for PE100 pipe i.e. 14 bar for PE100 SDR11 pipe.

For GIS/PL2-2, the full-scale RCP test shall be conducted on 250 mm, 315 mm and the manufacturer's maximum pipe size at 0 °C and a pressure of 4 bar (2 x MOP). The skin is left intact. If successful, approval is given to any smaller and intermediate pipe sizes and further to any SDR26 pipe if the SDR21 pipe has RCP approval.

In both cases, the S4 test method may be used instead at maximum temperatures of 0 °C and at the test pressure calculated from the correlation equation (**H.4.2**) i.e. GIS/PL2-1 at 3.2 bar; GIS/PL2-2 at 0.4 bar.

H.1.6 Multilayer Pipes (PE80 inner layer) – Sizes 16 – 225mm at SDR11, 17.6, 21 & 26 at up to 5.5 bar

For GIS/PL2-1 and the PE80 compound, the full-scale RCP test shall be conducted on one pipe size (wall thickness, t ≥15mm) at 0 °C and a pressure of 2 x maximum operating pressure (MOP) for the appropriate pipe size and SDR. and 0°C temperature.

For GIS/PL2-2, the full-scale RCP test shall be conducted on the manufacturer's maximum pipe size (t ≥15mm) at 0 °C and a pressure of 2 x MOP for the appropriate pipe size and SDR and 0°C temperature. If successful, approval is also given to any smaller pipe size, provided the wall thickness is not greater than that tested.

In both cases, the S4 test method may be used instead at maximum temperatures of 0 °C and at the test pressure calculated from the correlation equation (**H.4.2**).

H.1.7 Multilayer Pipes (PE100 inner layer) – Sizes 225 – 800mm at SDR21 & 26 at up to 2 bar

For GIS/PL2-1 and the PE100 inner layer pipe, the full-scale RCP test shall be conducted on one pipe size (t ≥15mm) at 0 °C and a pressure of 2 x MOP i.e. 14 bar for PE100 SDR11 pipe.

For GIS/PL2-2, the full-scale RCP test shall be conducted on the manufacturer's maximum pipe size (t ≥15mm) at 0 °C and a pressure of 4 bar (2 x MOP). If successful, approval is given to any smaller and intermediate pipe sizes and further to any SDR26 pipe if the SDR21 pipe has RCP approval.

In both cases, the S4 test method may be used instead at maximum temperatures of 0 °C and at the test pressure calculated from the correlation equation (**H.4.2**) i.e. GIS/PL2-1 at 3.2 bar; GIS/PL2-2 at 0.4 bar.

H.1.8 PE100 orange Pipes or Multilayer PE100/PE100 pipes (32-630mm)– SDR11 at up to 7 bar

These pipes are made from PE100 only. They may be constructed entirely of orange PE100 or an inner layer of black PE100 and a coextruded orange PE100 outer layer.

For GIS/PL2-1, the full-scale RCP test shall be conducted on one pipe size (t ≥15mm) at 0 °C and a pressure of 14 bar (2 x MOP) for *each* PE100 compound.

For GIS/PL2-8, the full-scale RCP test shall be conducted on the manufacturer's maximum pipe size (t ≥15mm) at 0 °C and a pressure of 14 bar (2 x MOP). If successful, approval is also given to any smaller pipe size.

In both cases, the S4 test method may be used instead at a maximum temperature of 0 °C and at the reduced test pressure of 3.2 bar calculated from the correlation equation (**H.4.2**).

H.2 Introduction

Rapid crack propagation (RCP) is the name used to describe a brittle crack travelling down a pipeline at very high speeds, **Figure H.1**. RCP is more likely to occur with large diameter polyethylene (PE) pipes operating at high pressures and low temperatures when crack speeds of up to 1000 km/hr (300 m/s) are produced. Once RCP conditions are produced, then the whole section of the pipeline may be lost. It could occur without warning and the results could be catastrophic. Consequently, the PE pipeline system has to be designed to ensure this failure mode cannot occur either during air pressure testing (commissioning) at 1.5 times maximum operating pressure (MOP) or later in service, carrying gas.

The pipeline's maximum operating pressures (MOP) are given in **Annex B** of the main document and GIS/PL2-8 for 7 bar pipe.

H.3 RCP Initiation & Arrest

Even if the conditions for RCP are present in the PE pipeline, a high speed crack first has to be initiated in the pipe wall to produce RCP. Normally, PE is very tough and cracks are difficult to initiate under normal conditions. A high speed crack may initiate by impact by heavy machinery e.g. back-hoe excavator, particularly if the teeth or bucket are sharp, however, the most likely cause of initiation is the sudden brittle failure of a defective butt fusion joint. Under axial bending loads, the crack can initiate at one small part of the weld's circumference. The crack then rapidly travels around the weld interface, but as it does so, the hoop stress in the pipe wall (due to the internal pressure) deflects the circumferential high speed crack to run along the length of the pipe. Whether this axial high speed crack arrests within a few metres or continues to propagate depends entirely on the pipeline conditions.

Once RCP conditions are established the crack will continue to run down the pipeline as the pipe in front of the crack tip is under exactly the same conditions as the section it has just cracked. The high speed crack will propagate through any butt fusion joints. Naturally, the crack will be stopped by mechanical joints - at valves for example. It is believed that an electrofusion fitting will also stop the crack and although there is some evidence for this, it has not yet been demonstrated conclusively.

H.4 RCP Test Methods

H.4.1 Full-Scale Test

H.4.1.1 Normal Full-Scale Technique

Test methods have been developed to assess the resistance of plastic pipes to RCP and are described in detail in BS EN ISO 13478 (full-scale) (**1**) and BS EN ISO 13477 (S4) (**2**).

The full-scale method simulates what could happen in service by testing a long length of PE pipe at the expected minimum below ground temperature. From historical information, it is assumed that a temperature of 0 °C is reached below ground at the normal pipe burial depth of 750 mm once in every 50 years in the UK.

The test method requires that at least 14 m of PE pipe at 0 °C is be used for the test. This is connected to a steel pipe reservoir, at least 28 m long, to simulate a longer PE pipeline.

Figure H.1 RCP in 315 mm SDR 17.6 PE80 pipe

As the gas exhausts down the pipe during RCP, the crack tip generally lags behind the gas decompression wave front that spreads down the pipe (see **Appendix H.A** of this **Annex H)**. Consequently, the gas pressure at the crack tip, which is driving the crack forward, is less than the original pipe pressure.

Each full-scale test determines whether RCP will occur under the pipe's particular conditions i.e. pressure, pipe size, temperature, etc. However from a series of tests, the full-scale critical pressure (P_{cFS}) between arrest and RCP under practical operating conditions can be measured at a temperature, normally of 0 °C. The critical pressure is conservatively taken as the highest arrest pressure; it is not an average of the highest arrest pressure and the lowest propagation pressure.

If the critical pressure for a particular pipe size is higher than that required by the gas utility, then all smaller diameter pipes of the same standard dimension ratio (SDR) will also be satisfactory. Smaller diameter pipes of the same SDR always have higher critical pressures.

Pipe Specifications GIS/PL2- 2 & 8 require the crack to arrest at a full-scale test pressure of 2 x MOP.

H.4.1.2 Modifications to Full-Scale Test Technique for PE100 Pipes & Pipes with PE100 Inner Layers or Cores

The full-scale test method is also used for PE100 pipes, multilayer pipes with an inner PE100 layer or peelable pipes with PE100 cores, though the technique is usually slightly modified

for these high RCP resistant PE100 pipes by first initiating a high-speed crack in a length of PE80 pipe before crossing a butt weld into the PE100 test section. The details are given in BS EN ISO 13478.

H.4.2 S4 Test Technique & Correlation Equation

A Small-Scale Steady-State (S4) laboratory test (BS EN ISO 13477) was developed as a cheaper and quicker alternative to the full-scale test method. The test uses pipe lengths of $7d_n$ (e.g. 1.75 m for 250 mm pipe), which are very much shorter than the 14 m (minimum) used in the full-scale tests. A system of internal baffles is also fitted inside the pipe bore that effectively stop axial gas exhaustion throughout the test, thus maintaining gas pressure at the crack tip at the initial test pressure, **Appendix H.A**.

Again, the test measures the critical pressure (P_{cS4}) between arrest and RCP but, because of the higher crack tip pressure during the test, P_{cS4} will always be lower than the equivalent P_{cFS}. A correlation between the full-scale and S4 results is therefore necessary in order to enable the S4 results to be recalculated to an equivalent full-scale critical pressure. A correlating equation has been developed for PE materials, but in cases of dispute or when the S4 test is not available for the larger sizes, the full-scale test is recognised as the reference test.

The correlation equation proposed by the ISO TC138/SC4 committee in producing ISO 13477 (**Appendix H.A**) is: -

$$P_{cFS} = 3.6P_{cS4} + 2.6 \quad bar \qquad (1)$$

Any pressure in the S4 test can be converted the equivalent pressure in the full-scale test using the equation but it is generally used for converting the S4 critical pressure (P_{cS4}), derived from a series of S4 tests, to the equivalent full-scale critical pressure (P_{cFS}).

All decisions on the suitability of the PE pipe for operational use are based upon the full-scale pressure (P_{FS}) or the equivalent full-scale pressure recalculated from the S4 pressure (P_{S4}).

Pipe specifications GIS/PL2 Parts 2 & 8 require the crack to arrest at a full-scale test pressure of 2 x MOP (see **Annex B** of the main document). When the S4 test is used, the full-scale test pressure requirements in the specifications are back-calculated to the equivalent S4 test pressure before conducting the S4 test (**H.4.2**).

H.5 RCP Testing of PE80 Pipes and yellow striped PE80 Pipes

Specifications require yellow PE80 pipes and black PE80 pipes with yellow stripes to be able to operate at temperatures down to -20°C at pressures up to: -

5.5 bar for SDR11
3 bar for SDR17.6
2 bar for SDR21 and SDR26

Due to RCP considerations, the MOPs of PE80 pipes in the larger sizes and lower temperatures have been reduced. The maximum operating pressures (MOP) are given in **Annex B** of the main document. Consequently, RCP tests are conducted at a “spot-check”

temperature of 0 °C to ensure they have at least the same RCP resistance as the original PE80 pipes from which the de-rated MOPs were obtained. The full-scale test pressures are 2 x MOP.

