

Gas Industry Standard

GIS/PL2-10: 2020

Specification for

Methods of repairing leaking PE gas mains operating at pressures up to 2 bar (UK) and 4 bar (Ireland)



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Foreword

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

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

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

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.

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Brief history

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1. Scope

This Gas Industry Standard specifies requirements for the performance of leak repair systems applicable to all grades of Polyethylene (PE) gas mains operating at pressures up to 2 bar in the UK, and up to 4 bar in Ireland. The specification is for the repair of PE pipe sizes 63 mm up to 355 mm (all pipe SDRs) within the installation temperature range of -5 °C to 30 °C.

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.

2.1 British and European standards

BS EN ISO 9001, *Quality management systems. Requirements*

ISO 13954 *International Standard plastic pipes and fittings – Peel decohesion test for polyethylene (PE) electrofusion assemblies of nominal outside diameter greater than or equal to 90mm*

BS EN ISO 3506 *British Standard mechanical properties of corrosion-resistant stainless steel fasteners*

BS EN ISO 1167-1 *Thermoplastic pipes, fittings and assemblies for the conveyance of fluids – Determination of the resistance to internal pressure – Part 1: General method*

ISO 13955 *Plastic pipes and fittings. Crushing decohesion test for polyethylene (PE) electrofusion assemblies*

BS EN 12814-4 *Testing of welded joints of thermoplastics semi-finished products. Peel test*

BS ISO 13951 *Plastic piping systems. Test method for the resistance of plastic pipe/pipe or pipe/fitting assemblies to tensile loading*

2.2 Gas Industry Standards

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

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/LC1, *Leak Repair and annulus sealants for metallic gas mains and services up to 7bar, 2018*

GIS/LC8-1, *Methods of repairing leaking ferrous gas mains - Part 1: External encapsulation systems, August 2006*

GIS/LC8-4, *Methods of repairing leaking ferrous gas mains - Part 4: Pipe repair clamps, split collars and under pressure branch connections, August 2006*

3. Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1 Definitions

3.1.1 Low Pressure

Internal operating pressure not greater than 75 mbar.

3.1.2 Medium Pressure

Internal operating pressure greater than 75 mbar but not greater than 2 bar (UK) or 4 bar (Ireland).

3.1.3 Distribution Main

Gas distribution mains deliver gas from the distribution points to services at the areas of consumption.

3.1.4 Non-structural damage / leak

Pipeline damage / leak insufficient to reduce structural integrity of pipeline, where the pipe damage area is less than $D/4$. A non-structural repair requires no structural enhancement capabilities only long term leak sealing.

3.1.5 Structural damage / leak

Pipeline and fusion joint damage / leak sufficient to reduce pipeline integrity, where the pipe damage area is greater than $D/4$. A structural repair requires structural enhancement capabilities including providing resistance to pull out / end load.

3.1.6 Simple Puncture

Single puncture hole with no other significant surface damage.

3.1.7 Compound Puncture

Puncture with significant surface disruption around puncture location.

3.1.8 Hot-iron and electrofusion socket damage

Leakage from socket joint interface.

3.1.9 Hot-iron and electrofusion saddle damage

Leakage from saddle joint interface.

3.1.10 Butt fusion damage

Leakage from butt fusion joint interface.

3.1.11 Minimum diameter pipe

The minimum diameter of pipe within the specified repair diameter range.

3.1.12 Mid-sized diameter pipe

The mid-point (or nearest standard size) of pipe within the specified repair diameter range.

3.1.13 Maximum diameter pipe

The maximum diameter of pipe within the specified repair diameter range.

3.1.14 Mechanical repair*

A bolted design that typically provides the long-term leak seal through a metallic or rigid structure, which compresses an elastomeric interface.

3.1.15 Tapes / wraps*

A tape / wrap system applied to the damage zone which provides the long-term leak seal.

3.1.16 Encapsulation*

An encapsulating sealant, which provides external protection and provides the long-term leak seal.

3.1.17 Fusion repair*

Fusion bonded components, which restore structural integrity and provide the long-term leak seal.

3.1.18 Adhesive repair*

Adhesive bonded components, which restore structural integrity and provide the long-term leak seal.

3.1.19 Resin based repair*

Repair is dependent on in-situ cure of a polymeric resin based product, which provides the long-term leak seal.

3.1.20 Plastic injection repair*

Internal application of sealant materials (which may be applied externally, being injected into the annulus from an external source), which restores structural integrity and provides the long-term leak seal.

**Repairs may require a combination of the above repair types*

3.2 Additional Symbols

D	diameter of pipe
P	failure pressure
F_m	average bolt load – average bolt load for all the bolts within the repair clamp
F_L	bolt load where leakage occurs
h	distance from pipe centreline to largest protrusion on repair system

3.3 Abbreviations

LP	low pressure
MP	medium pressure
MOP	maximum operating pressure
MAOP	maximum allowable operating pressure
SDR	standard dimension ratio
DCB	double cantilever beam
COSHH	Control of Substances Hazardous to Health

4. General requirements

The manufacturer shall supply details of their repair method, which includes, if applicable:

- All materials used for the repair shall be, where applicable, to a national or international standard. Exceptions may be permitted on consultation with the gas network operator
- The materials used for the repair shall not be affected by the presence of natural gas or its components and shall be chemically compatible with PE pipe material
- The material of the repair shall be resistant to the external environment in and around gas mains throughout the life of the repair
- Pipe size range, damage type(s) and pressure range (LP, MP) for which their repair method is suitable and has been tested and has met all the necessary performance requirements

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- Any requirement for pipe surface preparation. This shall not remove more than 10% of the pipe wall thickness, unless it can be demonstrated that it has no long-term effect on the life of the PE pipe when used in combination with the applied repair
 - The degree of moisture tolerance for an effective repair. This shall be demonstrated by making the test repairs under simulated conditions i.e. wet or dry depending whether the repair can accommodate moisture
 - Any chemical products brought into contact with the pipe surface. Exposure to these chemicals and reactants shall not induce stress cracking in the PE pipe, nor otherwise affect the long-term performance of the PE pipe. This requirement shall be demonstrated by proof testing such as the environmental stress cracking test outlined in Annex F of GIS/LC1
 - General product information for all chemicals used, including storage conditions, temperature dependency and the associated maximum storage life
 - The manufacturer should demonstrate that they can remove or accommodate removal of surface contamination such as Denso, oil and soap solution to an adequate level to not affect the long term performance of the repair
 - Use of two part resin systems. The mixing ratio and pot life shall be defined by the manufacturer. The curing times, (required before site handling of the repair), are to be supplied at the minimum (-5°C) and maximum (30°C) installation temperatures. Any chemicals used shall be stable once mixed. Any requirement on the mixing method or application method shall be defined by the manufacturer and contained within the installation guidance document.
 - An installation guidance document, which shall indicate the exposed length of pipe necessary and whether the method is suitable for key-hole excavations. The dimensions of the excavation required for installation shall be defined by the manufacturer
 - Any limits on the ovality of the PE pipe for effective repair shall be defined
 - Any operational limitations in the vicinity of the repaired pipe, e.g. minimum proximity to other fittings
 - The manufacturer shall define the maximum damage footprint, i.e. the maximum diameter of through wall hole the system can accommodate, for their specific repair system. Testing shall demonstrate suitable performance
 - COSHH information and any other legal requirements, including safe and correct disposal of waste components
 - Assurance that all metal items are resistant to corrosion. In particular, all bolts, washers etc. shall be made from a suitable stainless steel to BS EN ISO 3506 for below ground use
 - The necessary level of adhesion to the PE pipe surface, shall be sufficient to maintain long-term leak tightness and integrity of the repair system over its design life.
 - Manufacturers of mechanical clamp repair systems shall specify the required bolt torque for application on PE
 - Manufacturers shall seek qualification for each different design of the repair system used to cover the required diameter range. Each subsequent new design will also require qualification testing

5. Repair classification

Repair techniques shall be classified based upon operating pressure (LP or MP) and damage type. Damage types are classified as defined in Figure 1. Repair techniques shall be qualified for approval for damage types over the diameter range for which they are applicable. The manufacturer shall state the diameter range that the repair is to be qualified for.

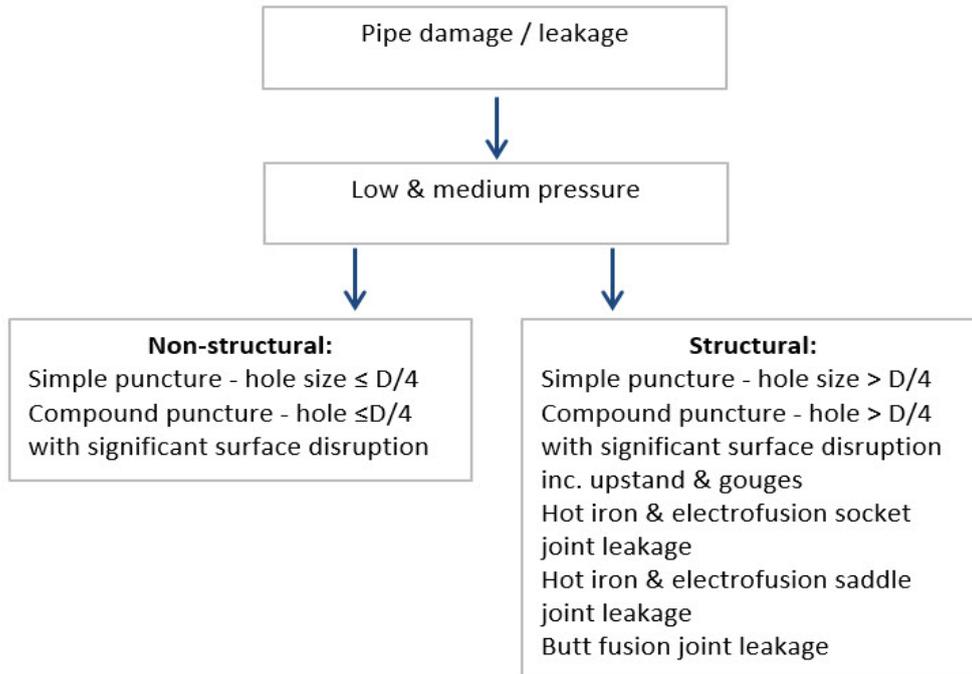


Figure 1 Damage type classification

Manufacturers shall declare the suitability of their product for the defined damage types. Repairs shall be qualified using the approval test criteria defined in Figure 2. To gain approval, all test requirements shall be met for each applicable damage type at low and / or medium pressure.

