Specification for

Glass reinforced plastics (GRP) pipes, joints and fittings for use for water supply or sewerage

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Plastics Standards Policy Committee (PLM/-) to Technical Committee PLM/9, upon which the following bodies were represented:

British Board of Agrément
British Gas plc
British Plastics Federation
British Plumbing Fittings Manufacturers' Association
British Valve and Actuator Manufacturer's Association
Department of the Environment (Building Research Establishment)
Department of the Environment (Construction Industries Directorate)
Department of the Environment (Property Services Agency)
Department of Transport
Electricity Supply Industry in England and Wales
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Royal Institute of Public Health and Hygiene
Society of British Gas Industries
Society of British Water Industries
Water Companies Association
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The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Association of Consulting Engineers
Federation of Civil Engineering Contractors
Institution of Mechanical Engineers
Pipeline Industries Guild

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Contents

Foreword

This British Standard has been prepared under the direction of the Plastics Standards Policy Committee.

It is a revision of BS 5480-1:1977 and BS 5480-2:1982 which are now withdrawn. BS 5480 specifies requirements for pipes, fittings and joints made of glass reinforced plastics (GRP) based on thermosetting resins in sizes corresponding to internal diameters ranging from 100 mm to 4 000 mm for use for water supply or sewerage, including some industrial drainage, under gravity flow or internal pressures up to 25 bar[1]. Requirements are specified for materials, design limits, dimensions, classification, physical properties, performance properties and marking. Where cross-references to other standards are not appropriate, associated methods of test are described in appendices. Guidance on sampling and quality control testing is provided as Appendix Q and a bibliography as Appendix R. For the construction of GRP piping systems for sewerage and/or drainage, attention is drawn to BS 8005 and BS 8301, and for the construction of pipelines using GRP pipework, attention is drawn to BS 8010 and in particular BS 8010-2.5.

For the design and performance of GRP pipes and fittings for process plants, attention is drawn to BS 6464; for the design and construction of GRP piping systems for individual plants or sites, attention is drawn to BS 7159.

In the preparation of this British Standard, account has been given to the work of Technical Committee 138 of the International Organization for Standardization (ISO), but this has not yet given rise to a corresponding specification. Nevertheless the opportunity has been taken to align this standard with the current ISO terminology and philosophy in respect of the determination of stiffness and in requirements for joints, with particular consideration being given to ISO/DIS 8639.

The major changes between this revision and the previous editions of BS 5480-1 and BS 5480-2 are as follows.

a) The requirements and specific test methods have been consolidated into a single publication.

b) The requirements are verifiable where appropriate, so that third party certification may be applicable. For guidance on installation, reference is made to applicable codes of practice. Information and guidance on sampling and quality control testing has been provided in an advisory appendix.

c) The requirements for materials for use with potable water have been updated, to make reference to BS 6920-1.

d) For the pipe design limits:

1) the limit for long term circumferential strength is based on the lower 95 % confidence limit of the extrapolated mean value obtained by statistical linear functional relationship analysis, instead of the extrapolated mean value previously used;

2) a factoring method is used to estimate the long term longitudinal strength from the short term longitudinal strength;

3) the short term longitudinal strength requirement is based on a draft ISO document, but with a minimum value of 100 kN/m of circumference.

e) Attention is drawn to the fact that special consideration is necessary for design limits for pipe intended to carry septic sewage or aggressive industrial waste if under pressure.

f) The nominal size range has been changed from (25 to 4 000) to (100 to 4 000), to better reflect current practice.

g) The deviation of the work size from the nominal size has been changed from $^{+1}_{-3.5}$ % to ± 3.5 %. (The manufacturing tolerances thereon are unchanged.)

[1] 1 bar = 10^5 N/m^2 = 10^5 Pa.

h) The pressure class range has been changed from (0 bar to 65 bar) to (0 bar to 25 bar), for consistency with the purpose of the specified components.

i) The stiffness class range has been changed from (250 N/m^2 to 8 000 N/m^2) to (1 250 N/m^2 to 20 000 N/m^2), for enhanced resistance to distortion.

j) The significance of any visual discontinuities, such as voids or contamination, is related to the requirements of this specification, instead of intangible or insignificant "impairment of performance in service".

k) For the determination of longitudinal tensile strength, the applied load is a function of the size and pressure class of the pipe.

l) The method for the determination of impact resistance allows the performance of the test piece to be assessed, and therefore any variations between samples can be assessed, instead of a simple pass/fail test. (For lack of suitable data, the basic requirement has not been made more stringent.)

m) The test pressure for the leaktightness of pressure pipes has been changed to (1.5 × pressure rating).

n) Requirements have been introduced for the leaktightness of prefabricated joints.

o) A method is provided for the assessment of long term stiffness consistent with the methods for determining compliance with the requirements for initial stiffness, which now includes the corresponding ISO method of test. It replaces the tests for semi-permanent set and ageing.

p) Requirements and associated methods of test (based on ISO/DIS 8639) are introduced for joints.

q) Basic statistical equations are provided (as Appendix P) for analysis of long term data, together with a data set and worked example for validation of use of alternative statistical computing packages.

r) Sampling and quality control procedures are provided in the form of revised guidance (as Appendix Q), as a basis for preparing quality plans and are designed to involve less destructive testing and to allow more comparison with the design performance of the pipe.

Product certification. Users of this British Standard are advised to consider the desirability of third party certification of product conformity with this British Standard based on testing and continuing surveillance, which may be coupled with assessment of a supplier's quality systems against the appropriate Part of BS 5750.

Enquiries as to the availability of third party certification schemes will be forwarded by BSI to the Association of Certification Bodies. If a third party certification scheme does not already exist, users should consider approaching an appropriate body from the list of Association members.

Attention is drawn to the provisions of the Health and Safety at Work etc. Act 1974 and the need to ensure that appropriate precautions are taken to ensure the safety of personnel when carrying out methods of test required by this standard.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 46, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This British Standard specifies requirements for materials, dimensions, classification, design, testing and marking for pressure and non-pressure pipes, fittings and joints made from glass reinforced thermosetting plastics (GRP) with or without an aggregate filler. It is applicable to pipes and associated fittings having nominal diameters from 100 to 4 000 for use at pressures up to 25 bar[2)] and intended for the conveyance of potable and non-potable water, foul sewage and storm water.

The pipework may also be used for conveying industrial wastes providing its suitability has been established.

Methods of test are given in Appendix A to Appendix N. Methods for statistical analysis of long term data from GRP pipes and fittings are given in Appendix P.

Guidance and information on quality control testing and associated sampling is given in Appendix Q. A bibliography is given in Appendix R.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard, the definitions given in BS 1755-1 and BS 6464 apply, together with the following.