Alternatively, the S4 test at 0 °C can be used. Note the S4 test pressure (P_{S4}) that the pipe must pass in the S4 test is calculated from the BS/EN/ISO correlation equation (**H.4.2**, **equation 1**) using 2 x MOP.

e.g. 250mm SDR11 PE80

Test Temperature = 0 °C

MOP = 4 bar (see Table B.1)

Therefore, P_{FS} = 2 x MOP = 8 bar

$$P_{S4} = \frac{(P_{FS} - 2.6)}{3.6} = 1.5\ bar$$

Consequently, the S4 test would have to demonstrate crack arrest at a minimum test pressure of 1.5 bar at 0 °C.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

For **GIS/PL2 Part 1**, the RCP test has to be conducted by the compound manufacturer only on one pipe size, provided the wall thickness is 15 mm or greater.

For **GIS/PL2 Part 2**, the RCP test is conducted on the manufacturer's maximum pipe size (≥15mm). If successful, approval is given to any smaller pipe size, provided the wall thickness is not greater than that tested (see GIS/PL2 Part 2: Table 13).

Extracts from the detailed specification requirements from GIS/PL2-1, GIS/PL2-2 and GIS/PL2-8 are given in **Appendix H.B of this Annex H**.

H.6 RCP Testing Peelable (PE100) Yellow Pipes

The specifications require all peelable pipes (SDR21 and SDR26) with a PE100 core to be able to operate at temperatures down to 0 °C and at operational pressures up to a MOP of 2 bar.

Consequently, the RCP test for all sizes must be conducted at 0°C. For all sizes, the full-scale test pressure will be 4 bar and for the S4 test, a pressure of 0.4 bar. Either the full-scale or S4 test can be used. Again if the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

It has been observed that the grade of the polypropylene skin, its thickness and the adhesion to the PE100 core pipe, all have a complex effect on the RCP performance. Consequently, the polypropylene grade, thicknesses and adhesion levels (and tolerances where appropriate) need to be declared by the pipe manufacturer in seeking Type Testing approval. Modifications to the current GIS/PL2 Part 2 have been necessary, together with additional test method(s).

For GIS/PL2 Part 1, there are no RCP test requirements for peelable pipes because the skin has an effect on the results and this is controlled by the pipe manufacturer. However, it is still necessary to demonstrate the RCP performance of the PE100 core pipe (≥15mm),

without any skin, meets the basic RCP requirements for PE100 pipe at 0 °C by either the full-scale or S4 test methods (see **H.8**). It is only in GIS/PL2 Part 2 that the peelable pipe, with its skin, is tested for RCP resistance down to 0 °C.

Therefore, for GIS/PL2 Part 1, the RCP test has to be conducted by the compound manufacturer only on one pipe size (without any skin) provided the wall thickness is 15mm or greater. For all sizes the test temperature is 0°C, with a full-scale test pressure of 14 bar for an SDR11 pipe or an equivalent S4 test pressure of 3.2 bar. In principle, a higher SDR (thinner-walled) pipe is acceptable (wall thickness must still be 15 mm or greater) but then the MOP has not been defined, which makes it difficult to set the test pressure of 2 x MOP.

The RCP test in GIS/PL2 Part 2 is conducted on a range of sizes: 250mm, 315mm and the manufacturer's maximum size e.g. 800mm. The polypropylene skin at low temperatures is generally more brittle than the PE100 and so may result in crack initiation that can jump across the interface into the PE100 pipe core. Though the skin thicknesses are controlled in the Specification (Table 5), they are almost constant across the entire diameter range and the current tolerances are relatively wide. It will not become clear until further research is completed on effect of the skin, whether a relatively thick skin on a smaller diameter pipe is more likely to reduce the RCP resistance than a relatively thin skin on a larger diameter, thicker-walled pipe. Hence at this stage, it cannot be assumed that smaller pipe sizes would have higher critical pressure, so testing a range of sizes is currently required.

For GIS/PL2 Part 2, either the full-scale or S4 RCP test can be used. The full-scale test for all sizes is conducted at 0 °C at a test pressure of 4 bar using a PE80 SDR21/26 pipe as the initiation pipe if necessary (see **H.4.1.2**). The S4 test for all sizes is also conducted at 0 °C with a test pressure of 0.4 bar, as calculated from equation 1. Coincidentally, an S4 test temperature of approximately -20 °C is necessary to obtain the correct initiation conditions (see **H.8**)

If successful, approval is given to any smaller and intermediate pipe size, and is also conferred on any SDR26 pipe if the SDR21 pipe of equivalent OD has RCP approval (see GIS/PL2 Part 2: Table 13).

H.7 RCP Testing Multilayer Pipes

The specifications require multilayer pipes, where the inner layer is constructed from black PE80 compound and the outer layer is a yellow PE80 compound, have to be able to operate at temperatures down to -20°C and at a maximum operational pressure of 5.5 bar.

Multilayer pipes, where the inner layer is constructed from black PE100 compound and the outer layer is a yellow PE80 compound, have to be able to operate at temperatures down to only 0°C. As the pipes are only SDR21 or SDR26, the maximum operational pressure is 2 bar.

The RCP test for all types and sizes are conducted at 0°C. For all sizes, the full-scale test pressure will be 2 x MOP and for the S4 test, a pressure calculated from the equation (**H.4.2**). Either the full-scale or S4 test can be used. Again if the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

For GIS/PL2 Part 1, the RCP tests have to be conducted on both the PE100 and the PE80 compounds by the compound manufacturer(s) but only on one pipe size provided the wall thickness is 15mm or greater. For all sizes the test temperature is 0°C. The PE100 compound is to be tested at a full-scale test pressure of 14 bar for an SDR11 pipe or an equivalent S4 test pressure of 3.2 bar. In principle, a higher SDR (thinner-walled) pipe is

acceptable (wall thickness must still be 15 mm or greater) but then the MOP for PE100 pipes has not been defined, which makes it difficult to set the test pressure of 2 x MOP. The PE80 compound is to be tested at a full-scale test pressure of 2 x maximum operating pressure (MOP) for the appropriate pipe size, SDR and 0°C temperature. The equivalent PE80 S4 test pressure at 0°C is calculated from equation 1 (**H.4.2**).

The RCP test in GIS/PL2 Part 2 is conducted on the manufacturer's maximum size of each type of multilayer pipe e.g. 225mm or 800mm. For GIS/PL2 Part 2, either the full-scale or S4 RCP test can be used. The full-scale test for all sizes is conducted at 0 °C at a test pressure of 2 x MOP using a PE80 as the initiation pipe for PE100 inner layer pipes, if necessary (**see H.4.1.2**). The S4 test for all sizes is also conducted at 0 °C with a test pressure calculated from equation 1. It is possible that an S4 test temperature of below 0 °C is necessary to obtain the correct initiation conditions in which case the S4 RCP test shall conducted at this lower temperature but with the same test pressure (see **G.8**)

If successful, approval is given to any smaller and intermediate pipe size, and is also conferred on any SDR26 pipe if the SDR21 pipe of equivalent OD has RCP approval (see GIS/PL2 Part 2: Table 13).

H.8 RCP Testing PE100 (Orange) Pipes

The specifications require that all PE100 (orange) pipes (which are all SDR11) are able to operate at a MOP of 7 bar but, only at temperatures of 0 °C and above. RCP testing is identical whether they are constructed of all PE100 orange compound or are coextruded with a black PE100 inner layer and an orange PE100 outer layer.

Consequently, the RCP test for all sizes must be conducted at 0 °C. For all sizes, the full-scale test pressure will be 14 bar and for the S4 test, a pressure of 3.2 bar. Either the full-scale or S4 test can be used. Again if the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

The full-scale method uses a PE80 crack initiation pipe length, butt welded onto the end of the PE100 test length (see **H.4.1.2**).

The S4 test can also be used for testing PE100 pipes. However, for the test to be valid it is necessary to prove the S4 initiation conditions can produce the start of a high speed crack into the test length (see BS EN ISO 13477). Otherwise, any crack arrest may have resulted from inadequate crack initiation rather than the pipe's test conditions (pressure, temperature, etc.). At 0 °C, suitable initiation conditions cannot be produced with modern PE100 compounds due to their high toughness, but it is possible to produce the required conditions at lower temperatures e.g. -20 °C. If, whilst using the same initiation conditions at the same low temperature, the S4 pipe test demonstrates crack arrest for the 3.2 bar test pressure, then the pipe would also show crack arrest at higher temperatures e.g. 0 °C. The RCP critical pressure never decreases on raising the temperature from -20 °C to 0 °C. Consequently, satisfactory RCP performance of the pipe would have been demonstrated for this pressure at 0 °C. Although the test is more severe than actually required, it is an effective way of addressing the problem of creating suitable crack initiation conditions and conducting a valid test. In practice, this test method works well with modern PE100 pipe compounds.

For GIS/PL2 Part 1, the RCP test has to be conducted by the manufacturer for each compound on one SDR11 pipe size provided the wall thickness is 15mm or greater. For all sizes the test temperature is 0°C, with a full-scale test pressure of 14 bar or a S4 test pressure of 3.2 bar.

For GIS/PL2 Part 8, the RCP test is conducted on the manufacturer's maximum pipe size, provided it has a wall thickness of 15mm or greater. For all sizes the test temperature is 0°C, with a full-scale test pressure of 14 bar or an S4 test pressure of 3.2 bar. If successful, approval is given to any smaller pipe size (see GIS/PL2 Part 8: Table 11 Note c).