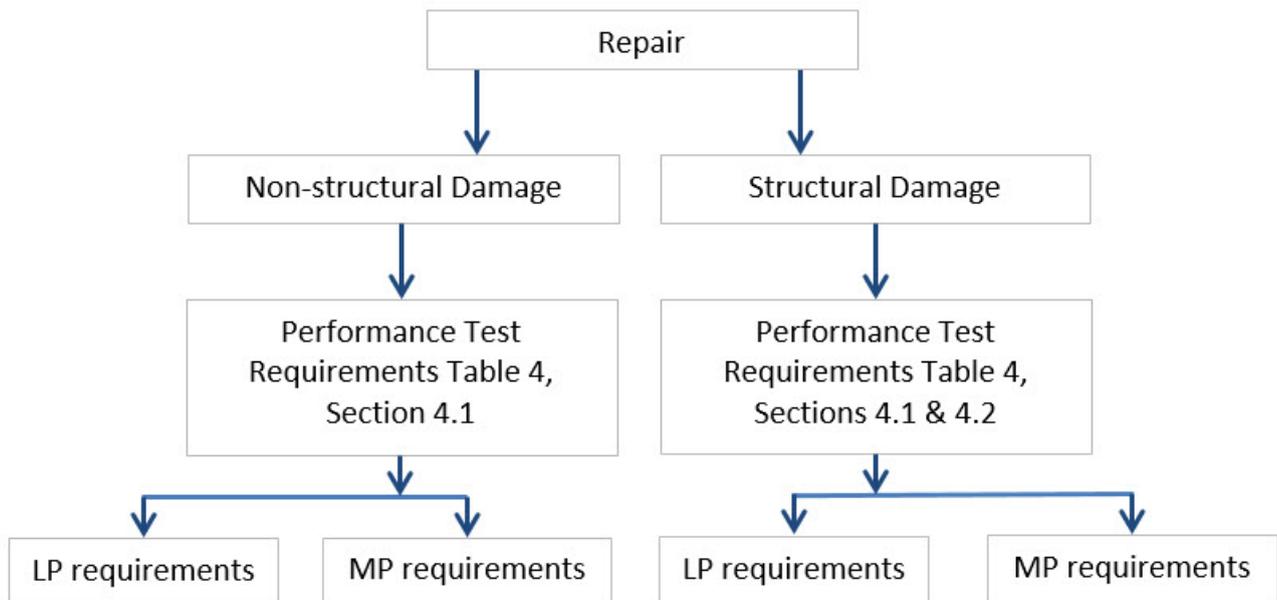


Figure 2 PE repair test requirements

5.1 Non-structural repairs (pipe)

5.1.1 Simple puncture (non-structural)

Single puncture hole ($\leq D/4$) with no other significant surface damage. The manufacturer shall declare the maximum defect size they can accommodate if they cannot accommodate $D/4$. Required sample lengths are detailed in the Appendices.

Drill a $D/4$, through wall, hole into the test pipe, see Figure 3.

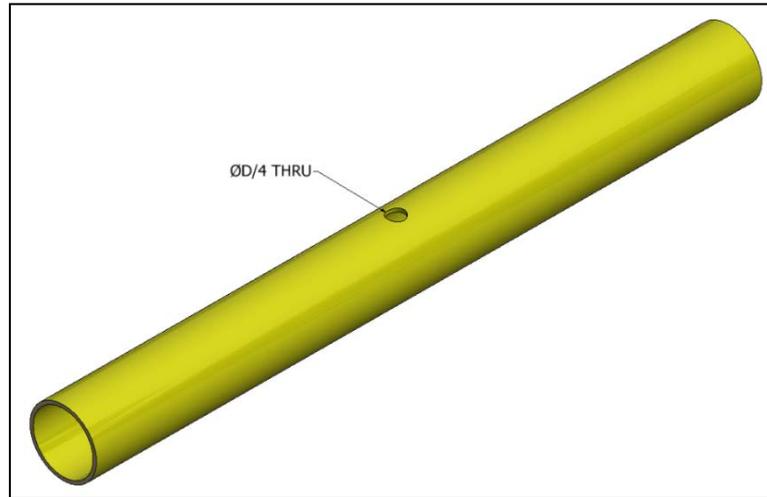


Figure 3: Simple puncture (non-structural)

5.1.2 Compound puncture (non-structural)

Puncture ($\leq D/4$) with significant surface disruption around puncture location. The manufacturer shall declare the maximum defect size they can accommodate if they cannot accommodate $D/4$. Required sample lengths are detailed in the Appendices.

Drill a $D/4$ hole through the test pipe. Drill 2 x 20mm diameter flat-bottomed blind holes into the outside of the PE test pipe to a depth of $50\% \pm 10\%$ of the wall thickness $0.5D$ either side of the hole. An axial V-groove of depth $9\% \pm 2\%$ of the wall thickness shall extend a length of $D/8$ from either side of the flat-bottomed blind holes, passing through the centreline of the $D/4$ hole, see Figure 4.

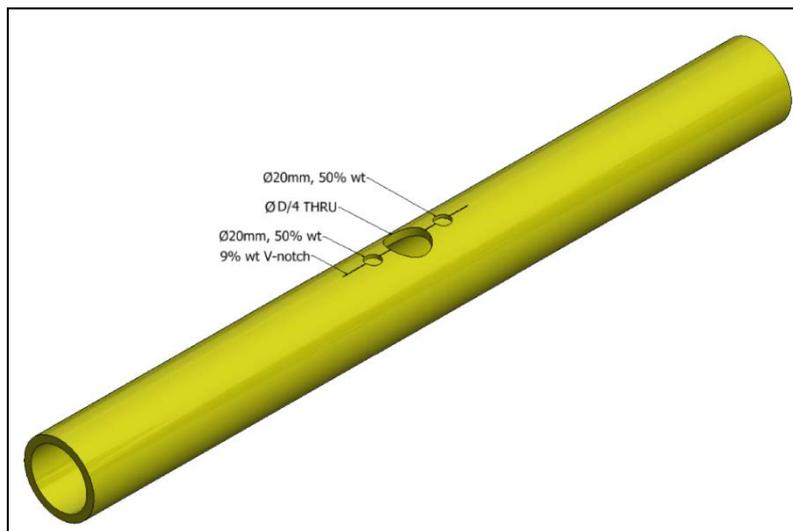


Figure 4: Compound puncture (non-structural)

5.2 Structural repairs (pipe)

5.2.1 Simple puncture (structural)

Single puncture hole ($>D/4$) with no other significant surface damage.

Drill a hole through the test pipe wall of maximum diameter the repair can accommodate into the pipe sample, see Figure 5. The repair system manufacturer shall declare the maximum defect size above $D/4$ for which they are seeking qualification and shall demonstrate the suitability of the repair system using this defect size. Required sample lengths are detailed in the Appendices.

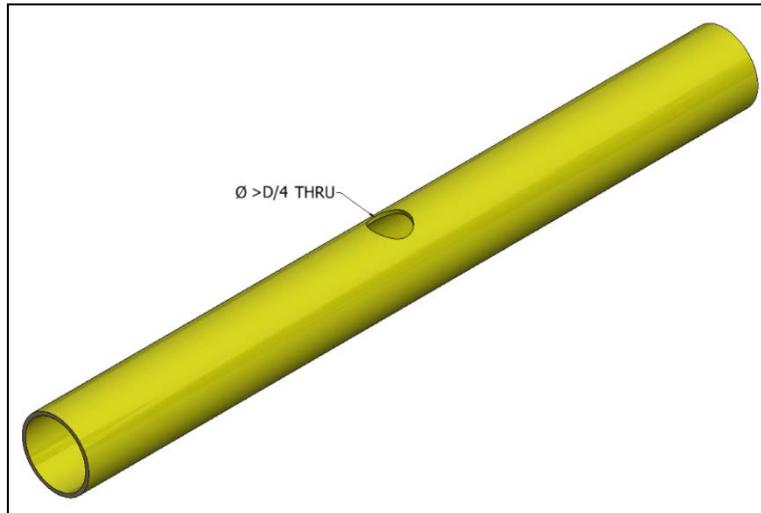


Figure 5: Simple puncture (structural)

5.2.2 Compound puncture (structural)

Puncture ($>D/4$) with significant surface disruption around puncture location.

Drill a hole through the test pipe wall of maximum diameter the repair can accommodate. The repair system manufacturer shall declare the maximum defect size above $D/4$ for which they are seeking qualification and shall demonstrate the suitability of the repair system using this defect size. Required sample lengths are detailed in the Appendices.

Drill 2 x 20mm diameter flat-bottomed blind holes into the outside of the PE test pipe to a depth of $50\% \pm 10\%$ of the wall thickness $0.5D$ either side of the hole. An axial V-groove of depth $9\% \pm 2\%$ of the wall thickness shall extend a length of $D/8$ from the flat bottomed blind holes, passing through the centreline of the hole, see Figure 6.