2.1
aggressive industrial waste

a fluid that may have a detrimental effect on glass reinforced plastics (GRP)

2.2
angular deflection

the angle of deflection of part of a joint related to the diametrical centreline of the fixed component of a joint

NOTE See Figure 7.

2.3
acceptable quality level (AQL)

the maximum percentage defective (or the maximum number of defectives per hundred units) that, for the purposes of sampling inspection, can be considered satisfactory as a process average

2.4
C glass

an alkali calcium glass with an enhanced boron trioxide content and intended for applications requiring enhanced chemical resistance accordingly

NOTE This definition is identical with **2.1** of BS 7158:1989. It is consistent with ISO 2078:1985 and equivalent to DIN 1259-1:1986.

2.5
draw

the maximum longitudinal movement of a joint

NOTE 1 See Figure 8.
NOTE 2 See also "total draw".

2.6
effective length

for a straight pipe, the distance between two planes normal to the pipe axis and passing through the extreme end points of the pipe, excluding the maximum design depth of insertion of the spigot in the socket where applicable

2.7
flexible joint

a joint capable of allowing relative movement between the component parts

NOTE 1 Flexible joints may have resistance to axial loading built into their design.
NOTE 2 Examples of this type of joint are:
a) a socket and spigot joint with an elastomeric sealing element (including double socket designs);
b) a flexible locked socket and spigot joint with an elastomeric sealing element (including double socket designs);
c) a clamped joint, for example a bolted coupling including joints made from materials other than GRP.

2.8
inspection level

a characteristic of a sampling plan chosen in advance that determines the relationship between the lot size and the sample size

2.9
lay-up

an assembly of resin impregnated material for processing

2.10
lot

a collection of units of a product for which a sample is representative and inspected to determine conformance with the acceptability criteria, and which may differ from a collection of units designated as a lot for other purposes, e.g. production, shipment

2.11
maximum service temperature

the maximum temperature that can occur during normal operation

[2)] 1 bar = 10^5 N/m^2 = 10^5 Pa.

2.12
nominal size (DN)

a numerical designation of size which is common to all components in a piping system other than components designated by outside diameters or by thread size. It is a convenient round number for reference purposes and is only loosely related to manufacturing dimensions

NOTE 1 It is designated by DN followed by a number.

NOTE 2 Not all piping components are designated by nominal size, for example steel tubes are designated and ordered by outside diameter and thickness.

NOTE 3 The nominal size DN cannot be subject to measurement and shall not be used for purposes of calculation.

NOTE 4 This definition and notes 1 to 3 are equivalent to the definition given in ISO 6708:1980. For the purposes of this standard, the following information is also relevant.

a) For pipes complying with BS 5480, DN is closely but not exactly related to the work size (see **2.21**) and hence the internal diameter of the pipe (see **5.2.2**).

b) Thermoplastics pipe sizes designated in accordance with with ISO 161-1 are sized with reference to their outside diameters: their wall thickness will depend upon their intended application and corresponding product specification.

c) With reference to note 3, it is not appropriate to use values of DN as a basis for design, but they are considered suitable and convenient as a basis for establishing certain test conditions, such as the length of a pipe test piece. (See, for example, Appendix H.)

2.13
non-pressure pipes and fittings

pipes and fittings subject to an internal pressure not greater than 0.5 bar measured at the top of the pipe cross section

2.14
out-of-squareness

the maximum distance between an end plane normal to the axis of a pipe and passing through the extreme end point of the pipe and a parallel plane passing through the nearest full wall section of the pipe, excluding the design depth of the socket, where applicable

NOTE See Figure 1.

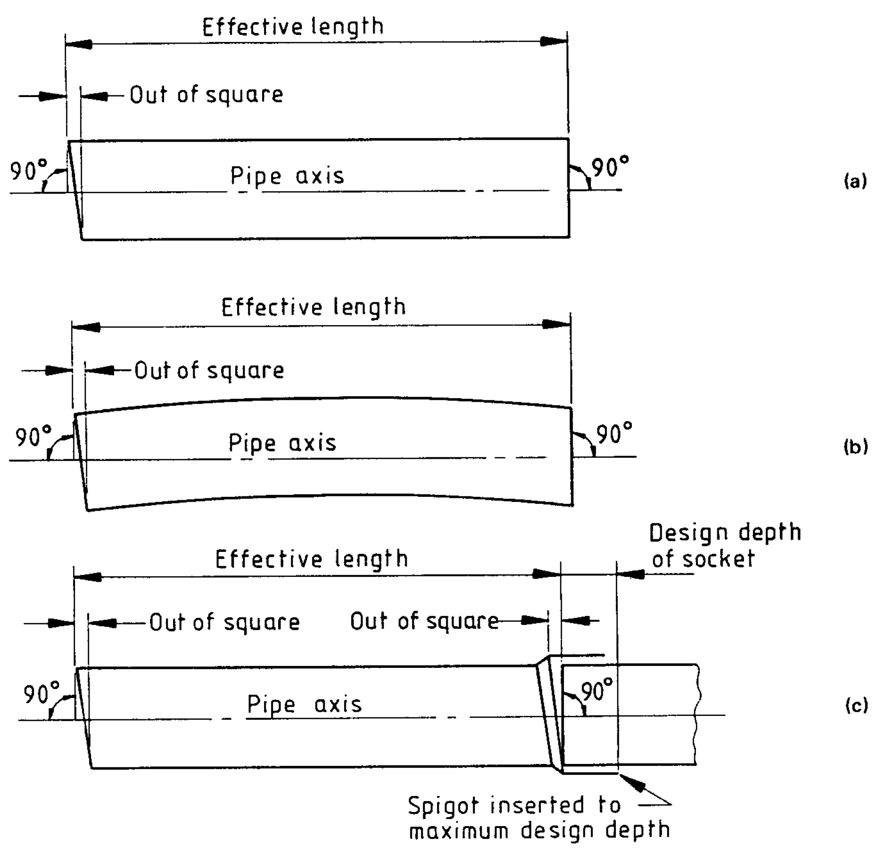


Figure 1 — Dimensional boundaries for effective length and out-of-squareness of nominally straight pipe

2.15
pressure pipes and fittings

pipes and fittings to be used with internal pressures greater than 0.5 bar

2.16
pressure rating

the maximum sustained working pressure for which the component is suitable for use for its intended purpose and design life

2.17
rigid joint

a joint which does not allow angular deflection and has an incorporated resistance to axial loading

NOTE Examples of this type of joint are:

a) a flanged joint, including integral and loose flanges;
b) a butt joint;
c) a rigid locked socket and spigot joint, with an elastomeric sealing element (including a double socket design);
d) a cemented socket and spigot joint (including a double socket design);
e) a threaded joint.