H.9 Application of the Critical Pressure Data

The critical pressure obtained from full-scale tests (or converted from S4 critical pressures) on a particular PE pipe size and SDR is not normally used to predict the RCP performance of larger pipe sizes and/or different SDRs. All that can be inferred is that the critical pressures of the larger sizes will be not be higher for the same SDR. Conversely, if the critical pressure is known for a PE pipe size and SDR, then the critical pressure of a smaller pipe size, but of the same compound and SDR will be higher. Naturally, this assumes the intrinsic RCP resistance of the PE compound/pipe batch is unchanged.

PE80 pipes are designed to operate down to -20 °C, though the probability of operating at this temperature is not high. It has been estimated that a PE main buried at the normal burial depth of 750 mm may only reach 0 °C once in 50 years in the UK, though the reference data for this is now unknown.

However, downstream of a pressure reduction station (PRS), the gas expansion will decrease the temperature by approximately 0.5 °C per bar pressure reduction. For example, a pressure reduction from 19 bar to 4 bar will cause the temperature to drop by 7.5 °C. In winter, the gas may already be at a temperature of +4 °C (for example), therefore the de-pressurised gas will be entering the downstream pipework at -3.5 °C. Naturally, the gas will warm as it travels along the pipeline so only a section will be affected by the sub-zero temperatures. The length of the section can be estimated and so could be replaced by a length of cross-linked polyethylene (PE-X) pipe, which has very high RCP resistance down to -60 °C. The gas can also be preheated to avoid the problem but this is expensive in energy, and requires automatic back-up systems and long-term maintenance.

Low temperature gas can also occur in liquid petroleum gas (LPG) systems in winter. The gas is normally stored in tanks above ground which tend to attain the air temperature and this can be reduced further to well below zero, as vaporisation of the gas cools the gas and remaining liquid.

The effect on the pipe's RCP performance due to variability of the PE compound between batches is not known. In addition, the effects of different pipe manufacturers' production techniques (e.g. different extrusion conditions) on RCP performance have also not been evaluated. However, significant pipe-to-pipe RCP variability in PE80 or PE100 compounds has not been reported.

H.10 References

1) EN ISO 13478, Thermoplastics pipes for the conveyance of fluids — Determination of resistance to rapid crack propagation (RCP) — Full-scale test (FST).
2) BS EN ISO 13477, Thermoplastics pipes for the conveyance of fluids — Determination of resistance to rapid crack propagation (RCP) — Small-scale steady-state test (S4) test.

H.11 Appendix H.A - Decompression in Full-Scale and S4 RCP Tests

H.11.1 Pressure at the crack tip

The internal "gas" pressure at the crack tip is driving the crack forward, partly because of the hoop stress in the pipe wall but more importantly the "gas" exhausting radially is acting on the two flaps of pipe behind the crack tip so wedging open the crack. The crack tip pressure does not depend upon the pipe material and size, but only on the initial pressure, crack speed and some physical properties of the "gas". The formula gives the theoretical crack tip pressure for an infinitely long pipe line in *any* material. Measurements of the crack speed in the full-scale tests in PE pipes have shown that they have never exceeded the "gas" decompression speed.

$$\frac{p_t}{p_0} = \left[1 - \frac{\gamma - 1}{\gamma + 1}\left(1 - \frac{a}{c_0}\right)\right]^{\frac{2\gamma}{\gamma - 1}} \quad \text{when } a < c_0 \qquad (2)$$

$$\frac{p_t}{p_0} = 1 \qquad \text{when } a \geq c_0$$

where: -

p_t = absolute pressure at the crack tip

p_0 = initial pressure in the pipe

γ = ratio of specific heats of the "gas" (heat capacity ratio)

a = crack speed

c_0 = velocity of sound at 0 °C (decompression speed)

In using **equation 2**, the crack path is assumed to be axial and the speed constant but in reality the crack is usually wavy with a variety of speeds along its path, **Figure H.1**. Nevertheless, if the axial crack speed is constant, the pressure at the crack tip, though reduced from the original test pressure, is also constant (see **Figure H.3** & **equation 2**). These "constant conditions" of crack tip pressure, pipe dimensions and properties continue to drive the crack forward indefinitely i.e. RCP conditions are produced.

As the crack speed slows and eventually stops, the ratio of $\mathbf{a/c_0}$ tends to zero, however, the pressure in the pipe never falls below 28% of the original pressure for an infinitely long pipeline using a "gas" with a specific heats ratio, γ, of 1.4 i.e. air or nitrogen, **Figure H.2**.

$$\frac{p_t}{p_0} \Rightarrow 0.28 = \frac{1}{3.6} \qquad (3)$$

H.11.2 Correlation equation

The full-scale RCP test simulates the fractured PE pipe in service during which the pressure at the crack tip is lower than originally set because the pipe pressure has reduced ahead of the crack tip, **Figure H.3**. The internal baffles in the S4 test method effectively stop axial decompression. Consequently, the pressure at the crack tip in the S4 test is always at the initial test pressure, whereas, for the full-scale test, the pressure is reduced. As a result, the

critical pressure measured in the S4 test will always be lower than the critical pressure in the full-scale test. A correlation between the two pressures is necessary.

As explained in the full-scale test (BS EN ISO 13477), the crack speed slows and momentarily arrests (slip-stick) at test pressures near the critical pressure. The crack tip pressure will therefore fall almost instantaneously to the minimum value of 28% of the initial pressure i.e. the ratio of $\mathbf{a/c_0}$ approaches zero (**equation 3**). In the S4 test, the full test pressure will always be present. Consequently, the ratio of the critical pressures (***absolute values***) is given by: -

$$\frac{P_{cFS}}{P_{cS4}} = \frac{1}{0.28} = 3.6 \quad \text{absolute pressures}$$

$$\frac{P_{cFS}+1}{P_{cS4}+1} = 3.6 \quad \text{pressures in barg}$$

$$P_{cFS} = 3.6P_{cS4} + 2.6 \quad \text{barg} \qquad (4)$$

Equation 4 does not depend upon the pipe material, size or SDR, but only on *γ* - ratio of specific heats Cp/Cv (Heat capacity ratio) of the "gas". The formula therefore only applies to nitrogen or air as the pressurising test "gas" because they have the same *γ* ratio of 1.40.

Several round-robin testing programmes to validate the formula have been completed (**1**). Typically, measured values of P_{cS4} on 250mm PE80 SDR11 pipes were in the range 1.0 - 1.5 barg so that on using the equation the *calculated* P_{cFS} range was 6.2 - 8.0 barg. This produced a *direct* correlation factor in the range 5.3 - 6.2. Typical *measured* P_{cFS} on the same pipes are 7 barg to 9.6 barg, which are in reasonable agreement with the *calculated* range.

It seems that this correlation equation can be used with a reasonable degree of assurance, however, it must be pointed out that all the RCP data on which the correlation factors have been verified were obtained using 250mm SDR11 pipes and two very similar PE80 resins.

In practice, critical pressures from full-scale tests have generally exceeded the calculated "full-scale pressures" from the S4 method i.e. the correlation equation is conservative in predicting the actual critical pressures.

H.11.3 Testing using air/nitrogen instead of natural gas

Normally air or nitrogen is used for test purposes for which the decompression speeds at 0°C are 334m/s and 337m/s respectively. In comparison, natural gas (methane) has a higher decompression speed of 430m/s, though a lower heat capacity ratio, *γ*, of 1.31. Generally, the pressure at the crack tip in air/nitrogen is higher than for natural gas, though at speeds at 25-75m/s as the crack arrests (slip-stick) the differences are negligible, **Figure H.4**.

Consequently, the critical pressure, P_{cFS} measured in the full-scale test using air/nitrogen is not significantly different to that when using natural gas. Practical tests to demonstrate that there are no differences have not been conducted.

H.11.4 Reference

J M Greig, Rapid crack propagation in polyethylene gas pipes, Plastic Pipes IX Conference, Edinburgh, September 1995 (British Gas R&T Report No E949, August 1995).

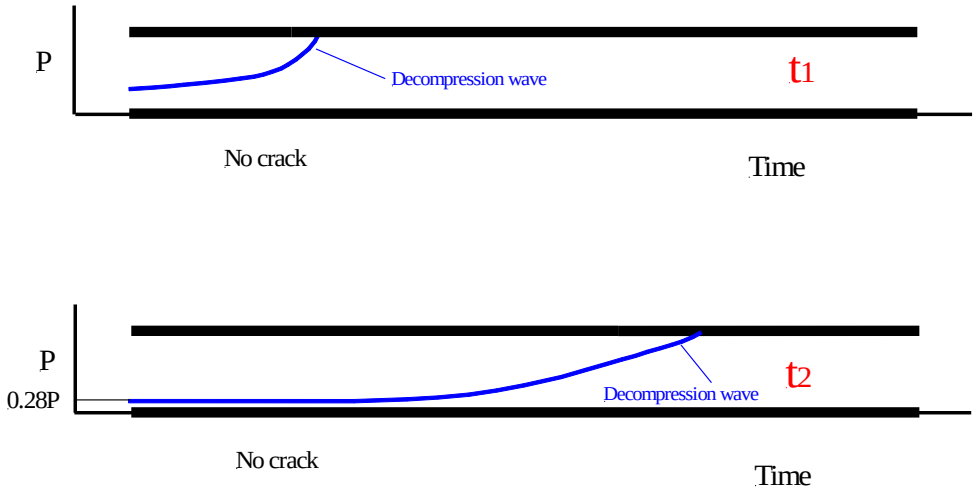


Figure H.2 A schematic of the pressure profile of a decompression wave travelling down a pipeline. For an infinitely long pipeline the pressure never reduces below 28% of the initial pressure for test gases nitrogen or air.