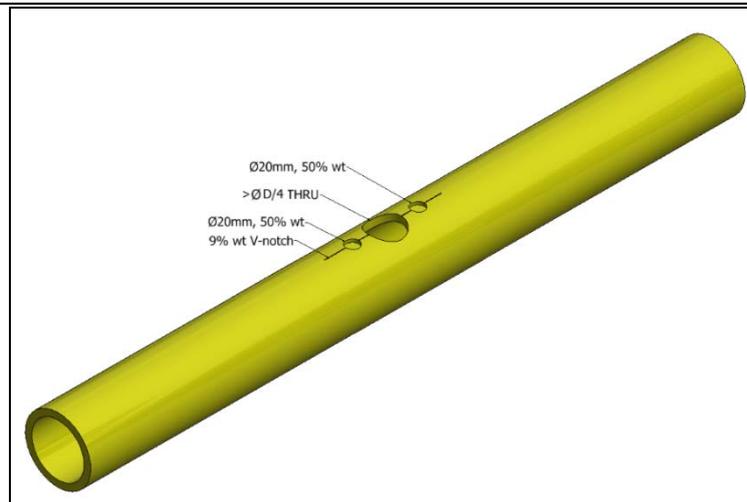


Figure 6: Compound puncture (structural)

5.3 Structural repairs (joints)

5.3.1 Hot-iron & electrofusion socket joint leakage (structural)

Leakage from socket joint interface.

On one length of pipe, mark where the edge of the electrofusion coupler is on the pipe when fully inserted. Create a 50% wall thickness deep, 3mm wide notch from the end of the pipe (within the coupler) to 5mm beyond the marked location i.e. the notch is located on one side of the coupler, see Figure 7. Scrape two lengths of PE pipe and assemble within the electrofusion coupler. Fuse the coupler and pipe lengths following GDN procedures. Required sample lengths are detailed in the Appendices.

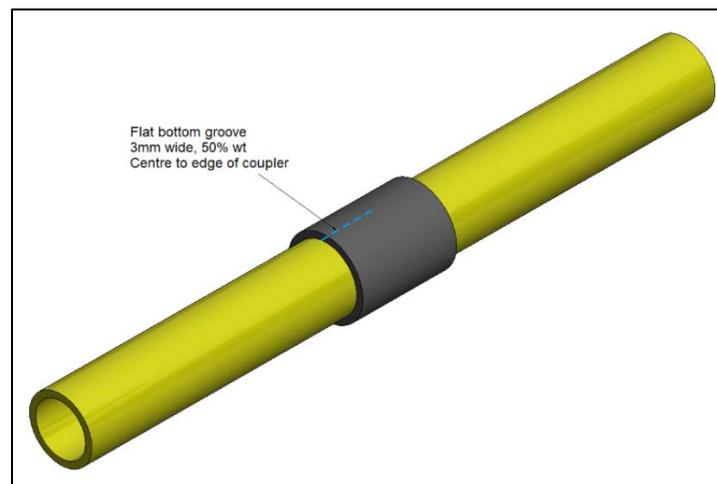


Figure 7: Hot-iron & EF socket joint leakage (structural)

5.3.2 Hot-iron & electrofusion saddle joint leakage (structural)

Leakage from saddle joint interface.

Place a tapping tee in the centre of a length of pipe. Mark the edge of the tapping tee and the centre position of the tapping tee on the pipe. Create a 50% wall thickness deep, 3mm wide notch between the two marked locations ensuring it extends 5mm beyond the footprint of the tee i.e. the notch is located on one side of the tapping tee, see Figure 8. Scrape the marked position and fuse the tapping

tee following GDN procedures. Use the integral cutter to cut through the PE pipe. Required sample lengths are detailed in the Appendices.

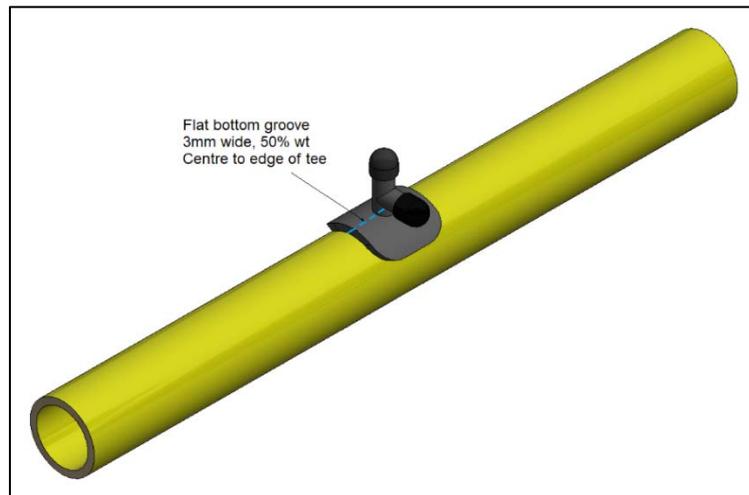


Figure 8: Hot-iron & EF saddle joint leakage (structural)

5.3.3 Butt fusion joint leakage (structural)

Leakage from butt fusion joint interface.

Butt and restrain two free square pipe ends 2mm apart such that axial movement is not possible under the test conditions e.g. when pressurised. Required sample lengths are detailed in the Appendices. See Figure 9.

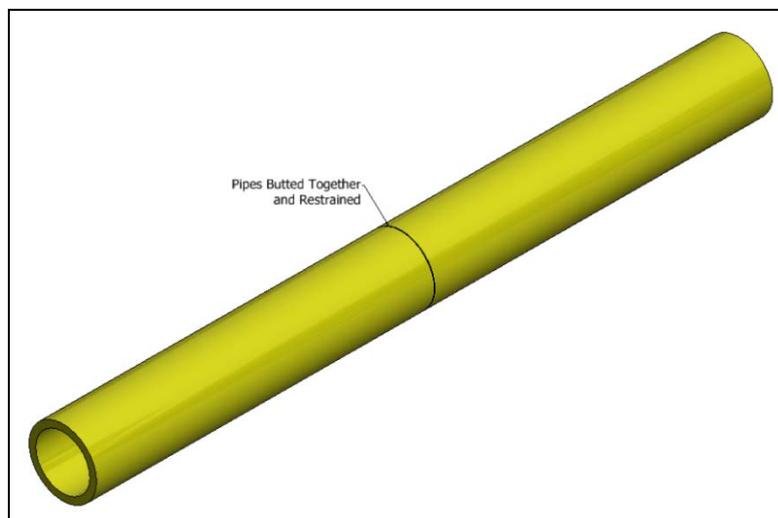


Figure 9: Butt fusion joint leakage (structural)

6. Qualification testing for damage types

Repair systems shall demonstrate successful application on all of the damage types for which approval is sought. Performance qualification testing shall then be undertaken for each individual damage type and applicable pressure tier. However, successful completion of application and performance qualification for the pipe compound puncture damage type shall also provide complete qualification for the less severe pipe barrel damage types, as defined in Tables 1 and 2. Joint damage types shall be qualified individually.

6.1 Non-structural damage (pipes)

Application and performance testing shall be undertaken for each damage type however, compound puncture can be used to qualify the other non-structural damage type as defined in Table 1. Successful testing undertaken at medium pressure will also qualify a repair method for use at low pressure.

Table 1 Non-structural damage qualification

Non-structural damage type	Application approval (LP & MP)	Complete Application Approval (LP & MP)	Individual qualification (LP & MP)	Complete qualification (LP & MP)
Simple puncture	X		X	
Compound puncture	X	X	X	X

6.2 Structural damage (pipes)

Application and performance testing shall be undertaken for each damage type however, successful testing with compound puncture damage type would also qualify use on all other structural forms of pipe barrel damage as defined in Table 2. Successful testing undertaken at medium pressure will also qualify a repair method for use at low pressure. Successful testing undertaken at medium pressure of 4 bar (Ireland) this will qualify the repair system for use at low pressure and medium pressure (UK).

Table 2 Pipe barrel structural damage qualification

Structural damage type	Application approval (LP & MP)	Complete Application Approval (LP & MP)	Individual qualification (LP & MP)	Complete qualification (LP & MP)
Simple puncture	X		X	
Compound puncture	X	X	X	X

6.3 Structural repairs (joints)

Application testing shall be undertaken individually on socket, saddle and butt fusion damage types as defined in Table 3. Individual performance testing can be undertaken for all joint damage types in Table 3, however, successful testing with hot iron and electrofusion socket damage would also qualify use for hot iron and electrofusion saddle damage. Successful testing carried out on butt fusion damage will qualify the repair system for use on all joint defects. Successful testing undertaken at medium pressure will also qualify the repair method for use at low pressure. Successful testing undertaken at medium pressure of 4 bar (Ireland) this will qualify the repair system for use at low pressure and medium pressure (UK).

Table 3 Joint structural damage qualification

Structural damage type	Application approval (LP & MP)	Individual qualification (LP & MP)	Qualification for use on socket & saddle joints (LP & MP)	Complete qualification (LP & MP)
Hot iron & EF saddle	X	X		
Hot iron & EF socket	X	X	X	
Butt fusion	X	X		X

7. Qualification testing

7.1 Application testing

Repair systems shall be applied to the damage types for which they are designed, to prove capabilities. This shall be conducted on the minimum, mid-sized and maximum applicable diameters at minimum and maximum application temperature. The repair manufacturer shall state the diameter range for which they are seeking approval.

Before assembly of the repair system, the pipe samples should be subjected to moisture, if moisture tolerance is claimed by the manufacturer. This shall be done by full wetting of the pipe samples. For assembly testing at -5 °C, the manufacturer should state what surface preparation is required to deal with ice formation.