2.18
septic sewage

sewage of an acidic nature, generally associated with the evolution of hydrogen sulphide

2.19
stiffness

for a pipe, the resistance of a pipe to circumferential deflection in response to external loading applied along one diametric plane: the stiffness of the pipe, S (in N/m^2), is given by the relationship

$$S = El/D_m^3 \quad (1)$$

where

E is the modulus of elasticity in flexure in the circumferential direction (in N/m^2);

l is the second moment of area of the pipe wall in the longitudinal direction, per unit length (in m^4/m);

D_m is the mean diameter of the pipe (in m), e.g.
$D_m = D_i + e$

where

D_i is the internal diameter of the pipe;

e is the minimum wall thickness of the pipe.

2.20
total draw

the sum of the draw and the longitudinal movement of joint components due to the presence of angular deflection

NOTE 1 See Figure 9.
NOTE 2 See also "draw".

2.21
work size (DW)

a design internal diameter related to the nominal size of the pipe and relative to which manufacturing tolerances are applied

3 Materials

3.1 Resins

The resin shall be a thermosetting resin such that when cured according to a schedule representative of that to be used for the finished pipework and then tested in accordance with BS 2782:Method 121A, the temperature of deflection of the resin shall be not less than 20 °C higher than the maximum service temperature at which the pipework component is to be used, if known, and otherwise not less than 50 °C.

If a polyester resin system is used, it shall comply with BS 3532.

NOTE Other thermosetting resin systems may be used providing that their temperature of deflection complies with **3.1** and that the finished pipe, fitting or joint complies with all the applicable requirements of this British Standard.

3.2 Fibrous reinforcement

Except for alternative surface tissues (see **3.3**) all fibrous reinforcement shall be derived from continuously drawn filaments of E. glass[3)] (see note) and shall be used in the following forms alone or in any combination subject to compatibility with the resin used:

a) rovings complying with BS 3691;

b) chopped strand mat complying with BS 3496;

c) woven fabrics complying with BS 3396-1, BS 3396-2 or BS 3396-3 as applicable;

d) woven fabric complying with BS 3749.

NOTE Such glass includes either alumino-borosilicate glass or alumino-calco-silicate glass, in either case optionally containing other oxides, mainly aluminium trioxide, incorporated for enhanced corrosion resistance and then sometimes described as E.CR glass.

[3)] Defined by term 1146 in BS 3447:1962.

3.3 Surface tissues

If surface tissues are incorporated into the superficial layers of the internal and/or external surfaces of a GRP pipe or fitting, they shall be made from glass materials complying with **3.2** or of C glass (see **2.4**) or from woven or non-woven textiles based on polyester or acrylic fibres.

3.4 Additional materials

3.4.1 *Aggregates.* Aggregates (inert granular material of a size range between 0.05 mm and 5 mm), such as graded silica sands, may be incorporated where they are a designed part of the composite structure.

3.4.2 *Fillers.* Inert fillers (fine material with a particle size below 0.05 mm), may be incorporated either on their own or with aggregate.

3.4.3 *Additives.* Additives may be incorporated for modifying the properties of the resin, e.g. for viscosity control of fire retardancy.

3.4.4 *Colourants.* The resin may incorporate pigments or dyes.

3.5 Effect of non-metallic products on water quality

When used under the conditions for which they are designated, non-metallic products in contact with or likely to come into contact with potable water shall comply with the requirements of BS 6920-1:1988. In the case of a GRP pipe, fitting or joint, such products shall be marked in accordance with **11.1** h) of this standard.

NOTE 1 Non-metallic products for installation and use in the United Kingdom which are verified and listed under the UK Water Fittings Byelaws Scheme are deemed to satisfy the requirements of this subclause. Details of the Scheme are obtainable from the Water Research Centre Byelaws Advisory Service, 660 Ajax Avenue, Slough SL1 4BG.

Non-metallic products approved by the Department of the Environment Committee on Chemicals and Materials of Construction for use in Public Water Supply and Swimming Pools are considered free from adverse health effects for the purpose of compliance with this subclause.

NOTE 2 A list of approved chemicals and materials and details of the approvals scheme is available from the Secretary of the Committee at the Department of the Environment, Water Division, Romney House, 43 Marsham Street, London SW1P 3PY.

4 Pipe design limits

4.1 Pipes carrying non-aggressive materials

The pipes shall be designed so that the design wall tensile stress or circumferential glass tensile stress, as applicable, at the rated pressure and throughout the design life of the pipe, does not exceed $0.625S_{\phi 95}$ or $0.625S_{\phi g95}$, as applicable, where $S_{\phi 95}$ or $S_{\phi g95}$ is the applicable 95 % lower confidence limit of the long term circumferential tensile strength, depending upon the form of the reinforcement glass.

Pipe designed to withstand end loads induced by internal pressure shall be designed so that the longitudinal tensile stress does not exceed $0.625S_{xL}$, where S_{xL} is the long term longitudinal tensile strength.

The long term longitudinal strength per unit of circumference, Q_{xL} (in N/mm) is obtained by factoring the initial longitudinal tensile strength, determined in accordance with Appendix A or Appendix B as applicable. The factor to be used is obtained by dividing the short term circumferential strength, determined in accordance with Appendix C or Appendix D, by the long term circumferential strength, determined in accordance with Appendix E. Thus

$$Q_{xL} = Q_{xi} \times \left\{ \left(\frac{S_{\phi L}}{S_{\phi i}} \right) \text{ or } \left(\frac{S_{\phi Lg}}{S_{\phi ig}} \right) \right\} \quad (2)$$

where

$S_{\phi i}$ or $S_{\phi ig}$ is the applicable initial circumferential tensile strength (in MPa) (see **C.6.3** or **D.6**);

$S_{\phi L}$ or $S_{\phi Lg}$ is the applicable long term circumferential tensile strength (in MPa) (see **E.6.3**);

Q_{xi} is the initial longitudinal strength per unit of circumference (in N/mm) (see **A.6** or **B.5.2**).

4.2 Pipes carrying septic sewage or aggressive industrial waste

For non-pressure pipes the total design circumferential strain, at the manufacturer's recommended maximum long term ring deflection, shall not exceed $0.625\epsilon_{95}$, where ϵ_{95} is the lower 95 % confidence limit of the extrapolated circumferential failure strain at the design service life when determined in accordance with Appendix F.