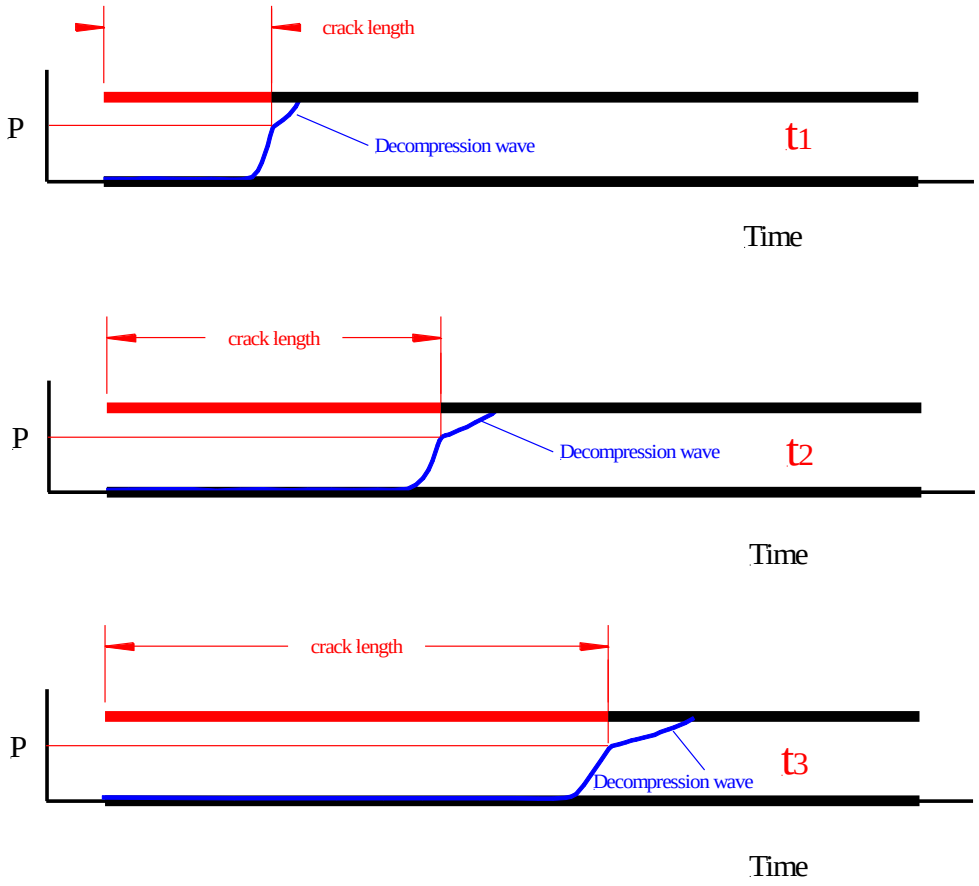


Figure H.3 A schematic of the pressure profile of a decompression wave travelling down a pipeline followed by a crack. For constant crack speed, the pressure at the crack tip is constant.

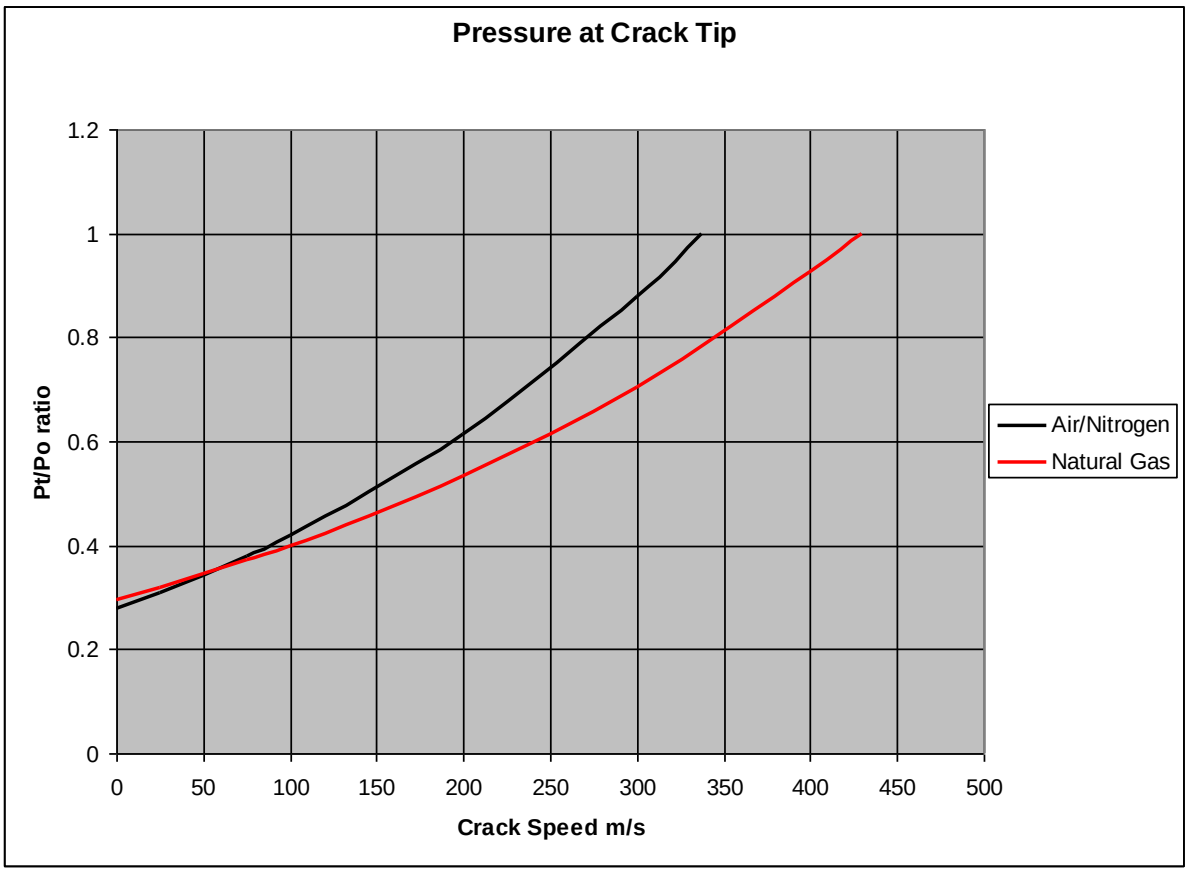


Figure H.4 The pressure at the crack tip depends upon the crack speed but as the crack slows completely and starts to go into a slip–stick mode, the pressure differences are negligible between air/nitrogen and natural gas (plotted using equation 2).

H.12 Appendix H.B – Detailed RCP Pipe Specification Requirements (GIS/PL2-1/2 & 8)

H.12.1 RCP Testing PE80 Yellow Pipes – All SDRs up to 5.5 bar (16-800mm) All SDRs

PE80 yellow pipes have to be able to operate at temperatures down to -20 °C at pressures up to: -

Up to 5.5 bar for SDR11
Up to 3 bar for SDR17.6
Up to 2 bar for SDR21 and SDR26

Due to RCP considerations, the maximum operating pressures (MOPs) of PE80 pipes in the larger sizes and lower temperatures have already been reduced (see **Annex B**). Consequently, RCP tests are conducted at a reference temperature of 0 °C.

The correlation equation proposed by the ISO TC138/SC4 committee in producing ISO 13477 is: -

$$P_{FS} = 3.6P_{S4} + 2.6 \quad bar \qquad (1)$$

where:

P_{FS} – full-scale pressure, bar

P_{S4} – S4 pressure, bar

GIS/PL2-1

For GIS/PL2 Part 1, the RCP test shall be conducted by the compound manufacturer on one pipe size provided the wall thickness is 15 mm or greater.

A full-scale RCP test (BS EN ISO 13478) **or** an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 2 x MOP. The MOP is selected for the appropriate pipe size, SDR and 0°C temperature.

The S4 test shall be conducted at a temperature of 0°C and a pressure (P_{S4}) calculated from Equation 1 (**H.4.2**) using a full-scale pressure (P_{FS}) of 2 x MOP for the appropriate pipe size, SDR and 0°C temperature.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

GIS/PL2-2

For GIS/PL2-2, the RCP test shall be conducted on the manufacture's maximum pipe size provided the wall thickness is 15mm or greater.

A full-scale RCP test (BS EN ISO 13478) **or** an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 2 x MOP for the appropriate pipe size, SDR and 0°C temperature.

The S4 test shall be conducted at a temperature of 0°C and a pressure (P_{S4}) calculated from equation 1 using a full-scale pressure (P_{FS}) of 2 x MOP for the appropriate pipe size, SDR and 0°C temperature.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

If successful, approval is given to any smaller pipe size, provided the wall thickness is not greater than that tested.

G.12.2 RCP Testing Peelable (PE100) Yellow Pipes (225-800mm) SDR21& 26

All peelable pipes (SDR21 and SDR26) with a PE100 core shall be able to operate at temperatures down to 0 °C and at operational pressures up to a MOP of 2 bar (see GIS/PL2 Parts 1 & 2).

GIS/PL2 Part 1

For GIS/PL2 Part 1, the RCP test shall be conducted by the compound manufacturer on one pipe size ***without the skin***, provided the core wall thickness is 15mm or greater.

A full-scale RCP test (BS EN ISO 13478) or an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 14 bar for SDR11 pipe.

The S4 test shall be conducted at a maximum temperature of 0°C and a pressure (P_{S4}) of 3.2 bar for SDR11 pipe.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

GIS/PL2 Part 2

For GIS/PL2 Part 2, the RCP test shall be conducted on 250mm, 315mm and the manufacturer's maximum pipe size. The skins shall be present.

A full-scale RCP test (BS EN ISO 13478) or an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 4 bar for SDR21/26 pipe.

The S4 test shall be conducted at a maximum temperature of 0°C and a pressure (P_{S4}) of 0.4 bar for SDR21/26 pipe.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

If successful, approval is given to any smaller and intermediate pipe sizes and further to any SDR26 pipe if the SDR21 pipe has RCP approval.

H.12.3 RCP Testing Yellow Striped (PE80) Pipes – (16-225mm) All SDRs up to 5.5 bar

Yellow striped pipes with a PE80 compound shall be able to operate at temperatures down to -20 °C and at operational pressures up to a MOP of 5.5 bar (see **Annex B**).