Repairs should be applied for performance testing using the same application methodology as used in the field, including when designed for keyhole installation.

All pipe samples shall extend the lesser of 2.5 x pipe diameter or 500mm, beyond the repair e.g.:

- For pipe diameter < 200mm, 2.5 x pipe diameter shall be used
- For pipe diameter ≥ 200mm, 500mm shall be used.

7.1.1 Application testing procedure

The repair manufacturer shall declare the maximum pressure that the repair system can be applied at or the manufacturer can use the following standardised application pressures.

For each damage type, undertake a repair of the associated test assembly at -5 °C and 30 °C at a pneumatic internal supply pressure of:

- 75 mbar for LP,
- 2 bar, or the manufacturer declared maximum application pressure, for MP (UK)
- 4 bar, or the manufacturer declared maximum application pressure, for MP (Ireland).

The regulated pressure shall be maintained during application of the repair system. Once the repair has stopped the flow, the internal pressure shall instantaneously equal the regulated pressure. Test at the minimum, mid-sized and maximum pipe diameter proposed by the repair manufacturer.

Following application and any cure / drying time, the repair shall be subjected to internal pressure at 23 °C without any visible leakage for a 24-hour period.

- Internal pressure of 75 mbar for LP systems
- Internal pressure of 2 bar for MP systems (UK)
- Internal pressure of 4 bar for MP systems (Ireland)

7.2 Performance testing

Performance test requirements based on repair system type and operating pressure are detailed in Table 4. Boxes marked with an “X” indicate the tests that shall be conducted for a particular repair system. Tests shall be conducted using the test methods detailed in Appendices A – J (referenced in brackets in Table 4). Performance test requirements and applicable test parameters are detailed in Table 5.

Table 4 LP & MP performance requirements

Test Requirement	Mechanical Repair	Fusion Repair	Encapsulation Repair Tape / Wrap Repair Adhesive Repair Resin based repair	Plastic Injection Repair
4.1 LOW AND MEDIUM PRESSURE – NON-STRUCTURAL AND STRUCTURAL DAMAGE TYPES				
Hydrostatic pressure test (A)	X	X	X	X
Pressure life testing (B) ^(a)	X	X	X	X
Thermal expansion/contraction cycles (C)	X	X	X	X
Resistance to water ingress (D)	X	X	X	X
Impact resistance (E)	X	X	X	X
Bolt load relaxation (F) ^(a)	X			
Pipe bending (G)	X	X	X	X
Vibration due to external loading (H)	X	X	X	X
Squeeze off proximity (I)	X	X	X	X
4.2 LOW AND MEDIUM PRESSURE - STRUCTURAL DAMAGE - ADDITIONAL TEST REQUIREMENT				
End load resistance (J)	X	X	X	X
a) For mechanical repairs, pressure life testing OR bolt load relaxation testing can be carried out.				

Table 5 Performance test requirements

Performance test	Requirements	Test parameters	LP	MP (UK)	MP (Ireland)	No of test samples
Hydrostatic pressure test (A)	Repair systems shall withstand a short-term high level pressure test followed by a long-term test at an elevated temperature	1 hour 23 °C short term, 5000 hour 40 °C long term	525 mbar short term, 112.5 mbar long term	4.5 bar short term, 3 bar long term	9 bar, short term, 6 bar long term	2 samples for each damage type at mid-sized pipe diameter
Pressure life testing (B)	The integrity of a repair system shall be determined	Hydrostatic pressure tests at 23 °C 6 month test duration	112.5 mbar	3 bar	6 bar	8 samples for each damage type at mid-sized pipe diameter
Thermal expansion / contraction cycles (C)	The repair shall maintain leak tightness throughout temperature cycling	Cycle 50 times from 0 °C to 17 °C to 0 °C using mid-sized samples from application tests	Following cycling, 24 hour pneumatic pressure test at 350 mbar	Following cycling, 24 hour pneumatic pressure test at 3 bar	Following cycling, 24 hour pneumatic pressure test at 6 bar	2 samples for each damage type at mid-sized pipe diameter
Resistance to water ingress (D)	Buried repair systems shall withstand the ingress of water due to external water head	External water head of 2m using minimum diameter samples from application tests	No internal pressure applied, 4 week duration, no water ingress			2 samples for each damage type at minimum pipe diameter
Impact (E)	Repair shall withstand impact energy of 100 Joules without failure	5 kg controlled drop from height of 2 m (100 J) at -5 °C	Following impact, 24 hr pneumatic pressure test at 350 mbar	Following impact, 24 hr pneumatic pressure test at 3 bar	Following impact, 24 hr pneumatic pressure test at 6 bar	2 samples for each damage type at mid-sized pipe diameter, testing at -5 °C for each damage type
Bolt load relaxation (F)	The bolted mechanical repair shall maintain sufficient clamping force over the predicted design life to avoid leakage	25 mbar leakage pressure	25 mbar pneumatic internal pressure applied during long term test			2 samples for each damage type at mid-sized diameter
Vibration due to external loading (G)	The repair shall accommodate pipe vibration and remain leak tight	Vibration – 1 Hz and 4 mm amplitude applied at centre line of repair system	Following bending, 24 hr pneumatic pressure test at 350 mbar	Following bending, 24 hr pneumatic pressure test at 3 bar	Following bending, 24 hr pneumatic pressure test at 6 bar	2 samples for each damage type at mid-sized diameter

Performance test	Requirements	Test parameters	LP	MP (UK)	MP (Ireland)	No of test samples
Pipe Bending (H)	The repair shall accommodate pipe deflection then pass pressure test	3 point bending to 40 x pipe diameter	Following vibration, 24 hr pneumatic pressure test at 350 mbar	Following vibration, 24 hr pneumatic pressure test at 3 bar	Following vibration, 24 hr pneumatic pressure test at 6 bar	2 samples for each damage type at mid-sized diameter
Squeeze off proximity (I)	Repair shall accommodate squeeze off at 2.5 D axial distance from edge of repair without leakage or visible damage		Following squeeze off, 24 hr pneumatic pressure test at 350 mbar	Following squeeze off, 24 hr pneumatic pressure test at 3 bar	Following squeeze off, 24 hr pneumatic pressure test at 6 bar	2 samples for each damage type at mid-sized diameter
End load resistance (J)	The strength of the repair must overmatch the pipe when loaded to yield	Tensile test to failure at 23°C	Following tensile test, 1 hr pneumatic leak test at 75 mbar			2 samples for each damage type at mid-sized diameter
<p>a) Approval at medium pressure (MP) will give approval to the same damage type at low pressure (LP)</p> <p>b) Approval for the most severe damage type will give approval to less severe damage types</p> <p>c) Approval to the above requirements will give approval to the manufacturer's full declared diameter range</p> <p>d) Most performance tests shall be carried out using mid-sized diameter for the diameter range the repair can accommodate, provided that the gas transporter is satisfied that the design is suitable for the whole range of sizes offered by the repair manufacturer. The resistance to water ingress test shall be carried out on the minimum pipe diameter of the diameter range the repair can accommodate. Application tests will be carried out on minimum, mid-sized and maximum diameter pipe.</p>						

Annex - A Hydrostatic pressure testing

A.1 Principle

A short-term pressure test at laboratory temperature, followed by a long-term pressure test at an elevated temperature shall be undertaken. This test will determine the ability of the repair system to resist internal pressure.

A.2 Apparatus

1. Room, cabinet or water bath, which can be maintained at a temperature of $23\text{ °C} \pm 2\text{ °C}$ and $40\text{ °C} \pm 2\text{ °C}$
2. Time, pressure and temperature logging device
3. Pressure supply, water

A.3 Preparation

For each damage type the repair manufacturer is seeking approval for, apply repair system under pneumatic pressure as per the application tests and according to the manufacturer's written instruction.

The repair system shall be applied such that the sample has a minimum of 2.5 times the pipe diameter or 500 mm of plain pipe either side of the repair:

- For pipe diameter < 200mm, 2.5 x pipe diameter shall be used
- For pipe diameter \geq 200mm, 500mm shall be used.

Type A end caps in accordance with BS EN ISO 1167-1 shall be applied to test samples.

Condition the fitting assembly at test temperature $23\text{ °C} \pm 2\text{ °C}$ for short term testing, followed by $40\text{ °C} \pm 2\text{ °C}$ for long term testing for 4 h.

A.4 Test procedure

For short-term pressure testing, the internal pressure shall be applied at a rate of 1 bar/min and maintained at the test pressure for a period of 1 hour at a test temperature of $23\text{ °C} \pm 2\text{ °C}$.

Internal pressure requirements for short term hydrostatic testing at 23 °C are detailed below:

- Low pressure, 525 mbar test pressure
- Medium pressure, 4.5 bar test pressure (UK)
- Medium pressure, 9 bar test pressure (Ireland)

The test samples shall then be subjected to an additional long-term pressure test at an elevated temperature, to simulate aging of the pipe and the repair system. The test shall be undertaken at 40 °C for a period of 5000 hours.

Internal pressure requirements for long-term pressure testing at 40 °C are detailed below:

- Low pressure 112.5 mbar test pressure
- Medium pressure (UK) 3 bar test pressure
- Medium pressure (Ireland) 6 bar test pressure

A.5 Performance requirements

For pressures up to 2 bar, 2 off repaired SDR 17.6 PE pipe sample assemblies shall be subjected to each test condition at the mid-sized diameter for each applicable damage type. For pressures up to 4 bar, 2 off repaired SDR 11 PE pipe samples shall be subjected to each test condition at the mid-sized diameter for each applicable damage type. No leakage from either of the repaired PE pipe assemblies shall occur throughout the test period.