NOTE For pipe operating under internal pressure and hence under conditions of constant load in such environments, the method given in Appendix F is not suitable for determining the design strain. GRP pipes and fittings are often suitable for carrying septic sewage or industrial waste under pressure but in the absence of a suitable test method or criteria, no related requirements are included in this specification in respect of such applications. Constant load conditions are more arduous than those of constant deflection and if the nature of the sewage or waste is such that the corrosive effects are potentially severe the advice of the manufacturer should be obtained regarding the design of pressure pipe for such applications.

5 Dimensions

5.1 General

Dimensions shall comply with **5.2** to **5.4** inclusive. In case of dispute, compliance with dimensional limits specified in this standard shall be determined at 23 ± 2 °C, using any applicable method of sufficient accuracy to establish compliance.

NOTE Attention is drawn to BS 2782:Method 1101A.

5.2 Diameter of pipes

5.2.1 *Nominal size.* Pipes shall be designated by a nominal size (DN) selected from the values given in Table 1.

Table 1 — Nominal sizes of pipes

Nominal size (DN)	Increments
⩾ 100 to 500	50
> 500 to 2 600	100
> 2 600 to 4 000	200

5.2.2 *Work size.* The work size (DW) shall be declared in millimetres by the manufacturer and shall not differ from the value of the nominal size of the pipe by more than ± 3.5 %.

5.2.3 *Manufacturing tolerance.* The manufacturing tolerance on the work size shall comply with one of the following sets of permissible deviations, as applicable:

a) for pipes up to and including 150 nominal size: ± 1.5 mm;

b) for pipes of nominal size over 150 and up to and including 600: ± 3.0 mm;

c) for pipes over 600 nominal size: ± 0.5 %.

In case of dispute, when measured in accordance with Appendix G, all deviations from circularity, with the exception of pipe deformation due to its own mass, shall be contained within the limits given in a), b) or c) as applicable.

NOTE If the total deviations from circularity fall within the specified limits, it is not necessary to determine or compensate for the deflection of the pipe in response to its own mass.

5.3 Effective lengths of pipe

5.3.1 *Effective length.* The pipe shall comprise a straight length (see **5.5**) for which an effective length (see **2.6** and Figure 1) of 3 m or 6 m in accordance with **5.3.2** shall be preferred, subject to the following conditions.

a) Other effective lengths are permissible and may be supplied by agreement between the manufacturer and the purchaser.

b) Apart from item c), of the total length supplied in any one nominal size and class on any one order, the manufacturer shall supply no more than 5 % in random lengths where the random length shall be not less than 1.5 m. The manufacturer shall supply additional pipes, and where appropriate, jointing components to make up any difference in the total length stated in the order.

c) Where it is necessary to cut pipes for quality control purposes to an extent that would conflict with item b), the variation in effective lengths to be supplied shall be agreed between the manufacturer and the purchaser.

5.3.2 *Tolerance on effective length.* The permissible deviations on the effective length shall be ± 25 mm.

NOTE For some applications closer tolerances may be desired, in which case these should be agreed between the manufacturer and the purchaser.

5.4 Out-of-squareness of pipe

5.4.1 *Unflanged pipe.* The out-of-squareness of unflanged pipes shall not exceed (2 mm + 0.005 DW) or 10 mm, whichever is the smaller, where DW is the work size of the pipe in millimetres.

5.4.2 *Flanged pipe.* For pipes of up to and including nominal size 400, the flange face shall be perpendicular to the axis within 0.5° and shall be flat to ± 0.5 mm, and for pipes of larger nominal size it shall be perpendicular within 0.25° and flat to ± 0.5 mm.

5.5 Straightness

The deviation from straightness of the bore of the pipe shall not exceed 0.3 % of the effective length of the pipe or 15 mm, whichever is the smaller.

6 Classification

6.1 General

The classifications given in **6.2** and **6.3** relate to sustained service temperatures up to 30 °C.

NOTE GRP pipes are generally suitable for intermittent use up to 45 °C, but if it is intended to use the pipe persistently at temperatures above 30 °C the manufacturer should be consulted.

6.2 Pressure

Pipes shall be classified for use under gravity, indicated by G, or by a pressure rating selected from the range 1 to 25 inclusive in increments of 0.5, where classification G shall imply that the component is capable of withstanding internal hydrostatic pressures up to 0.5 bar. Otherwise the pressure rating selected shall be equal to or less than the maximum internal hydrostatic pressure, in bar, which the pipe is capable of withstanding for a design life of 50 years (see clause **4** concerning design limits).

NOTE 1 For the purposes of this standard, all references to pressure relate to gauge pressure unless otherwise stated.

NOTE 2 Unless specifically designed to the contrary, GRP pipes are not normally designed to withstand end loads developed by internal pressure, therefore external anchorages are necessary at changes in direction.

6.3 Stiffness

Pipes shall be classified according to their minimum initial specific stiffness when determined in accordance with Appendix H and with reference as applicable to the following preferred numbers (SN values) for nominal minimum initial stiffness in newtons per metre squared:

1 250; 2 500; 5 000; 10 000; 15 000; 20 000.

In case of dispute, compliance shall be determined using method A of Appendix H.

NOTE 1 The actual minimum stiffness established by design and measurement may comprise any value and may be supplied and declared as additional information (see **11.2**).

NOTE 2 To eliminate ambiguity, for marking purposes, stiffness numbers are not subdivided into groups of 3 digits or less.

7 Physical properties

7.1 Appearance

When inspected with the unaided eye, the internal surface of the pipe or fitting shall be smooth and both the internal and external surfaces shall be clean and free from any imperfection that would impair its compliance with this standard.

7.2 Dimensions

7.2.1 *Inside diameter.* The inside diameter of the pipe shall comply with the manufacturing limits on the work size declared and derived in accordance with **5.2.2** and **5.2.3**.

7.2.2 *Wall thickness.* When measured to an accuracy of 0.1 mm the wall thickness shall be not less than the figure declared and used by the manufacturer in the calculations for the design of the pipe.

7.3 Beam strength

NOTE 1 The ability of a pipe to support beam loads may be measured by its longitudinal strength. The following requirement is intended to ensure adequate strength for normal handling and laying purposes. It is not intended for use for design purposes.

Pipes of all classifications shall have an initial longitudinal tensile strength per unit of circumference of not less than the applicable value given in Table 2, when measured in accordance with either Appendix A or Appendix B. In case of dispute, Appendix A shall be used.

NOTE 2 Appendix B is not applicable to pipes of nominal size greater than 600.

NOTE 3 The limits given in Table 2 are applicable to the average value obtained in accordance with Appendix A.

7.4 Impact resistance

When tested in accordance with Appendix J, H50 shall be at least 0.3 m.

8 Performance properties of pipes

8.1 Leaktightness

8.1.1 *Non-pressure pipes.* When tested in accordance with Appendix K to a pressure of 1.5 bar, a non-pressure pipe, i.e. pressure rating G, shall not allow any water to pass through the pipe wall and appear on the outside surface.