GIS/PL2-1

For GIS/PL2 Part 1, the RCP test shall be conducted by the compound manufacturer on one pipe size provided the wall thickness is 15 mm or greater.

A full-scale RCP test (BS EN ISO 13478) **or** an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 2 x MOP. The MOP is selected for the appropriate pipe size, SDR and 0°C temperature.

The S4 test shall be conducted at a temperature of 0°C and a pressure (P_{S4}) calculated from Equation 1 (**H.4.2**) using a full-scale pressure (P_{FS}) of 2 x MOP for the appropriate pipe size, SDR and 0°C temperature.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

GIS/PL2-2

For GIS/PL2-2, the RCP test shall be conducted on the manufacture's maximum pipe size provided the wall thickness is 15mm or greater.

A full-scale RCP test (BS EN ISO 13478) **or** an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 2 x MOP for the appropriate pipe size, SDR and 0°C temperature.

The S4 test shall be conducted at a temperature of 0°C and a pressure (P_{S4}) calculated from equation 1 using a full-scale pressure (P_{FS}) of 2 x MOP for the appropriate pipe size, SDR and 0°C temperature.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

If successful, approval is given to any smaller pipe size, provided the wall thickness is not greater than that tested.

H.12.4 RCP Testing Yellow Striped (PE100) Pipes – (225-800mm) All SDR21 & 26

Yellow striped PE100 SDR21/26 pipes shall be able to operate at temperatures down to 0 °C and at operational pressures up to a MOP of 2 bar (see **Annex B**).

GIS/PL2-1

For GIS/PL2 Part 1, the RCP test shall be conducted by the compound manufacturer on one pipe size provided the wall thickness is 15 mm or greater.

A full-scale RCP test (BS EN ISO 13478) **or** an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 2 x MOP e.g. 14 bar for SDR11.

The S4 test shall be conducted at a maximum temperature of 0°C and a pressure (P_{S4}) of 3.2 bar for SDR11 pipe.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

GIS/PL2-2

For GIS/PL2-2, the RCP test shall be conducted on the manufacture's maximum pipe size provided the wall thickness is 15mm or greater.

A full-scale RCP test (BS EN ISO 13478) **or** an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 4 bar (2 x MOP).

The S4 test shall be conducted at a maximum temperature of 0°C and a pressure (P_{S4}) of 0.4 bar for SDR21/26 pipe.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

If successful, approval is given to any smaller pipe size, provided the wall thickness is not greater than that tested.

H.12.5 RCP Testing Multilayer (PE80 inner layer) Pipes – (16-225mm) All SDRs up to 5.5 bar

Coextruded multilayer pipe with PE80 inner and PE80 outer layers shall be able to operate at temperatures down to -20 °C and at operational pressures up to a MOP of 5.5 bar (see **Annex B**).

GIS/PL2-1

For GIS/PL2 Part 1, the RCP test shall be conducted by the compound manufacturer on one PE80 pipe size provided the wall thickness is 15 mm or greater.

A full-scale RCP test (BS EN ISO 13478) **or** an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 2 x MOP. The MOP is selected for the appropriate pipe size, SDR and 0°C temperature.

The S4 test shall be conducted at a temperature of 0°C and a pressure (P_{S4}) calculated from Equation 1 (**H.4.2**) using a full-scale pressure (P_{FS}) of 2 x MOP for the appropriate pipe size, SDR and 0°C temperature.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

GIS/PL2-2

For GIS/PL2-2, the RCP test shall be conducted on the manufacture's maximum pipe size provided the wall thickness is 15mm or greater.

A full-scale RCP test (BS EN ISO 13478) **or** an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 2 x MOP for the appropriate pipe size, SDR and 0°C temperature.

The S4 test shall be conducted at a temperature of 0°C and a pressure (P_{S4}) calculated from equation 1 using a full-scale pressure (P_{FS}) of 2 x MOP for the appropriate pipe size, SDR and 0°C temperature.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

If successful, approval is given to any smaller pipe size, provided the wall thickness is not greater than that tested.

H.12.6 RCP Testing Multilayer (PE100 inner layer) Yellow Pipes – (225-800mm) SDR21 & 26 at up to 2 bar

All multilayer pipes (SDR21 and SDR26) with a PE100 inner layer and a PE80 outer layer shall be able to operate at temperatures down to 0 °C and at operational pressures up to a MOP of 2 bar (see **Annex B**).

GIS/PL2-1

For GIS/PL2-1, the RCP test shall be conducted by the compound manufacturer on one PE100 pipe size, provided the core wall thickness is 15mm or greater.

A full-scale RCP test (BS EN ISO 13478) **or** an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 14 bar for SDR11 pipe. Alternatively, the S4 test shall be conducted at a maximum temperature of 0°C and a pressure (P_{S4}) of 3.2 bar for SDR11 pipe.

For the PE80 pipe material, the full-scale test shall be conducted on a PE80 pipe at a temperature of 0°C and pressure of 2 x maximum operating pressure (MOP) for the appropriate size, SDR and 0°C. The S4 test shall be conducted at a maximum temperature of 0°C and a pressure (P_{S4}) calculated for appropriate size and SDR using equation 1 (**H.4.2**).

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

GIS/PL2-2

For GIS/PL2- 2, the RCP test shall be conducted on the maximum pipe size provided it has a wall thickness of 15mm or greater.

A full-scale RCP test (BS EN ISO 13478) **or** an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 4 bar for SDR21/26 pipe.

The S4 test shall be conducted at a maximum temperature of 0°C and a pressure (P_{S4}) of 0.4 bar for SDR21/26 pipe.

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

If successful, approval is given to any smaller and intermediate pipe sizes and further to any SDR26 pipe if the SDR21 pipe has RCP approval.

H.12.7 RCP Testing PE100 (orange) Pipes

All PE100 (orange) SDR11 pipes, including co-extruded PE100/PE100 multilayer SDR11 pipes, shall be able to operate at a MOP of 7 bar but only for temperatures of 0 °C and above (see GIS/PL2-8).

GIS/PL2-1

For GIS/PL2-1, the RCP test shall be conducted by the compound manufacturer on one pipe size for each PE100 compound, provided the wall thickness is 15mm or greater.

A full-scale RCP test (BS EN ISO 13478) **or** an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 14 bar (SDR11).

The S4 test shall be conducted at a maximum temperature of 0°C and a pressure (P_{S4}) of 3.2 bar (SDR11).

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

GIS/PL2-8

For GIS/PL2 Part 8, the RCP test shall be conducted on the manufacturer's maximum pipe size, provided it has a wall thickness of 15mm or greater

A full-scale RCP test (BS EN ISO 13478) **or** an S4 RCP test (BS EN ISO 13477) shall be conducted.

The full-scale test shall be conducted at a temperature of 0°C and pressure of 14 bar (SDR11).

The S4 test shall be conducted at a maximum temperature of 0°C and a pressure (P_{S4}) of 3.2 bar (SDR11).

If the pipe fails the S4 test, it is permitted to re-test using the full-scale test, which if successful takes precedence, as the full-scale test is the reference test.

If successful, approval is given to any smaller pipe size, provided the wall thickness is not greater than that tested.

Annex I Method for the Determination of Level of Adhesion of Skin from Peelable Skin Pipes (normative)

I.1 Principle

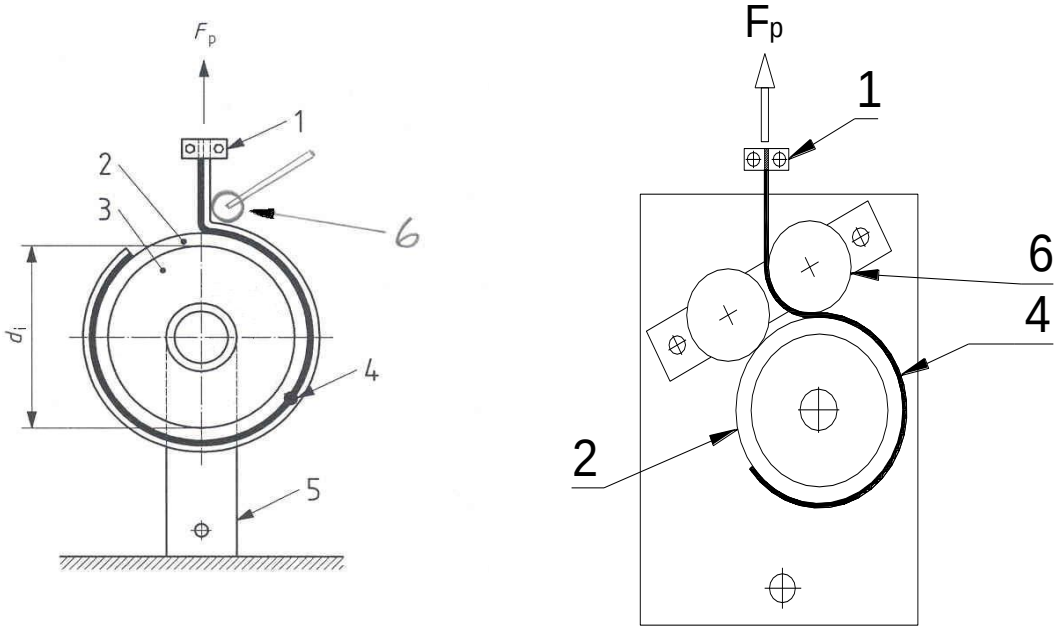
Pipe sections cut from peelable skin pipe are retained in a test rig that permits the removal of the outer skin perpendicular to the axial direction by suitable mechanical means such as a tensile machine. The removal of the skin generates pulling force from which the level of adhesion and the ease of removal of the peelable skin can be determined.

I.2 Apparatus

I.2.1 *Tensile testing machine* in accordance with ISO 5893.

I.2.2 *A pulling rig* conforming to the principle as represented in **Figure I.1** or **Figure I.2**.