Annex - B Pressure life testing at 23 °C

B.1 Principle

The integrity of a repair system over a 50-year lifetime is determined following the procedure as detailed in the now superseded GIS LC8 Part 1 (2006). The test shall establish the lifetime of the repair. Testing shall be undertaken on applicable damage types for which the repair systems are designed.

B.2 Apparatus

1. Room, cabinet or water bath, which can be maintained at a temperature of 23 °C ± 2 °C
2. Time, pressure and temperature logging device
3. Pressure supply, water

B.3 Preparation

For each standardised damage type the repair manufacturer is seeking approval for, apply repair system under pneumatic pressure as per the application tests and according to the manufacturer's written instruction.

The repair system shall be applied such that the sample has a minimum of 2.5 times the pipe diameter or 500 mm of plain pipe either side of the repair:

- For pipe diameter < 200mm, 2.5 x pipe diameter shall be used
- For pipe diameter ≥ 200mm, 500mm shall be used.

Type A end caps in accordance with BS EN ISO 1167-1 shall be applied to test samples.

Condition the fitting assembly at 23 °C ± 2 °C for 4 hours. Carry out a pneumatic pressure test at 75 mbar for LP repairs, 2 bar for MP repairs (UK) and 4 bar for MP repairs (Ireland), for 15 minutes to confirm the integrity of each sample prior to the pressure life testing.

For pressures up to 2 bar, 8 off SDR 17.6 repaired pipe samples at mid-sized diameter are required for testing. For pressures up to 4 bar, 8 off repaired SDR 11 pipe samples shall be tested at the mid-sized diameter for each applicable damage type

B.4 Test procedure

The test procedure is based on the now superseded GIS LC8 Part 1, Section D.7.

Pressurise 2 off samples to a pressure that will cause failure within a time period of between 1 hour and 3 hours. Note the average pressure, P at which this failure occurs and average time period to failure T_p .

P_1 shall be established by drawing a straight line joining the initial point (T_p, P) to the 50 year point at 1.5 x the maximum operating pressure (50 year/ $1.5P_{max}$) see Figure 10. P_{max} is the specified maximum operating pressure multiplied by factor of safety (1.5 x MAOP). P_1 shall then be measured on the graph as the pressure corresponding to six months on the time axis.

P_2 and P_3 shall be determined as follows:

$$P_2 = P_1 + \frac{P - P_1}{3}$$

$$P_3 = P_1 + \frac{2(P - P_1)}{3}$$

Hold 2 samples at P_1 , 2 samples at P_2 and 2 samples at P_3 for 6 months or until failure, whichever is the shorter period. The results obtained shall be plotted on the graph to show the failure band. A line of best fit shall be added to the lower end of the failure band and extrapolated to 50 years (as shown in Figure 10); the corresponding pressure shall not be less than 1.5 times the MAOP.

The test shall be repeated for each applicable damage type.

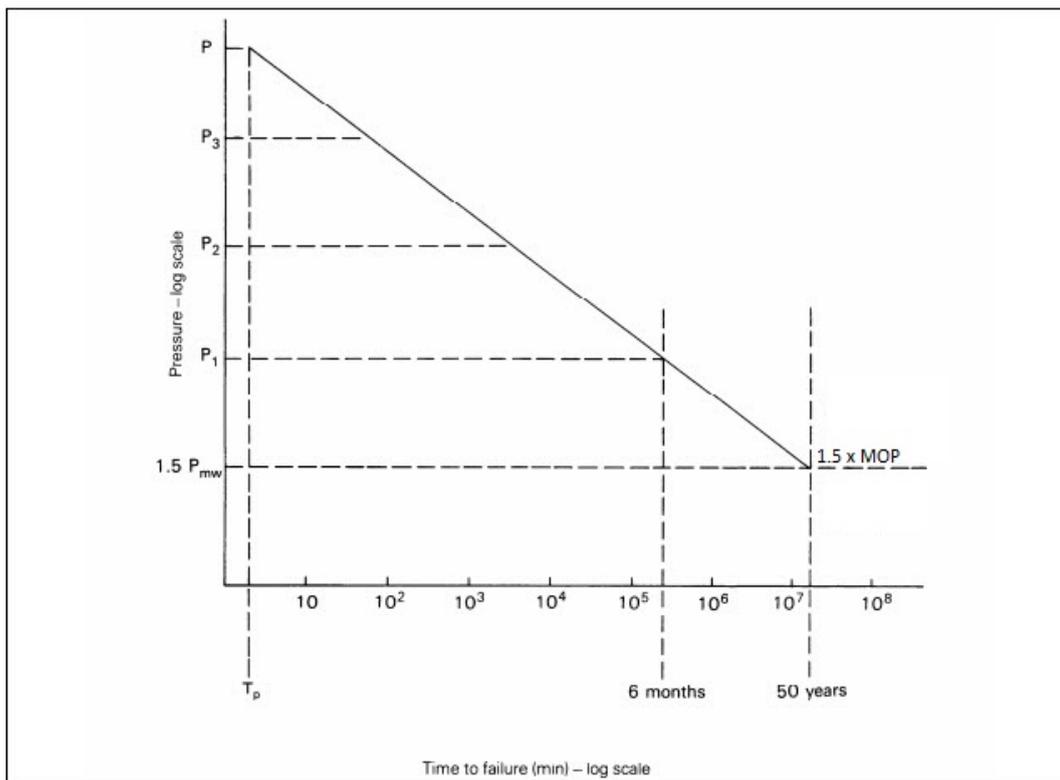


Figure 10 Pressure life testing (GIS LC8 Part 1)

B.5 Performance requirement

The time period at which graphically the pressure life line drops below the P_{\max} value is the applicable life of the repair system.

Annex - C Thermal cycling

C.1 Principle

Throughout the life cycle of a repair system, temperature variation will cause expansion and contraction of the pipe, joints and any installed repair system. Differential expansion/contraction between the PE pipe and the repair system may lead to long-term leakage.

C.2 Apparatus

1. Temperature cabinet which can be cycled at a temperature range of $0\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ to $17\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$
2. Time, pressure and temperature logging device.
3. Pressure supply, air

C.3 Preparation

The mid-sized diameter test samples shall be taken from the application tests.

Carry out a pneumatic pressure test at 75 mbar for LP repairs, 2 bar for MP repairs (UK) and 4 bar for MP repairs (Ireland), for 15 minutes to confirm the integrity of each sample prior to thermal cycling.

C.4 Cyclic testing

Pressurise samples to an internal pressure of 75 mbar for LP systems, 2 bar for MP systems (UK) and 4 bar for MP systems (Ireland). The temperature shall be cycled from $0\text{ }^{\circ}\text{C}$ to $17\text{ }^{\circ}\text{C}$ to $0\text{ }^{\circ}\text{C}$ over a 48-hour period. A minimum of 50 cycles shall be completed to simulate the maximum temperature variation expected to be encountered over the life of the repair system.

Following temperature cycling a pressure test shall be undertaken at the following pressures for a period of 24 hours to confirm integrity. Testing shall then be undertaken at $23\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$:

- Internal pressure of 350 mbar for LP systems
- Internal pressure of 3 bar for MP systems (UK)
- Internal pressure of 6 bar for MP systems (Ireland)

For pressures up to 2 bar, 2 off SDR 17.6 repaired pipe samples shall be tested at the mid-sized diameter for each applicable damage type. For pressures up to 4 bar, 2 off repaired SDR 11 pipe samples shall be tested at the mid-sized diameter for each applicable damage type

C.5 Performance requirements

No leakage shall occur throughout the pressure test period.

Annex - D Resistance to water ingress at 23 °C

D.1 Principle

Buried repair systems will need to withstand the ingress of water due to changes in the water table over the lifetime of the installation. The combination of 2 m water head and no internal pressure is to simulate worst-case flood conditions with minimum internal pressure conditions.

D.2 Apparatus

1. Temperature controlled cabinet maintained at $23\text{ °C} \pm 2\text{ °C}$
2. Time, pressure and temperature logging device.
3. Pressurised water supply

D.3 Preparation

The minimum diameter test samples shall be used following the application tests, once they have returned to ambient temperature. Condition the application test assemblies at $23\text{ °C} \pm 2\text{ °C}$ for 4 hours. Carry out a pneumatic pressure test at 75 mbar for LP repairs, 2 bar for MP repairs (UK) and 4 bar for MP repairs (Ireland), for 15 minutes to confirm the integrity of each sample prior to testing.

D.4 Water head testing

The test assemblies shall be setup to allow pressurized water to surround the repair system externally. The ends of the pipe sample shall be sealed with no internal pressure applied with a means of recording the backpressure applied.

An external pressure equivalent to a 2m head of water shall be applied externally to the pipe repair. The external pressure shall be maintained for a period of 4 weeks and the sample visually inspected to ensure no water ingress occurs through the repair. Test temperature shall be maintained at $23\text{ °C} \pm 2\text{ °C}$ throughout.

For pressures up to 2 bar, 2 off SDR 17.6 repaired pipe samples shall be tested at the minimum diameter for each applicable damage type. For pressures up to 4 bar, 2 off repaired SDR 11 pipe samples shall be tested at the mid-sized diameter for each applicable damage type

D.5 Performance requirements

No water ingress shall occur throughout the test period.

Annex - E Impact resistance

E.1 Principle

This test simulates a sudden load being accidentally applied to the completed repair prior to backfilling. The repair system shall withstand a single impact of 100 Joules resulting from a single controlled impact of 5 kg load falling 2.0 m.