8.1.2 *Pressure pipes.* When tested in accordance with Appendix K to a pressure of 1.5 times its pressure rating, a pressure pipe shall not allow any water to pass through the pipe wall and appear on the outside surface.

8.2 Strain corrosion resistance

When tested in accordance with Appendix F, the 95 % lower confidence limit on the mean of the line at 50 years shall not be less than 0.5 %.

8.3 Long term specific ring stiffness and creep factor

If such data is essential for design purposes it shall be obtained using Appendix H, Appendix L and Appendix P.

NOTE This standard does not include requirements for either long term specific ring stiffness or the creep factor [i.e. the ratio of the initial specific stiffness/long term specific stiffness (of the same test piece)], both the measurement of and requirements for which are currently under consideration by Technical Committee 138 of the International Organization for Standardization (ISO). Such data may however be of interest for design purposes, and therefore a method for obtaining such data consistent with the methods included in this standard for measurement of initial specific stiffness (Appendix H) and analysis of long term data (Appendix P) is provided, as Appendix L.

Table 2 — Minimum values for initial longitudinal tensile strength per unit of circumference

Nominal size (DN)	Pressure rating (in bar)					
	⩽ 4	> 4 ⩽ 6	> 6 ⩽ 10	> 10 ⩽ 12½	> 12½ ⩽ 16	> 16 ⩽ 25
	Minimum initial longitudinal tensile strength per unit of circumference					
	kN/m	kN/m	kN/m	kN/m	kN/m	kN/m
100	100	100	100	100	100	100
150	100	100	100	100	100	115
200	100	100	100	100	105	138
250	100	100	100	107	123	164
300	100	100	107	121	141	190
350	100	101	120	136	159	216
400	100	102	132	150	176	242
450	100	111	144	165	194	268
500	100	119	156	179	211	294
600	114	136	180	207	246	345
700	126	152	204	236	281	397
800	150	169	228	265	316	449
900	153	186	252	294	351	506
1 000	166	203	276	322	387	552
1 100	179	220	301	351	422	—
1 200	192	236	325	380	457	—
1 300	205	253	349	409	492	—
1 400	218	270	373	437	527	—
1 500	231	287	397	466	563	—
1 600	244	303	421	495	598	—
1 700	258	320	445	524	633	—
1 800	271	337	469	552	668	—
1 900	284	354	493	581	703	—
2 000	297	370	517	609	738	—
2 100	310	387	542	638	774	—
2 200	323	404	566	667	809	—
2 300	336	421	590	700	844	—
2 400	349	437	614	724	879	—
2 500	362	454	638	—	—	—
2 600	375	471	662	—	—	—
2 800	401	504	710	—	—	—
3 000	428	538	759	—	—	—
3 200	454	571	807	—	—	—
3 400	480	605	855	—	—	—
3 600	506	638	903	—	—	—
3 800	532	672	952	—	—	—
4 000	558	706	1 000	—	—	—

9 Fittings

9.1 Fittings made from GRP

NOTE GRP fittings are not subject to tests for strength and it is essential that external restraint be considered for installation.

9.1.1 *General.* All GRP fittings, such as bends, tees, junctions and reducers, shall be equal or superior in performance to pipe of the same classification and shall be smoothly finished internally.

9.1.2 *Fittings made from straight pipe.* The fitting shall be fabricated from complete pipes or portions of straight pipe complying with this standard as applicable for the pipe classification. The fitting shall comply with the declared design requirements and be suitably mitred. The mitre shall be overwrapped externally and, if practicable, internally with woven roving and/or chopped strand mat to ensure the longitudinal and circumferential tensile strength is at least equal by design to that of the pipe with which the fitting is to be used.

9.1.3 *Fittings made by moulding.* Moulded GRP fittings shall be made by hand lay-up, contact moulding, hot or cold press moulding or tape winding.

9.1.4 ***Tolerances for GRP fittings***

9.1.4.1 Except for flanged pipework, which may require closer tolerances, the permissible deviations from the stated value of the angle of change of direction of a fitting such as a bend, tee or junction shall not exceed ± 1°.

9.1.4.2 Except for flanged pipework, which may require closer tolerances, the permissible deviations on the manufacturer's declared length of a fitting, exclusive of the socket where applicable, shall be ± 25 mm taken from the point of intersection to the end of the fitting.

10 Joints

10.1 General

Joints may be flexible (see **10.2**) or rigid (see **10.3**), and in either case may incorporate one or more joint rings (see **10.4**) or other seals.

If they are intended for pipework for use in contact with potable water, any non-metallic joint components likely to come into contact with the water shall comply with **3.5**.

10.2 Flexible joints

10.2.1 *Design performance.* Flexible joints such as rolling or restrained joint ring joints or clamped joints shall be by design equal or superior in performance to pipe of the classification of the main pipe barrel in the circumferential direction only, up to the limits of angular deflection and straight draw indicated by the manufacturer of the joint.

10.2.2 *Leaktightness.* When a joint, assembled in accordance with the manufacturer's instructions and subject as applicable to the conditions in items a) to d), is tested in accordance with Appendix M, including full sequential testing in accordance with **M.4.2** and/or **M.4.3**, as applicable, the joint shall comply with items e) and f).

a) The maximum draw for which the manufacturer declares the joint to be suitable and which shall be not less than a draw, including Poisson contraction and temperature effects, of 0.3 % of the effective length of the longest pipe with which the joint is intended to be used.

b) The maximum angular deflection for which the manufacturer declares the joint to be suitable and which shall be not less than the applicable value given in Table 3.

c) A misalignment force, F_r, dependent upon the nominal size of the pipe as follows:

1) for pipes up to and including DN 1800, a force of (20 × DN) N;

2) for pipes of DN greater than 1800, a force of 36 kN.

d) The applicable test pressure(s) and pressure cycle(s) given in Table 8.

e) The joint shall not leak when inspected visually or, for loss of vacuum, as indicated by a change of pressure greater than 0.08 bar (0.008 MPa).

f) The joint shall not exhibit damage in the form of crushing, cracking or delamination of the joint components or dislocation of any intermediate seal component such as a joint ring when assessed for the following properties:

1) initial leaktightness while subject to angular deflection and draw;

2) leaktightness while subject to angular deflection and draw;

3) leaktightness while subject to misalignment and draw;

4) vacuum leaktightness while subject to misalignment and draw.

10.3 Rigid joints

10.3.1 *Design performance.* Rigid joints, such as flanged joints, butt and overwrap joints, socket and spigot joints with bonding compounds and screwed joints, shall be by design equal or superior in performance to pipe of the same classification in both the circumferential and longitudinal directions.