Figures I.1 & I.2 – Pulling Test Rig



Key

F_p	pulling force of the pulling rig in Newtons
1	clamp
2	inner layer
3	support mandrel including a roller bearing (optional)
4	print line on pipe
5	pivoted sample holder (optional)
6	guide roller to ensure vertical movement of peeled skin

I.2.3 *Device* capable of monitoring the force applied to the skin layer of a test piece

I.2.4 *Device* capable of measuring either the pulling speed arranged so as to subject the test piece to a constant pulling speed or the angle of rotation of the support mandrel.

I.3 Test Specimen Preparation

I.3.1 In order to generate a clear point of reference, which allows any issue identified during the test to be directly related back to a position on the pipe as extruded, **"**Top Dead Centre" (TDC) shall be marked on the pipe and 4 test pieces shall be cut from the pipe to be tested, 2 from each end of the pipe. The first test piece obtained from each pipe end shall be discarded to negate any possible effect of end reversion.

The test piece may be cut into sections to facilitate rotation in the test rig. The number of sections for each pipe diameter is given in **Table I.1**

Table I.1 – Number of test sections per test piece

Pipe Diameter	Number of sections
≤ 225	1 (whole ring)
>225 ≤ 300	2
>300 ≤ 400	3
>400 ≤ 500	4
>500 ≤ 600	5
> 600	6

I.3.2 Each test piece shall have a minimum width, W, of 25 mm.

I.3.3 The skin shall be cut in the axial direction with the cut coincident with the TDC of the pipe as identified and marked in **Clause I.3.1**.

I.3.4 The skin shall be pulled loose over a length sufficient to allow it to be fed through the guide rollers and into the clamp shown in **Figures I.1** and **I.2**.

I.4 Test Method

I.4.1 Conduct the test at the temperature specified in Table 7, as applicable.

I.4.2 Measure and record the width of the specimen, W.

Where the test specimen is comprised of a whole ring then it shall be measured at 4 positions equally spaced around the circumference.

For a test specimen that is a section of pipe, the width shall be measured in 2 positions, these being located at the start and end of that section.

I.4.3 Insert the test piece into the pulling test rig and ensure free rotation of the test piece.

I.4.4 Install the clamp onto the loosened skin section.

I.4.5 Apply a cross head speed of (50 ±5) mm/min

I.4.6 Record the applied force, F_p over the rotation through the duration of the test.

I.5 Processing of results

I.5.1 The mean value of F_p, calculated from the force deflection trace obtained, is recorded for the test pieces from each end of the pipe. This force is used to calculate the peel strength as follows:

Peel Strength N/mm = F_p / W_x

Where: F_p = Mean force obtained during test in Newtons.

W_x = Average sample width in millimetres

When it has been necessary to section the test piece then the result for that test piece is the average peel strength calculated from all the sections tested.

I.6 Pass/Fail criteria

I.6.1 For each individual test specimen: -

The peel strength shall be within the range specified in Table 7

The skin shall peel away from the core pipe in one piece without breaking.

A new and clean surface shall be generated on the outside of the core pipe.

Annex J Summary of and Rationale for changes to document April 2008.

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
General	Include RCP report in PL2-2 & PL2-8 for completeness	M Greig	Additions are Clause 11 + Annex D & Annex H
Page 1	ISO9080 is just a method for gaining MOP with ISO12162 for classification. Include for completeness.	N Taylor	Add Reference
Page 2	EN ISO 3126 is also a BS	N Taylor	Change Reference
Page iv	November 2007 – should change to reflect date of "final WG meeting". Felt that date of full agreement should be included in table.	M Greig	Change to date when document accepted. Feb 2008 inserted to reflect final WG Meeting.
Clause 3	Definitions identified as required in PL2-1 need including in PL2-2.	M Greig	Include definitions
Page 5 3.2.6	Pipe batch not defined in terms of min and max but is at "discretion of manufacturer". Need something – see later.	M Greig	See later.
Page 8 Clause 4	Change note to "these are additional peelable skins".	M Greig	Changed.
Page 8 Clause 4.2	100% rework qualifying other "blends" as worst case. Suggested that "x%" rework shall qualify rework for that particular company who can then use "up to X%". Those present felt that the current wording was OK plus TN had made no remarks to TP which would suggest that Wavin were unhappy with the words as is.	M Greig	Leave as stated in text.
Clause 7.1	EN ISO 3126 is a BS EN ISO 3126	G Essam	Change to reflect current document.
Table 1	Proposed tests for pigment dispersion & volatile content deleted as they are recognised compound manufacturer tests. Pipe manufacturer's preference is to put the responsibility on the compound manufacturers. The closed loop transportation systems employed by the polymer suppliers seeks to minimise /negate the possibility of moisture getting in the system.	T Peach	Volatile Content & Pigment Dispersion deleted from Table.
Table 1	Pellet geometry – can definition be given as to what constitutes pass/fail. Should obtain representative pellet samples from compound suppliers.	All	Obtain "reference" samples from compound suppliers for each grade purchased.
Table 1	Suggest change sampling frequency of tests to 6 monthly or by resin batch.	T Peach	Changed to per raw material compound batch.

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
Table 1 Note C	Discussion about MFR of material being such that it makes butt fusion bead sizes in DIS 5.3.1. Bead shape is ok, but size is not.	M Hunter	Further work required to define bead widths which may lead to changes in DIS 5.3.1. Leave words unchanged.
Table 2	In liquid at 80°C has 2 brackets 2 open brackets	G Essam	Change as defined.
Table 2	No temperature for air conditioning	N Taylor	Add 23 ±2°C
Table 3	Change note to “other SDRs” dropping SDR 13.6 as specific. Checked EN1555, which quotes “S series”, this wording was not seen as appropriate. Put in full stop after SDR 13.6.	M Greig	Full stop to terminate table after SDR 13.6
Table 3	Can Note re SDRs be annotated as separate note, then becomes informative.	G Essam	Change to have SDR as separate note.
Table 3	Additional thicknesses placed in table for pipes “missing” from range that could be offered.	T Peach	Leave table with proposed dimensions but check with respect to rounding for consistency. Checked & amended.
Clause 7.5	Discussion on “in process” Pipe Peelability check. Wording needs to be agreed relating to “not too easy or not too sticky”, i.e. when how and what are “pass criteria”	D Robinson	Agree formal words TP/NT/MG to cover this Proposed wording e-mailed to MG/NT 6.3.08 for comment. Revised wording agreed by MG, 11.3.08 and by GPS 19.3.08.
Table 5	Discussion re peelable pipes for breakout moling. Can these pipes have skin thickness as per “standard pipes”. Based on field trial there “may” be scope to change, however the recommendation was that it would be better to leave as stated in table.	M Greig	Leave skin thickness for breakout moling sizes as is.
Table 5	Discussion seemed to suggests that skin thickness be reduced on $\geq$ 250 to 0.6 to 1.2mm.	M Greig	GPS/Uponor to check if compliance can be achieved. Discussed with GPS 20.3.08 Leave Table 5 as is for ≥250mm.
Table 5	Colours of stripes already referenced in 6.?? Should these be deleted.	G Essam	Remove or add note referencing relevant clause.
Table 6	Add size 160mm to table.	T Peach	Included.

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
Table 6	Propose change to max coil diameter on 180mm to 4.2m from 4.0m.	T Peach	Idea dropped by Uponor following discussion with coil dispensing trailer providers.
Table 6	90mm SDR 17.6 coiled at 1.8 but spec shown min 2.5. practice has been like this for some time. Other issues down table but as table specifies minimums these are in effect not issues.	R Marks	Change table to SDR 11 minimums.
Table 7	Clarify wording re duration of 20°C testing of weathered and non-weathered peelable & plain pipes.	T Peach	Note a) accompanying Table 7 given greater clarity as requested.
Table 7	Possibility of reducing duration of non-weathered pipe 20°C test from 5000hrs to 2500hrs.	P Rugraff (Ineos)	Working Group rejected proposal based on number of years this requirement had been in the standard.
Table 7 / Page 23	Reference to clause 11 should be clause 12	M Greig	Change document.
Table 7 Squeeze off & Offset B/F	Reduction of samples proposed from 3 to 2.	T Peach	Accepted & changed.
Table 7	Add note to show that Table continues on next page.	M Greig	Try to change such that table and notes sit on one page or add link via “continued overleaf”. (Perform similar exercise with other tables similarly effected).
Table 7	Replace EN 921 with ISO1167.	N Taylor	Change as defined.
Table 7 Note J	Amend note J to reflect that already agreed in PL2-1. Also add RCP clause as defined in Part 1.	T Peach	Change as defined.
Table 7 Note L	Should be small “l”	M Greig	Change as defined.
General	Need to review test data where it exists for pipe shelf life to see if the current requirement of 12months can be extended to 2 years.	D Robinson	Uponor circulated its 2year pipe re-test data from 2000 onwards for review by MG. (May also need to reflect any change in DIS 5.3.1).
Table 8	Proposal to populate table with peelable pipe pressures including SDR11 & SDR17.6, which are currently not purchased.	T Peach	Leave table as is. Remove details for SDR11 & 17.6.
Table 9	PE80 yellow test stress maybe too high at 4.5MPa and will give ductile failure mode in notch. Given that failures on 165hr notch pipe test are rare, leave as is.	P Rugraff	Leave as defined.