E.2 Apparatus

1. Temperature cabinet which can be maintained at $-5\text{ °C} \pm 2\text{ °C}$
2. Time, temperature and pressure monitoring equipment
3. Compressed air supply
4. Impactor equipment

E.3 Test specimen

For each standardised damage type the repair manufacturer is seeking approval for, apply repair system under pneumatic pressure as per the application tests and according to the manufacturer's written instruction.

The repair system shall be applied such that the sample has a minimum of 2.5 times the pipe diameter or 500 mm of plain pipe either side of the repair:

- For pipe diameter $< 200\text{mm}$, $2.5 \times$ pipe diameter shall be used
- For pipe diameter $\geq 200\text{mm}$, 500mm shall be used.

Type A end caps in accordance with BS EN ISO 1167-1 shall be applied to test samples.

Condition the fitting assembly at test temperature of $-5\text{ °C} \pm 2\text{ °C}$ for 24 hours. Carry out a pneumatic pressure test at 75 mbar for LP repairs, 2 bar for MP repairs (UK) and 4 bar for MP repairs (Ireland), for 15 minutes to confirm the integrity of each sample prior to testing.

E.4 Impact Testing

There shall be no pressure inside the test sample during impact. For resin, tape and encapsulation based repair systems; the impact shall be applied at the centre point of the repair axially and at top dead centre. For a mechanical clamp or fusion bonded repair, the impact shall be at the edge of the fitting and the pipe. The impactor head shall be hemispherical of 50 mm radius; see Figure 11. The impact shall be undertaken on test samples conditioned at $-5\text{ °C} (\pm 2\text{ °C})$.

For pressures up to 2 bar, 2 off SDR 17.6 repaired pipe samples shall be tested at the mid-sized diameter for each applicable damage type. For pressures up to 4 bar, 2 off repaired SDR 11 pipe samples shall be tested at the mid-sized diameter for each applicable damage type

A visual inspection of the repair and pipe shall be carried out after impact and before the subsequent pressure test, and any cracks, indents or other damage recorded.

Following impact, the repair shall be pressure tested at $23\text{ °C} \pm 2\text{ °C}$ without failure for a 24-hour period.

- Internal pressure of 350 mbar for LP systems
- Internal pressure of 3 bar for MP systems (UK)
- Internal pressure of 6 bar for MP systems (Ireland)

E.5 Performance requirements

No leakage shall occur throughout the pressure test period.

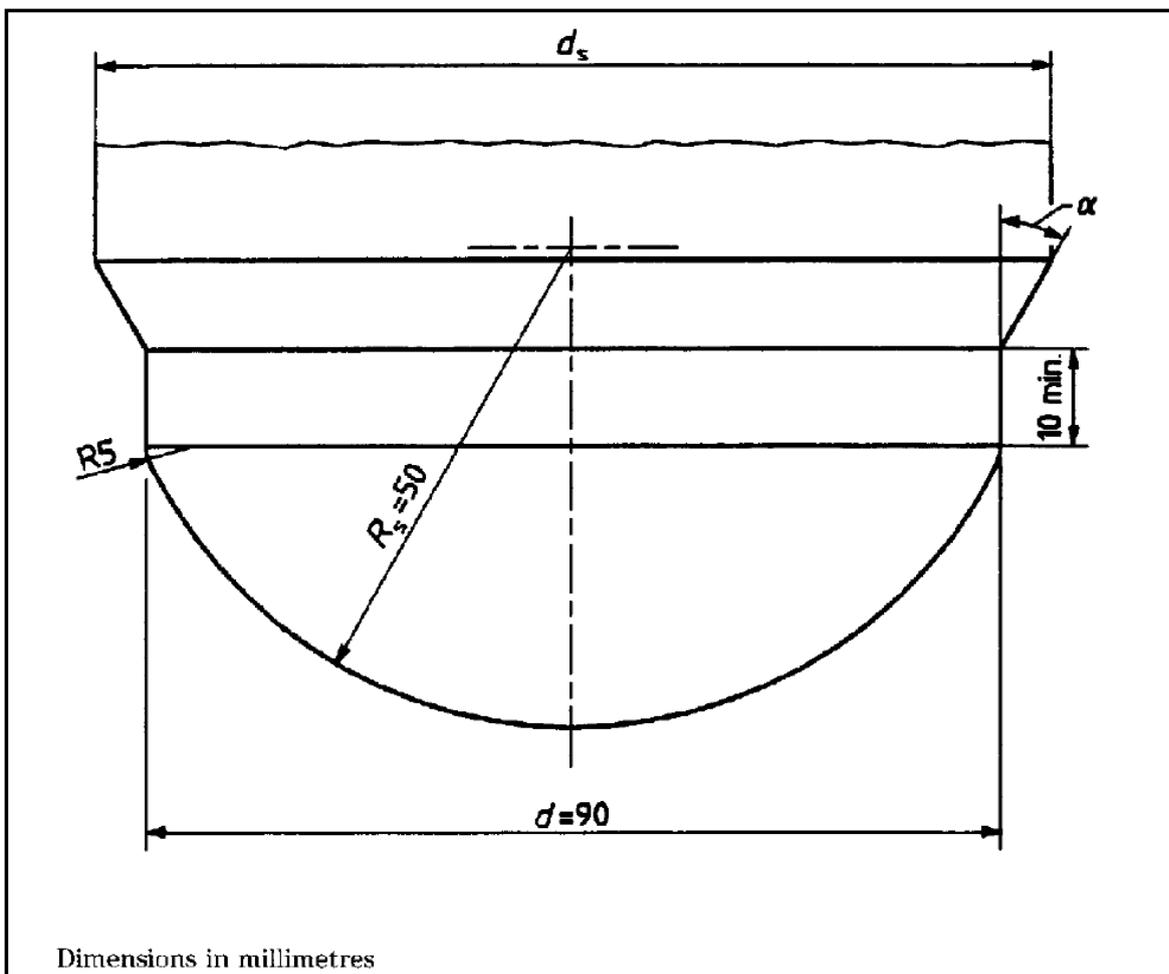


Figure 11 Impactor dimensions

Annex - F Bolt load relaxation at 23 °C

F.1 Principle

This test method is applicable to repair systems where bolts are used to provide a long-term clamping force.

F.2 Apparatus

1. Room maintained at 23 °C ± 2 °C
2. Strain gauge load cells, spherical seated washers and data logging equipment
3. Temperature monitoring equipment
4. Pressure monitoring equipment
5. Compressed air supply
6. Torque wrench

F.3 Test specimen

For each standardised damage type the repair manufacturer is seeking approval for, apply repair system under pneumatic pressure as per the application tests and according to the manufacturer's written instruction.

The repair system shall be applied such that the sample has a minimum of 2.5 times the pipe diameter or 500 mm of plain pipe either side of the repair:

- For pipe diameter < 200mm, 2.5 x pipe diameter shall be used
- For pipe diameter ≥ 200mm, 500mm shall be used.

Type A end caps in accordance with BS EN ISO 1167-1 shall be applied to test samples

Carry out a pneumatic pressure test at 75 mbar for LP repairs, 2 bar for MP repairs (UK) and 4 bar for MP repairs (Ireland), for 15 minutes to confirm the integrity of each sample prior to testing.

Apply strain gauge load cells and spherically seated washers to the bolts of the clamp.

Condition the fitting assembly at 0 °C ± 2 °C for 24 hours prior to the 3-month bolt load relaxation test.

F.4 Bolt load relaxation testing

The test procedure is taken from the now superseded GIS LC8 Part 4. Determine the bolt load (F_L) at 0 °C at which leakage just occurs at an internal pressure of 25 mbar for LP repairs and MP repairs. Do this by loosening the bolts progressively, maintaining the bolt loads as evenly as possible, until leakage occurs and record the average bolt load F_L .

Re-tighten the bolts to the suppliers recommended method and torque. Pressurise the test sample to 25 mbar at 23 °C ± 2 °C for all samples, to ensure the sample is leak tight, and then depressurize the sample. After completion of bolt tightening, measure the average bolt loads over

a period of 3 months (ignoring the first 10 minutes of data), recording the minimum of two average bolt loads (F_m) per logarithmic decade of time in minutes.

Plot a graph of F_m against \log_{10} time (minutes) and draw a straight line through the points, based on the least sum of the squares of the errors in the value of F_m (see Figure 12).

For pressures up to 2 bar, 2 off SDR 17.6 repaired pipe samples shall be tested at the mid-sized pipe diameter for each applicable damage type. For pressures up to 4 bar, 2 off SDR 11 repaired pipe samples shall be tested at the mid-sized diameter for each applicable damage type.