Table 3 — Angular deflection limits relative to the nominal size of the pipework

NOTE 1 The limits given in column 2 should be regarded as minimum values for the purpose of testing for joint design or performance and maximum recommended values for installation design.

NOTE 2 Attention is drawn to the warning given at the beginning of Appendix M.

Nominal size (DN)	Angular deflection
	degrees
< 500	3
⩾ 500 to < 900	2
⩾ 900 to < 1 800	1
⩾ 1 800	0.5

10.3.2 *Leaktightness.* When a joint assembled in accordance with the manufacturer's instructions is tested in accordance with Appendix N, including sequential testing in accordance with **M.4.2** and/or **M.4.3** as applicable, and using the applicable test pressure(s) and pressure cycle(s) given in Table 8, the joint shall comply with the following.

a) It shall not leak when inspected visually or, for loss of vacuum, as indicated by a change of pressure greater than 0.08 bar (0.008 MPa).

b) It shall not exhibit damage in the form of crushing, cracking or delamination of the joint components or dislocation of any intermediate seal component such as a joint ring, when assessed for the following properties:

1) initial leaktightness while subject to static pressure of 0.5 bar;

2) leaktightness while subject to positive static pressure;

3) vacuum leaktightness while subject to negative pressure.

10.4 Elastomeric joint rings

In the case of joints incorporating elastomeric joint rings, the joint rings shall comply with BS 2494 as appropriate for the application(s) for which the jointed pipework is designed.

11 Marking and information

11.1 All pipes and fittings supplied shall be indelibly marked with the following information.

a) The number and date of this British Standard, e.g. BS 5480:1990[4].

b) The manufacturer's name, initials or identification mark.

c) The nominal size.

[4] Marking BS 5480:1990 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 standard. 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.

d) The pressure rating. To avoid possible confusion, pipes rated at a non-integer value shall be marked with a fraction, e.g. 12½ bar and not 12.5 bar.

e) The nominal minimum initial stiffness (in N/m^2).

f) The date of manufacture.

g) The effective length, if other than 3 m or 6 m.

h) The letter "P" set in a square, where the pipe or fitting is suitable for use with potable water, otherwise an empty square.

i) The letters "LS" set in a square, where pipes and fittings are designed to withstand longitudinal end loads developed by internal pressure.

j) The angle of bend (in degrees) of fittings.

This information shall be stated in the following order.

BS 5480:1990 – ABC – 300 – 16 – 5 000 –

Jan '90 – 900 – [P] – [LS] – 90°

11.2 The information given in **11.1** may be arranged in several lines provided that the sequence is preserved. Any additional marks required by the purchaser shall be the subject of agreement between the manufacturer and the purchaser. The manufacturer may add other marks provided that they do not conflict with those stated in **11.1**.

11.3 The following information shall be provided upon request, as applicable.

a) For non-pressure pipes, the manufacturer's recommended maximum long term ring deflection (see **4.2**).

b) For pipes, the work size (DW) (see **5.2.2**).

c) For pipes, any variation in effective length agreed in accordance with **5.3.1** c).

d) For pipes or fittings ordered for use at temperatures above 30 °C, the applicable classification(s) (see clause **6**, including the note to **6.1**).

e) For pipe, the design wall thickness (see **7.2.2**).

f) For a flexible joint, the maximum draw and maximum angular deflection for which the joint is suitable [see **10.2.2** a) and b)].

Appendix A Method for determination of initial longitudinal unit tensile strength by a tensile strip test

A.1 Principle

The initial longitudinal unit tensile strength is determined as the average of the maximum forces sustained per unit width by longitudinally aligned strips removed from the pipe wall when extended to breaking in tension in a restricted period of time.

A.2 Apparatus

A.2.1 *A tensile testing machine* capable of indicating the force applied to the test piece with an accuracy of within ± 1 % of the indicated value.

A.3 Test pieces

Each test piece shall comprise a strip cut from a pipe and profiled to the dimensions shown in Figure 2. A minimum of three test pieces is required (see **A.5.5**).

It is permissible to cut the test pieces from the ring used for the determination of initial specific stiffness in accordance with Appendix H.

If profile cutting is impractical, parallel-sided test pieces of width between 2*e* and 3*e* (see Figure 2) shall be used, where *e* is the thickness of the test piece.

A.4 Test conditions

Conduct the test at 15 ± 10 °C except in cases of dispute, in which case conduct the test at 23 ± 20 °C.