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
Clause 10.3 Extreme Butt Fusion	Uponor performed the work defined, and the opinion expressed was that this sits better as "project work". Manufacturers would not like to see this as part of the standard. However, it is a lift from EN1555 with the intention to make PL2 part 2 an EN1555+ document. NG standpoint is that we need to be able to demonstrate jointing at extreme temperatures. (Continued on next page) Uponor work demonstrated that joints could be satisfactorily made and performed to the requirements of the standard.	Pipe Producers	Agreement to drop – delete from draft (include references in tables and table 12)
Table 10	Propose that Peelable pipe sizes are changed to align with previous comments in PL2-1. After discussion leave as stated 75-180mm.	M Greig	Leave as proposed draft.
Table 10	Drop extractability of additives from table as per PL2-1.	T Peach	Changed to align with PL2-1.
Clause 11	Need to change clause 11 to reflect 4.6 in PL2-1, and insert RCP information between 11 & 12.	M Greig	Change as defined.
Clause 11	Becomes Clause 12		Change as defined
Clause 11.1	"Annex D with further information in Annex H"	M Greig	Change as defined
Table in Clause 11	With original Table 12 deleted, Extreme conditions for Butt Fusion call this Table 12 to help editorial issues.	M Greig	Change as defined
Table 13	Peelable pipe skins appears in table (geometrical characteristics) but is not something that would be done every 4 hours as TT	M Greig.	Delete from table**.**
Table 13	Added comment against mechanical properties "non weathered pipes all types".	T Peach	Change as defined.
Table 13	Change sample requirements for squeeze off and offset butt fusion to 2 as per Table 7.		Change as defined.
Table 13	Note a) to cover largest size.	D Robinson	Change as defined.
Table 13	Resistance to weathering of peelable pipes shows 75mm – 180mm SDR21. Amend wording in Table to read "resistance to weathering of peelable pipes".	M Greig	Change as defined.
Table 13	OIT removed in favour of pipe fusibility – also delete note f)	T Peach	Change as defined.
Table 13	Under extreme conditions the 80°C test shall be un-notched.	M Greig	Change as defined.

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
Table 13	Remove wording re strength of butt fusion at extreme conditions.		See earlier comments.
Table 13	Move strength of butt fusion above marking	G Essam	Change as defined.
Clause 13	Typo – after raw material no comma	M Greig	Change as defined.
Clause 13	Proposed table 15 with parts 1 & 2. Part 1 is for no history with need to earn right to change frequency. Uses same words as PL2-4 review.	T Peach	No objections raised to proposed Table.
Clause 13	Change tables 15-1 and 15-2 to tables 15 & 16 (therefore change notes 1 and 2	M Greig	Change as defined.
Table 15	Circumferential pipe reversion change to 1/size/week.	T Nicholson	Change as defined.
Table 15	Proposed one sample/start & end of pipe batch. May need to change to cover size groups on basis that there is a need to test smaller sizes more frequently. Change to per pipe batch (or 1/week).	T Peach	Change as defined.
Table 15	Need to change wording for peelable skin to reflect adhesion test.	M Greig	Agree better descriptive wording.
Table 15	Peelable pipe skin peel adhesion test. Need to define requirements in table. Also need to define “sample number” i.e. 1 and “number of measurements”	M Greig	Change as defined.
Table 16	Change to table 16 and amend as per table 15	M Greig	Change as defined.
Table 16	Proposal to use compound batch as driver for BRT. Uponor data suggests that 68% of pipe batches produced see a hydrostatic pressure test. This approach also affords the opportunity to introduce differing tests. Increase notch test frequency to 3 diameters and delete offset butt fusion.	T Peach	Change as defined.
Table 16	Peelable pipe adhesion test – change frequency to weekly	M Greig	Change as defined.
Table 16	Size groups in Table need to reflect Table 14 as they are different, or change 14 to reflect accordingly.	M Greig	Table 16 changed to reflect Table 14.
Table 16	Proposed RCP frequency changed from 1 /year to 1/10th batch of raw material delivered to pipe manufacturers. This equates to circa 3 tests per annum.	T Peach	Change as defined.
Clause 14.2	Request to extend the size from 32mm to 75mm re single indented strip to give better quality / clarity. Propose to change to mandatory for indent on one side and ink jet on the other. (Continued overleaf) Also for larger sizes switch to 2 clear indents and one black inkjet.	T Peach	Check with Wavin and change if agreement reached. No response received from Wavin as at 11.4.08, hence assumed no issue.

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
Table 17	Proposed changing 30/09/05 to DD/MM/YY	G Essam	Change as defined.
Table 18	"Sequence of cutting bands". Past Uponor practice has been to print booklet to attach to coils, which subsequently falls off or is unreadable after inclement weather. Would prefer to get message across via training.	T Peach	Use of a label describing "Sequence of cutting bands" deleted. Uponor wording used on label for Water Industry "caution must be exercised when cutting bands" is not the same message as cutting bands in sequence. This label could be applied if the Gas Industry wants it.
Clause 14.4 / Table 18	Additional comment proposed re "before unstrapping, ensure that both pipe ends and coil/drum are firmly mechanically restrained".		Leave as drafted
Clause 15	Do not always supply in multiples of 50m (e.g. 75mm x 120m). Propose to stop at 50m i.e. no multiples.	M Hunter	Change as defined.
Annex D	Even though there is to be a further annex relating to RCP, it was felt that Annex D should remain.		Leave as is.
Annex D	Typo – Need to shuffle text which has dropped down	M Greig	Change as defined
Annex E	Due to number of coiler types it is proposed that each manufacturer defines their own requirements, agrees them with the customer and makes them available to BSI. The need for Health & Safety and effective transportation must be considered in any proposal. Can manufacturers work together to agree a common baseline, incorporating enough flexibility to gain compliance. Consider using words such as "typical".		Pipe Manufacturers to seek to reach agreement on minimum requirements, define and incorporate. Information to be shared with coil handling group via MH.
Annex E	Definitions already included in definitions section which need cross check.	M Greig	Check and amend.
Annex E1	Change "practicable to the centre axis of pipe" to entry to coiler or similar words.	M Greig	Agree and change as defined.

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
Annex E2.3	Proposed that breaking strain be increased to 2 tonnes based on current supply(at 23°). (Along with after weathering in the UK).	D Robinson	Pipe manufacturers to confirm what is achievable and then change as agreed. Reviewed with GPS 20.3.08 Bands & Tape supplied as new >1.5 Tonnes
Annex E2.3	Define PP using correct material name	M Greig	Change as defined.
Annex E.2.3	Clause dealing with bands. Need to insert Adhesive before tape.	M Greig	Change as defined.
Annex E2.3	The wording is such that the manufacturer needs to ensure that the banding will perform at high and low temperatures. Should define UK weathering. Also who is responsible for this and is manufacturers data acceptable	D Robinson	Pipe manufacturers to check with their suppliers whether compliance can be achieved. Suppliers unable to provide this kind of data. Refer to e-mail sent to Declan 28.3.08
Annex F	Proposed due to previous lack of testing around rework. This is for 100% rework from 1 grade of material but could be applied for “blends” on the basis that 100% is tested as the worst case scenario then the addition of a % of virgin makes it better. Thus this annex approves anything from 1% to 100%.	T Nicholson T Peach	Pick up definition in clause 4.2, which allows use of blends.
Annex F	Need to reflect that already agreed in clause 4.2 and change title to 100% rework	G Essam & M Greig	Change as defined**.**
Annex F Table	RCP pipe sizes given do not meet wall thickness criteria (15mm) for that test. Therefore this calls into question test validity. Could do 180 SDR 11 for PE80 and 315 SDR 21 on peelable. Also may need comment re approving smaller sizes.	M Greig	Change as agreed**.**
Annex F Table	6259-3 does not have “ISO”	G Essam	Change as agreed**.**
Annex I	Although two methods in the same annex are ok it was suggested that both manufacturers should seek to identify a method of giving the same comparable unit to which can be set limits or pass fail criteria.	M Greig	Uponor & GPS met 20.3.08 and agreed a unified Skin Peel Adhesion test method. GPS confirmed Peel Strength range 3.4.08
Annex I	Need to include in TT table and do at temperatures of -5°c and +30°c to take into account extremes	M Greig	Change as defined**.**

Annex K Summary of and Rationale for changes to document – June 2013 (inclusion of multilayer pipe).

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
General	New Annex G to be inserted into the main body of the specification.	M Greig	Insertion of new Annex G for Multilayer PE pipe required and updating of subsequent Annexes and references to these altered Annexes
Scope	Inclusion of multilayer PE pipe in the scope	M Greig	Addition to scope of multilayer PE pipes consisting of a co-extruded PE100 inner layer and a PE80 outer layer.
Page 11	Addition of wall thickness of size 469mm SDR17.6	M Greig	Add the SDR17.6 min & max wall thicknesses
Page 14	Clause 7.6. Error in reference to Clause 14.4	M Greig	Replace clause14.4 by clause15.4
Page 16	80°C Hydrostatic strength after squeeze-off also applies to peelable pipes	M Greig	Add reference to peelable pipes ≤ 630mm in first column
Page 17	Note (J) missing	M Greig	Add the text of Note (e) in Table 2 in GIS/PL2-1
Page 17	GIS/PL2-4: 2012 introduced the concept for mature / approved UK suppliers and at the gas transporters discretion, that new suppliers using European approved resins with a proven track record of supply to gas transporters within the European Commission may substitute the 5000 h test period by a test for 100 h.	M Greig	The same text as in GIS/PL2 added to Note a) in Table 7.
Page 19	Clause 10.2. para 2. Missing reference to 80°C hydrostatic strength (un-notched) of butt joints	M Greig	Insert “and 80°C hydrostatic strength (un-notched)” after The tensile strength…
Page 26	Table 13. Strength of Butt Fusion Joint. Missing 80°C Hydrostatic Strength (un-notched) test. See 10.2	M Greig	80°C Hydrostatic Strength (un-notched) test added to Table 13.
Page 26	Table 13. Incorrect reference to De-cohesion test	M Greig	Replace with Skin Peel Adhesion Test and reference to Clause 8.2
Page 26	Table 13, Note (a) testing of the largest size in the manufacture’s product range refers only to weathered pipe.	M Greig	Note (a) text “for weathered” added after “except”.
Page 30	Table 16. Yield strength and Resistance to slow crack growth clauses. The number of measurements per sample should be 1, not 6 or 7, which are the total number of measurements.	M Greig	Change the number of measurements per sample to 1

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
Page 36	Annex B MOP. Include multilayer pipes	M Greig	Alter Annex B title
Page 38	Annex B. Change Table B.2 because peelable and multilayer pipes are now only used down to 0℃.	M Greig	Replace Table B.2
Page 41	RCP of multilayer pipe required in Annex D.	M Greig	Include Annex D clause 1.3 with reference to Annex G clause G.12
Page 49	Editorial change to add note (d) to Table G.1	M Greig	Modify text to add note (d)
Page 53	Addition of RCP requirements for multilayer pipes	M Greig	Add RCP clause H.1.4 Multilayer Pipes (PE80 layer over PE100 core). Adjust old Clause H.1.4 to Clause H.1.5
Page 53	Annex H. Avoidance of confusion as to the location of Appendices A, B & C.	M Greig	Replace Appendices A, B & C by Appendix H.A, Appendix H.B & Appendix H.C to indicate they are part of Annex H. Modify text to suit changes.
Page 58	Add section to include RCP testing of multilayer pipes	M Greig	Insert new Clause H.7 on RCP testing of Multilayer Pipes.
Page 62	Annex H. Change Table H.2 in Appendix H.A of Annex H because peelable and multilayer pipes are now only used down to 0℃. (see also page 38)	M Greig	Replace Table H.2
Page 72	Annex I. Avoidance of confusion as to the location of Figures 1 & 2 and Table 1	M Greig	Replace Figures 1 & 2 and Table 1 by Figure I.1, Figure I.2 and Table I.1.