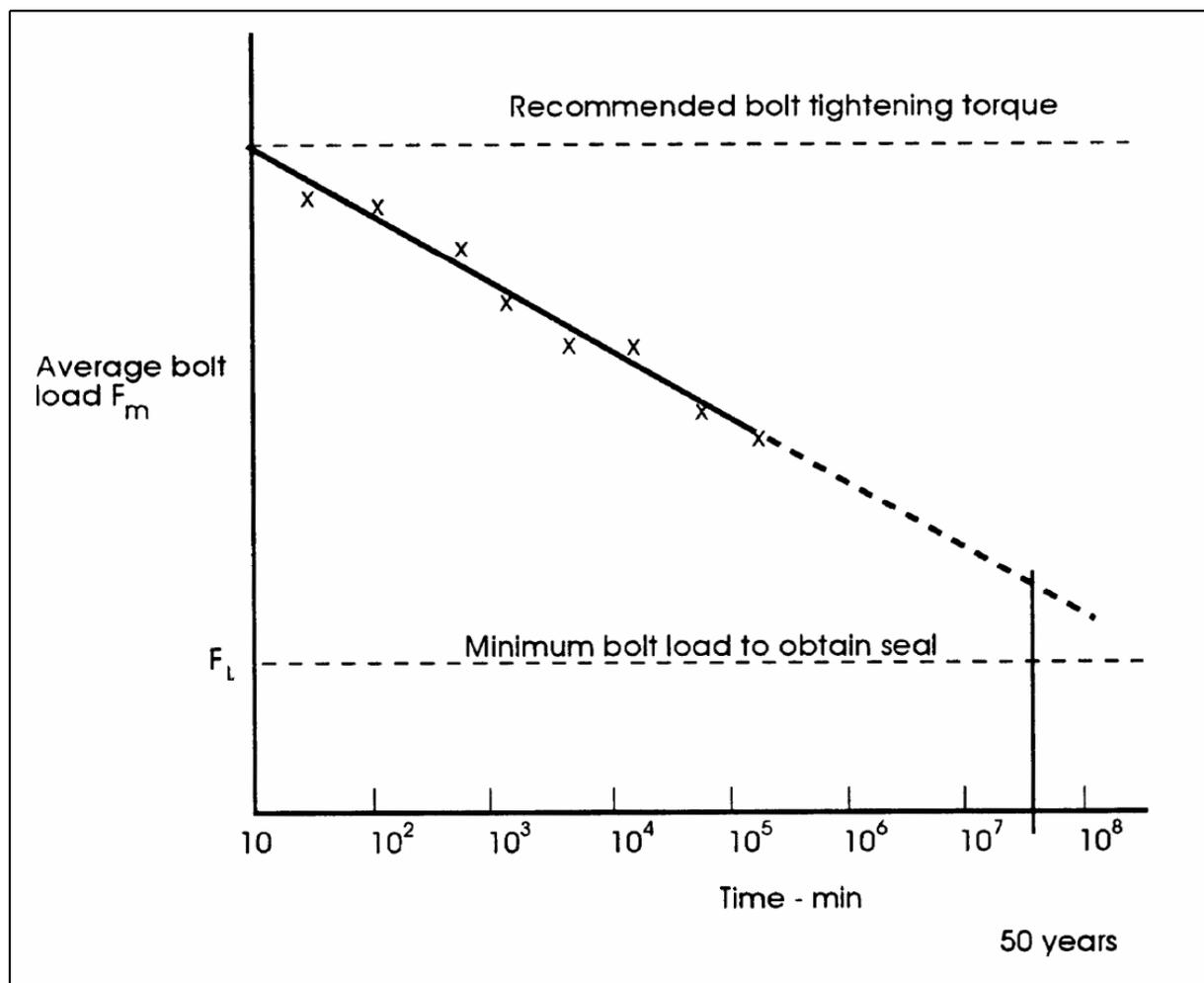


Figure 12 Bolt load relaxation

F.5 Performance requirements

Ensure the estimated bolt load after 50 years is not less than the bolt load at which leakage occurs (F_L).

Annex - G Pipe vibration

G.1 Principle

The ability of the repair system to accommodate ground vibration of the pipe to simulate traffic loading shall be determined.

G.2 Apparatus

1. Room maintained at $23\text{ °C} \pm 2\text{ °C}$
2. Temperature monitoring equipment
3. Compressed air supply
4. Pressure monitoring equipment
5. Vibration bend rig suitable of accommodating a 3 m pipe length

G.3 Test specimen

For each standardised damage type the repair manufacturer is seeking approval for, apply repair system under pressure as per the application tests and according to the manufacturer's written instruction. The damage shall be located at the centre of a 3 m long test pipe sample, see Figure 13.

Type A end caps in accordance with BS EN ISO 1167-1 shall be applied to the test samples.

Condition the fitting assembly at $23\text{ °C} \pm 2\text{ °C}$ for 4 hours. Carry out a pneumatic pressure test at 75 mbar for LP repairs, 2 bar for MP repairs (UK) and 4 bar for MP repairs (Ireland), for 15 minutes to confirm the integrity of each sample prior to testing.

Loads shall be applied at the centre line of the repair system.

G.4 Pipe vibration

Vibration of the pipe and repair system shall be restricted to a single plane. The centre of the 3 m long sample shall be subjected to 1 Hz frequency and 4 mm amplitude, for 0.5 million cycles at $23\text{ °C} \pm 2\text{ °C}$.

Following vibration, the repair shall be pressure tested at $23\text{ °C} \pm 2\text{ °C}$ without failure for a 24 hour period.

- Internal pressure of 350 mbar for LP systems
- Internal pressure of 3 bar for MP systems
- Internal pressure of 6 bar for MP systems (Ireland)

For pressures up to 2 bar, 2 off SDR 17.6 repaired pipe samples shall be tested at the mid-sized diameter for each applicable damage type. For pressures up to 4 bar, 2 off SDR 11 repaired pipe samples shall be tested at the mid-sized diameter for each applicable damage type.

G.5 Performance requirements

No leakage shall occur throughout the pressure test period.

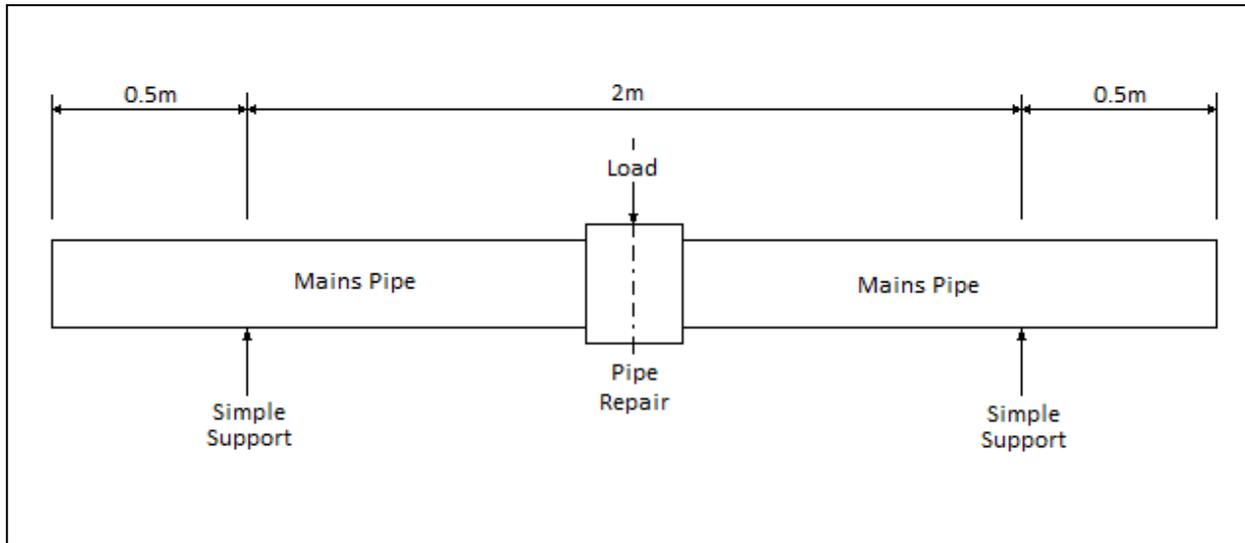


Figure 13 Pipe vibration

Annex - H Pipe bending

H.1 Principle

The ability of the repair system to accommodate bending of the pipe that may be applied during reinstatement or later ground movement shall be determined.

H.2 Apparatus

1. Room maintained at $23\text{ °C} \pm 2\text{ °C}$
2. Temperature monitoring equipment
3. Compressed air supply
4. Pressure monitoring equipment
5. 4-point bend rig suitable for accommodating a 3 m pipe length

H.3 Test specimen

The test samples shall be taken from the vibration tests. The damage shall be located at the center of a 3 m long test sample.

Condition the fitting assembly at $23\text{ °C} \pm 2\text{ °C}$ for 4 hours. Carry out a pneumatic pressure test at 75 mbar for LP repairs, 2 bar for MP repairs (UK) and 4 bar for MP repairs (Ireland), for 15 minutes to confirm the integrity of each sample prior to testing.

H.4 Pipe bending

3-point bend testing shall be undertaken to apply a displacement at the center of the repair on the 3 m long PE pipe. The 3 loading points in the bend test shall be equally spaced, see Figure 14. The load shall be applied at the centre of the pipe repair with the supports then spaced accordingly as shown in Figure 14. A displacement shall be applied either side of the repair to induce a 40 D curvature within the central loading section at $23\text{ °C} \pm 2\text{ °C}$.

Whilst held at this bend radius, the repair shall be pressure tested without failure for a 24-hour period at $23\text{ °C} \pm 2\text{ °C}$.

- Internal pressure of 350 mbar for LP systems
- Internal pressure of 3 bar for MP systems (UK)
- Internal pressure of 6 bar for MP systems (Ireland)

For pressures up to 2 bar, 2 off SDR 17.6 repaired pipe samples shall be tested at the mid-sized diameter for each applicable damage type. For pressures up to 4 bar, 2 off SDR 11 repaired pipe samples shall be tested at the mid-sized diameter for each applicable damage type.

H.5 Performance requirements

No leakage shall occur throughout the pressure test period.