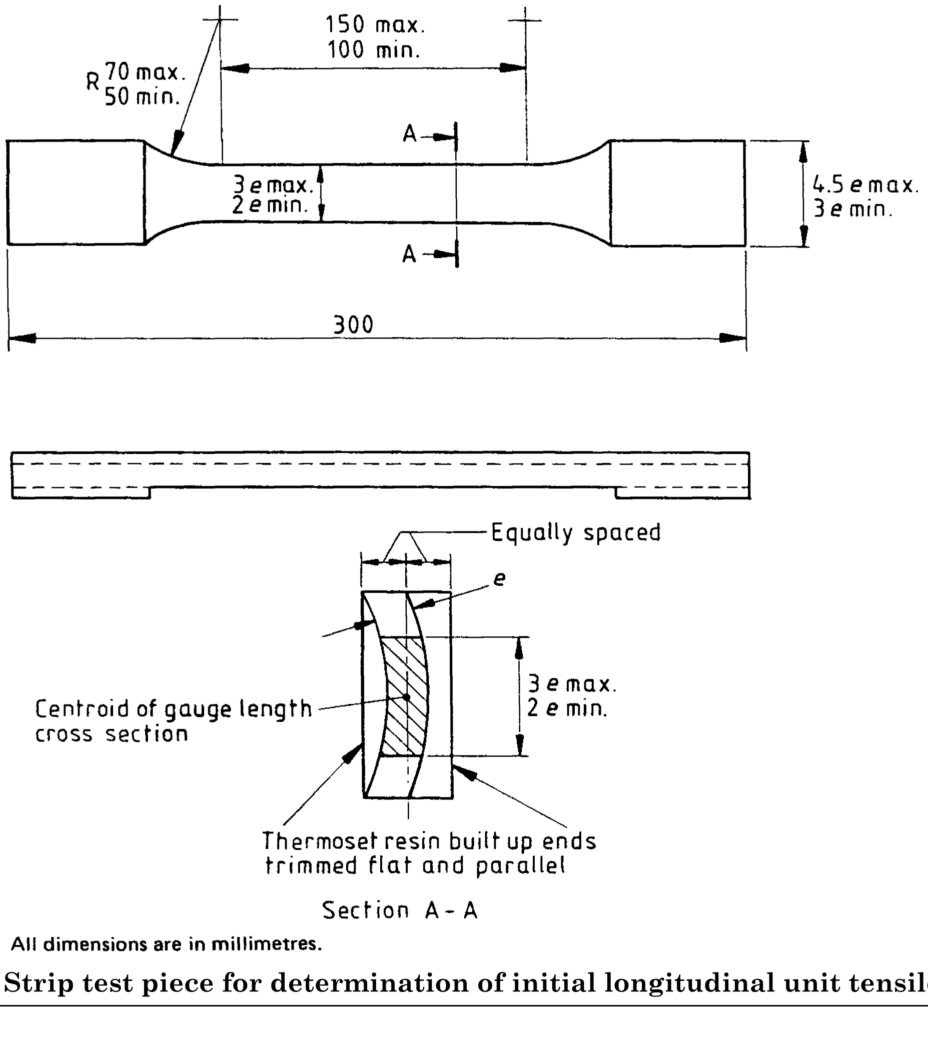


Figure 2 — Strip test piece for determination of initial longitudinal unit tensile strength

A.5 Procedure

A.5.1 Measure the width and thickness of the test piece at the centre of the gauge length and at points within 5 mm of each end of the gauge length. Record the average width as *w*, and the average thickness as *e*.

A.5.2 Either use curved jaws or build up the thickness of the test piece ends over the grip length with a compatible thermosetting resin. When cured, trim the built up ends flat and parallel and ensure that the centroid of area of the curved pipe wall section will lie on the loading centreline of the testing machine when gripped.

A.5.3 Grip the test piece in the testing machine with the test piece centreline positioned along the loading axis of the machine.

A.5.4 Extend the test piece by separating the grips at a rate selected to ensure that failure occurs between 1 min and 3 min. Record the maximum force as the failure force *F*.

A.5.5 Repeat **A.5.1** to **A.5.4** until three results have been obtained. Discard any test piece that breaks outside the gauge length and test additional test pieces until three results are obtained.

A.6 Calculation

For each test piece, calculate the initial longitudinal tensile strength of the pipe per unit of circumference, Q_{xi} (in N/mm), using the following equation:

$$Q_{xi} = \frac{F}{W} \tag{3}$$

where

F is the failure force (in N);

w is the average width of the gauge length portion of the test piece (in mm).

NOTE The difference between *w* and the arc length is considered to be negligible.

A.7 Test report

The test report shall include the following.

a) The size and classification of the pipe and the manufacturer's code.

b) A reference to this method of test, i.e. Appendix A of BS 5480:1990.

c) The date of testing.

d) The shape of the test piece used, i.e. profile or parallel sides.

e) The width, *w*, and thickness, *e*, of the test piece.

f) The failure force, *F*, for each test piece.

g) The individual values and average value of the initial longitudinal unit tensile strength Q_{xi} (in N/mm).

h) The test temperature.

Appendix B Method for assessing initial longitudinal unit tensile strength by a beam test

B.1 Principle

For pipe of not more than 600 mm nominal diameter, compliance with a minimum level of the initial longitudinal unit tensile strength is assessed by loading the pipe in 4 point bend to induce a proof stress to be supported without signs of failure for at least 10 min.

B.2 Apparatus

The apparatus shall be as shown in Figure 3.

B.3 Test pieces

The test piece shall be a pipe of sufficient length to provide a span of length, *L*, as given in Table 4, when supported as shown in Figure 3.

B.4 Test conditions

Conduct the test at 15 ± 10 °C except in cases of dispute, in which case conduct the test at 23 ± 20 °C.

B.5 Procedure

B.5.1 Place the test pipe on fixed saddles that are a distance L to centrelines with the pipe ends held by plugs or caps to keep them round (see Figure 3).

B.5.2 Apply equal and increasing forces to each of two unrestrained saddles positioned symmetrically between and diametrically opposite the fixed saddles, as shown in Figure 3, so that each force attains a value of F_B after a period of between 1 min and 2 min, where F_B, in newtons, is calculated in accordance with the following equation.

$$F_B = 3\pi Q_{xi\,min} \left\{ \left(\frac{D_e}{2}\right)^4 - \left(\frac{D_i}{2}\right)^4 \right\} / 0.002 D_e L e \quad (4)$$

where

- $Q_{xi\,min}$ is the minimum initial longitudinal unit tensile strength applicable to the nominal size and pressure rating of the pipe in accordance with Table 2 (in N/mm);
- D_e is the external diameter of the pipe (in mm);
- D_i is the internal diameter of the pipe (in mm);
- L is the span in accordance with Table 4 (in mm);
- e is the thickness of the pipe wall (in mm).

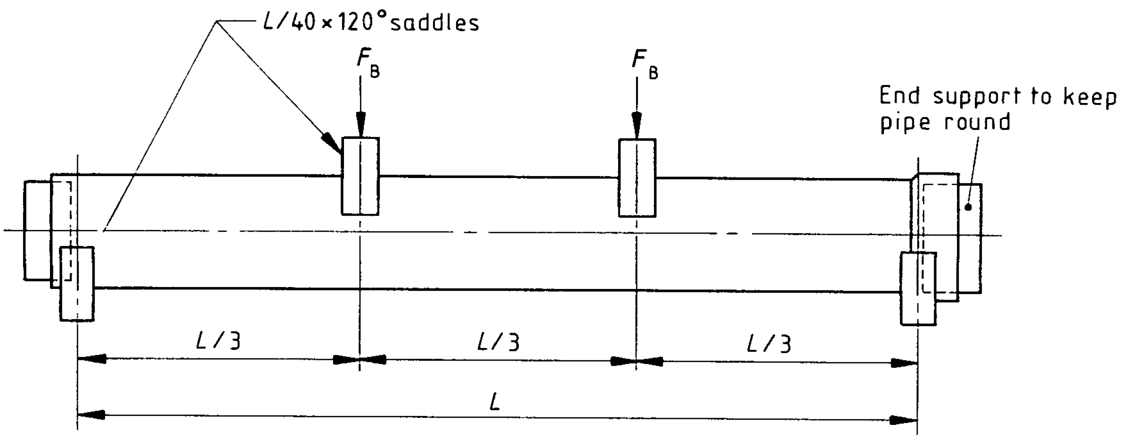


Figure 3 — Diagrammatic representation of apparatus for the beam test

Maintain these forces for at least 10 min while monitoring the test for signs of failure in the form of any of the following:

a) fracture of the test piece;

b) an abrupt loss of force;

c) abrupt increase in deflection.