Annex L Summary of and Rationale for changes to document – December 2014 (increase pipe sizes to 800mm).

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
Scope	Increase pipe sizes to 800mm.	D Robinson	Insertion of nominal pipe size 16 to 800mm. Insertion of peelable pipes in sizes 90 - 630mm SDR 21 & 26. Insertion para 3: It is applicable to Multilayer PE pipes consisting of a co-extruded PE80 inner layer and a PE80 outer layer in sizes 63-225mm SDR 11, 21 & 26 for use at pressures not greater than 5.5 bar. Modify para 4 ….. and a yellow PE80 outer layer in sizes 250-800mm SDR 21 & 26 for use at pressures not exceeding 5.5 bar.
Clause 4.2 para 2	Delete restriction of PE80 & PE100 for peelable pipes	D Robinson	Delete “for peelable pipe”.
Clause 4.2 para 2	Ensure coloured stripes are made from a base polymer that fusion compatibility has been demonstrated.	M Greig	Add: The compound used for coloured stripes on the pipe shall be from the same base PE compound as one of the pipe compounds for which fusion compatibility has been proven.
Clause 6.2 para 1	Also permit black pipes with yellow stripes	D Robinson	Add: or black with yellow stripes
Clause 6.2 para 3	Allow multilayer pipes with an external layer in yellow or black with yellow stripes	D Robinson	Add “co-extruded” and “or black with yellow stripes”
Clause 6.3	New clause to list the types of pipe construction permitted	D Robinson	See extensive text
Table 1	Addition of 213mm SDR 21	M Greig	Add SDR21 wall thicknesses of 10.1 (min) and 11.2 (max)
Table 1	Addition of 710mm & 800mm sizes	D Robinson	Add maximum OD and range of wall thickness for SDR11, 17.6, 21 & 26
Table 1	New note to define the maximum OD tolerances for 710mm & 800mm	D Robinson	b) Mean outside diameter tolerances at 0.005dn for sizes 710mm to 1000mm rounded up to the nearest 1.0mm

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
Table 7	Editorial changes to include all the different types of pipe construction	D Robinson	Add PE80 core & PE100 core
Table 7	Multilayer pipes up to 500mm included for squeeze-off	D Robinson	Add Multilayer ≤ 500mm
Table 8	Editorial changes to include all the different types of pipe construction	D Robinson	Add PE80 core & PE100 core
Table 9	Title change to include all the different types of pipe construction	D Robinson	Replace by “all PE pipes”
Clause 10.2	Clarification of the butt joint assemblies	M Greig	Note added
Table 11	Editorial changes to include all the different types of pipe construction	D Robinson	Add PE80 core & PE100 core
Clause 11	Only conventional yellow PE80 pipes are to be used at temperatures down to -20°C. The MOPs of larger sizes and lower temperature have been previously reduced	M Greig	Clarification of the text
Clause 11	All other pipes are to be operated above 0°C and depending on SDR and construction at operating pressures up to 5.5 bar	M Greig	Clarification of the text
Table 12	Separation of different types of PE pipe and calculation of the service design coefficient and design stress	M Greig	Revision of Table 12 for the various pipe types
Clause 12	Editorial changes to include all the different types of pipe construction	D Robinson	Revision of text
Table 13	Deletion of un-notched pressure test at 80°C for peelable pipes because it’s a duplicate of the more onerous test of a 80°C pressure test after squeeze-off	M Greig	Deletion of un-notched pressure test at 80°C test
Table 13 Notes c, e	Revision to include the additional types of PE pipes	D Robinson	Revision of text
Table 14	Increase of Size Group 3 to 800mm	D Robinson	Size Group 3 revised to $250 \leq dn \leq 800$
Clause 14 Para 1	Remove inconsistency between authorisation text and Note 2	M Greig	Remove “and”
Annex B Table B.1	Increase pipe sizes up to 800mm	D Robinson	Revision of Table B.1
Annex B Table B.2	Revision of Table B.2 to include the multilayer and striped pipes	D Robinson	Revision of Table B.2
Annex C	This test only applies to peelable pipes because of the uncertain performance of the skin and its adhesion. A similar test for other PE pipes is in PL2-1	M Greig	Adjust text to remove reference to 125mm SDR11 PE80
Annex D Clause D.1.3	Permit PE100 and PE80 cores	D Robinson	Delete (PE100/PE80) from title

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
Annex D Clause D.1.4	Add RCP section dealing with PE and PE100 Striped pipes	M Greig	Add section
Annex F	Add striped and multilayer pipes	D Robinson	Add striped & multilayer
Annex G Clause G.1	Permit the core layer to be PE80 with an outer layer of PE100	D Robinson	Add sentence
Annex G Clause G.4.1	Permit the core layer to be PE80 with an outer layer of PE100	D Robinson	Delete reference to PE100 and PE80
Annex G Clause G.10.5.1	Include the yield stress for PE80 core	M Greig	Add 15MPa (PE80 core)
Annex H Appendix H.A	Removal of Tables H.1, H2 & H3 as they are copies of Table B.1 & B.2 and for 7 bar Table E.1 in PL2-8	M Greig	Delete Tables H.1, H.2 & H.3

Annex M Summary of and Rationale for changes to document – December 2016 (extend pipe size range 16-500mm for co-extruded, PE80 inner layer pipes).

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
Scope	Increase pipe sizes range to 16-500mm.	M Greig	For Multilayer PE pipes extend nominal pipe sizes 16- 500mm for all SDRs.
6.3	Increase pipe sizes range to 16-500mm	M Greig	Extend Multilayer PE pipes nominal pipe sizes 16-500mm for all SDRs
G.1	Increase pipe sizes range to 16-500mm	M Greig	Extend Multilayer PE pipes nominal pipe sizes 16-500mm for all SDRs
4.2	Rewording of 4.2: - to permit rework of co-extruded pipes	M Greig	Add - rework (reprocessed) material from multilayer co-extruded pipes shall be blended only with virgin inner layer compound and used to make the same type of co-extruded pipe. Explanatory Note Example added.
4.2	Rewording of 4.2: - to clarify use of rework from inner layer material of peelable pipes	M Greig	Add – own rework (reprocessed) material from the inner layer of peelable pipes and used to make pipe with the same inner layer compound
4.2	Reduction in multilayer co-extruded pipes testing programme where several inner layer compounds and several external layer compounds could be used in various combinations		Add - Once a multilayer co-extruded pipe has been approved to this standard, then any other compound approved to PL2-1 may be substituted for either of the two compounds
4.2	Avoidance of undefined “base PE compound” in reference to coloured stripes.		Substitute - The compound used for coloured stripes on the pipe shall be from one of the unpigmented pipe compounds for which fusion compatibility has been proven when normally pigmented.
15.3 footnote 2	Incorrect reference to PL2-2: 2014	M Greig	Deleted date
H. 12.5	Increase pipe sizes range to 16-500mm	M Greig	Extend Multilayer PE pipes nominal pipe sizes 16-500mm for all SDRs

Annex N Summary of and Rationale for changes to document – December 2016 (changes to NPT to cover multimodal PE80 pipes).

GIS/PL2-2 Clause	Comment & Rationale	Proposer	Action Required (if applicable)
Table 7 (c)	If brittle failure, the repeat test can be at any of the pressure/time combinations in Table 9. It is not necessary to restrict the pressure/time to 4MPa – 1000h	M Greig	Delete " at the reference time of 1000h"
Table 9	Delete the pressure-time combinations from 165h to 331h	M Greig	As multimodal PE80 will not pass the higher pressure requirements due to its special characteristics, then the choices should be applicable to all types of PE80. The number of tests has been greatly reduced.
Clause 14 BRT	The alternative BRT is largely set up to be able to test every batch of material rather than every batch of pipe. The slow crack resistance test is main material test and this has now been moved to PVT. The PVT is a materials/compound test so making this alternative BRT largely redundant.	M Greig	Delete Clause 14 except leave "The checks shown in Table 15 shall be carried out at the stated frequency on production from each pipe extrusion line."
Table 15	Move the BRT Resistance to slow crack growth to PVT	M Greig	Delete Resistance to slow crack growth test
Table 16	See Clause 14 BRT	M Greig	Delete Table 16
New Table 16	Introduce the slow crack growth test as a monthly PVT test on each compound used in the previous month (calendar or 4 weeks)	M Greig	New Table 16
Table 16 Note b	Material with a large quantity of rework, should be treated as new compound and so be subject to PVT testing	M Greig	Table 16 - Note b added
Annex F Note 1	Tests on carbon black are necessary for all black compounds used.	M Greig	Add "or co-extruded pipes with black inner layers

Bibliography

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/IEC 17025, *General requirements for the competence of testing and calibration laboratories.*

BS EN ISO 12162, *Thermoplastics materials for pipes and fittings for pressure applications – Classification, designation and design coefficient.*