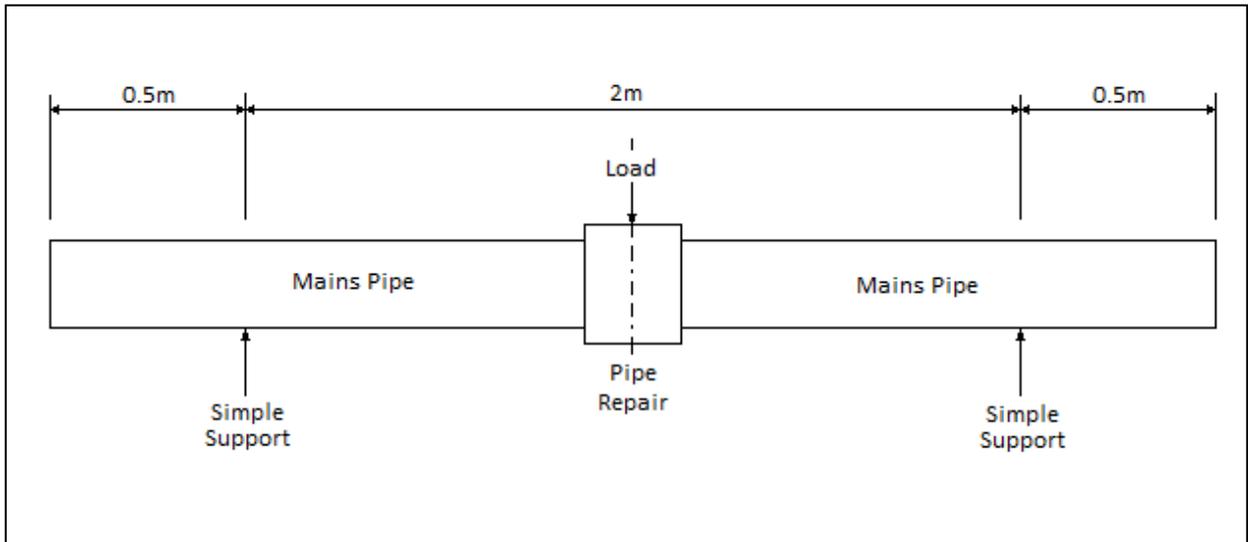


Figure 14 Pipe bending

Annex - I Squeeze off proximity at 0 °C

I.1 Principle

To ensure normal maintenance practices can be accommodated, application of a squeeze off at 2.5 D from the end of the repair shall have no detrimental effect on the performance of the repair system.

I.2 Apparatus

1. Temperature cabinet which can be maintained at a temperature of $0\text{ °C} \pm 2\text{ °C}$
2. Temperature monitoring equipment
3. Compressed air supply
4. Pressure monitoring equipment
5. Squeeze off equipment

I.3 Test specimen

For each standardised damage type the repair manufacturer is seeking approval for, apply repair system under pressure, as per the application tests and according to the manufacturer's written instruction.

The repair system shall be applied such that the sample has a distance of at least 5 times the pipe nominal diameter to one pipe end and the lesser of 2.5 D or 500mm to the other side, see Figure 15:

- For pipe diameter < 200mm, 2.5 x pipe diameter shall be used
- For pipe diameter \geq 200mm, 500mm shall be used.

Type A end caps in accordance with BS EN ISO 1167-1 shall be applied to the test samples.

Condition the fitting assembly at $0\text{ °C} \pm 2\text{ °C}$ for 4 hours prior to squeeze off.

Condition the fitting assembly at $23\text{ °C} \pm 2\text{ °C}$ for 4 hours prior to subsequent pressure test.

Carry out a pneumatic pressure test at 75 mbar for LP repairs, 2 bar for MP repairs (UK) and 4 bar for MP repairs (Ireland), for 15 minutes to confirm the integrity of each sample prior to testing.

I.4 Squeeze off

Apply squeeze off for 24 hours at $0\text{ °C} \pm 2\text{ °C}$. Equipment shall be manufactured in accordance with PL2 – Part 7.

Following application of squeeze off at a distance of 2.5 D from the repair, the repaired pipe shall be subjected to a pressure test at $23\text{ °C} \pm 2\text{ °C}$ for 24 hours. The pipe shall not be re-rounded following squeeze off.

Applicable internal pressure for pressure testing:

- Internal pressure of 350 mbar for LP systems
- Internal pressure of 3 bar for MP systems (UK)
- Internal pressure of 6 bar for MP systems (Ireland)

Examine the repair for visible damage or leakage.

For pressures up to 2 bar, 2 off SDR 17.6 repaired pipe samples shall be tested at the mid-sized pipe diameter for each applicable damage type (up to 250 mm diameter). For pressures up to 4 bar, 2 off SDR 11 repaired pipe samples shall be tested at the mid-sized diameter for each applicable damage type (up to 250 mm diameter).

I.5 Performance requirements

No leakage shall occur throughout the pressure test period.

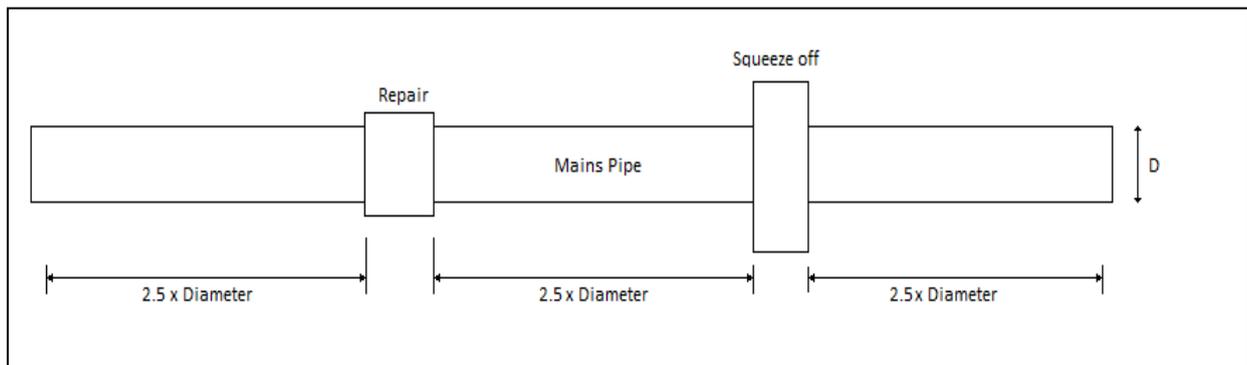


Figure 15 Squeeze off

Annex - J End load resistance at 23 °C

J.1 Principle

The ability of the repaired pipe assembly to continue to accommodate the applied end loads shall be determined for structural repair systems.

J.2 Apparatus

1. Temperature cabinet which can be maintained at a temperature of $23\text{ °C} \pm 2\text{ °C}$
2. Temperature monitoring equipment
3. Compressed air supply
4. Pressure logging equipment
5. Tensile testing machine or other equipment sufficiently powerful to allow tests to be carried out up to the load values in Table 6. The machine shall be capable of sustaining, between its clamping jaws, a constant force with maximum variation of 5%

J.3 Test specimen

For each standardised damage type the repair manufacturer is seeking approval for, apply repair system under pneumatic pressure as per the application tests and according to the manufacturer's written instruction.

The repair system shall be applied such that the sample has a minimum of the lesser of, 2.5 times pipe diameter or 500 mm, either side of the repair, see Figure 16:

- For pipe diameter < 200mm, 2.5 x pipe diameter shall be used
- For pipe diameter \geq 200mm, 500mm shall be used.

Type A end caps in accordance with BS EN ISO 1167-1 shall be applied to test samples.

Condition the fitting assembly at $23\text{ °C} \pm 2\text{ °C}$ for 4 hours.

J.4 Pipe end load

A repaired damaged test sample shall be initially pressure tested for a 1-hour period, the test temperature shall be $23\text{ °C} (\pm 2\text{ °C})$.

- Internal pressure of 350 mbar for LP systems
- Internal pressure of 3 bar for MP systems (UK)
- Internal pressure of 6 bar for MP systems (Ireland)

The repaired section shall then be axially loaded in tension at an extension rate of 25 mm/min as defined in BS ISO 13951. The strength of the repair must overmatch the pipe and therefore the pipe shall yield before the repair fails.

No internal pressure shall be required during the test.

Following application of the axial load, the repair assembly shall be leak tested for a 1-hour period at $23\text{ °C} \pm 2\text{ °C}$ to confirm integrity of the repair has not been comprised.

For pressures up to 2 bar, 2 off SDR 17.6 repaired pipe samples at the mid-sized pipe diameter shall be tested for each applicable damage type. For pressures up to 2 bar, 2 off SDR 11 (PE80) repaired pipe samples shall be tested at the mid-sized pipe diameter and for repairs up to 4 bar 2 off SDR 11 (PE100) repaired pipe samples shall be tested for each applicable damage type.

J.5 Performance requirements

No leakage shall occur throughout the pressure test period.

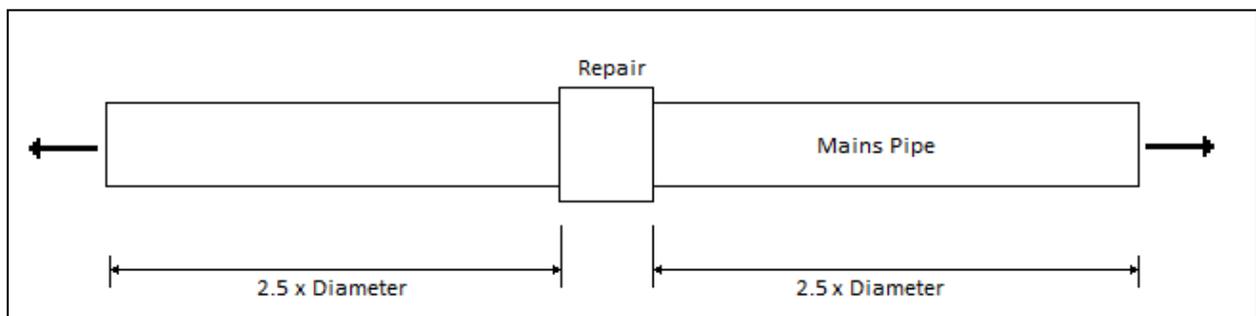


Figure 16 End load resistance