B.6 Test report

The test report shall include the following.

a) The size and classification of the pipe and the manufacturer's code.

b) A reference to this method of test, i.e. Appendix B of BS 5480:1990.

c) The date of testing.

d) The test temperature.

e) The forces applied (i.e. F_B).

f) The minimum initial longitudinal unit tensile strength demonstrated (i.e. $Q_{xi\,min}$), or the sign(s) of failure observed.

Table 4 — Beam test span (L)

Nominal size of pipe	Span of pipe
	mm
⩽ 150	3 000
> 150 to 600	6 000

Appendix C Method for determination of initial circumferential tensile strength by a burst test

C.1 Principle

The initial circumferential tensile strength is determined from the pressure required to rupture pipe samples. Depending upon the method of construction, the strength is related to the overall pipe wall thickness or, in the case of continuous filament reinforcement, to the effective thickness of the glass reinforcement.

C.2 Apparatus

C.2.1 *Means for pressurizing a test piece*, using water as the internal medium and capable of raising the pressure in accordance with **C.5.2**.

C.2.2 *Devices to seal the ends of each test piece* such that for testing pipes intended to withstand the end load resulting from internal pressure, the devices transmit the entire end load to the test piece and otherwise the devices do not transmit end load to the test piece.

C.2.3 *Means for determining the internal diameter and the wall thickness of the pipe* to an accuracy of within ± 1 %.

C.3 Test pieces

Test pieces shall comprise full length pipes, or lengths cut from separate pipes, of the same classification. All test pieces shall be approximately the same length which shall be not less than that necessary to provide a clear length between the end seals of 1.5 times their nominal diameter or winding pitch, whichever is the greater. A minimum of three test pieces is required except for pipes intended to withstand the end load resulting from internal pressure, in which case a minimum of six is required.

C.4 Test conditions

Conduct the test at 15 ± 10 °C except in cases of dispute, in which case conduct the test at 23 ± 2 °C.

C.5 Procedure

C.5.1 Determine the mean diameter and the mean wall thickness of the test piece to an accuracy of within ± 1 %.

C.5.2 Fill and seal the test piece in an appropriate manner which does not submit it to the end load (see **C.2.2**) and pressurize at a rate such that failure occurs between 1 min and 3 min after pressurization commenced.

C.5.3 Record the pressure required to rupture the pipe and the time taken to fail, where failure is defined as bursting of the pipe. If failure occurs within a distance of 0.25 times the diameter of the end of the test piece, or if leakage through the pipe wall prevents an increase in pressure, discard the test piece and test an additional test piece.

C.5.4 Repeat **C.5.1** to **C.5.3** twice to obtain results for a total of three test pieces not subject to end load. In the case of pipes intended to withstand end loads, then repeat **C.5.1** to **C.5.3** a further three times but using test pieces sealed in a manner which transmits the end load to the test piece.

C.6 Calculation

C.6.1 For each test piece, calculate the initial circumferential tensile stress at failure from equation (5) or (6) according to the form of reinforcement.

If the test piece contains non-continuous glass fibre reinforcement only, determine the initial circumferential wall tensile stress at failure, $\sigma_{\phi i}$ (in N/m^2) using the following equation:

$$\sigma_{\phi i} = \frac{p\ (D_i + e)}{20e} \tag{5}$$

where

p is the internal pressure (gauge) (in bar);

D_i is the mean internal diameter of the pipe (in mm);

e is the mean wall thickness of the pipe (in mm).

If the test piece contains continuous helical glass fibre reinforcement only, determine the initial circumferential glass tensile stress at failure, $\sigma_{\phi ig}$ (in MPa) using the following equation:

$$\sigma_{\phi ig} = \frac{p\ (D_i + e)}{20h \sin^2\theta} \quad (6)$$

where

p is the internal pressure (gauge) (in bar);

D_i is the mean internal diameter of the pipe (in mm);

e is the mean wall thickness of the pipe (in mm);

h is the cross-sectional area of continuous helical glass fibre reinforcement determined normal to the fibre per unit axial length of pipe wall (in mm);

θ is the winding angle (i.e. the plane angle between the helical glass fibre reinforcement and the longitudinal axis of the pipe) (in degrees).

C.6.2 For pipes intended to withstand the end load resulting from internal pressure, calculate the circumferential stress at failure for test pieces sealed by means of devices that transmit the entire end load to the pipe wall separately from those sealed by means of devices that do not transmit end load to the pipe wall.

C.6.3 Depending upon the form of reinforcement (see **C.6.1**) or method of installation (see **C.2** and **C.6.2**) record the tensile strength $S_{\phi i}$ or $S_{\phi ig}$, as applicable, as equivalent to the average value for the tensile stresses at failure for the set of test pieces (see **C.3**).

C.7 Test report

The test report shall include the following.

a) The size and classification of the pipe and the manufacturer's code.

b) A reference to this method of test, i.e. Appendix C of BS 5480:1990.

c) The date of testing.

d) The failure pressure, time to failure and method of sealing for each test piece.

e) A description of failure and reference to any discards.

f) The strength basis (pipe wall tensile strength or glass tensile strength).

g) The average initial circumferential wall tensile strength, $S_{\phi i}$, or the average initial circumferential glass tensile strength, $S_{\phi ig}$, as applicable.

h) For pipes intended to withstand the end load resulting from internal pressure, the average value for each of the two sets of individual values obtained using different sealing methods (see **C.5.4**).

i) The test temperature.

Appendix D Method for determination of initial circumferential tensile strength by a split disc test

D.1 Principle

The initial circumferential tensile strength is determined from the maximum force required to fracture a hoop specimen from a reinforced plastic pipe by separation of two parts of a close-fitting split disc within the test piece. It is not suitable for pipes where the winding angle is less than 80° (i.e. the circumferential reinforcement is at an angle greater than 10° from the circumferential direction).

D.2 Apparatus

D.2.1 *A testing machine,* capable of a progressive rate of separation of the split discs to produce failure of the test piece within 1 min to 3 min of initial loading.

D.2.2 *Rigid split discs,* similar to those shown in Figure 4 (a), sized to make even contact with the internal diameter of the test piece and that immediately prior to the test piece being stressed by their separation are not separated by more than 1 % of the pipe diameter.

D.2.3 *A force indicator,* capable of measuring the force applied with an accuracy of within ± 1 %.

D.2.4 *Means for measuring the width and thickness of the test piece* with an accuracy of within ± 1 %.

D.3 Test pieces

The test piece [see Figure 4 (b)] shall be a ring cut from a pipe. The minimum width of the test piece shall be 8 mm; the maximum width shall be dependent on the method of manufacture and the testing equipment available. The width of the test piece shall not exceed the width of the split disc. A minimum of three test pieces is required.

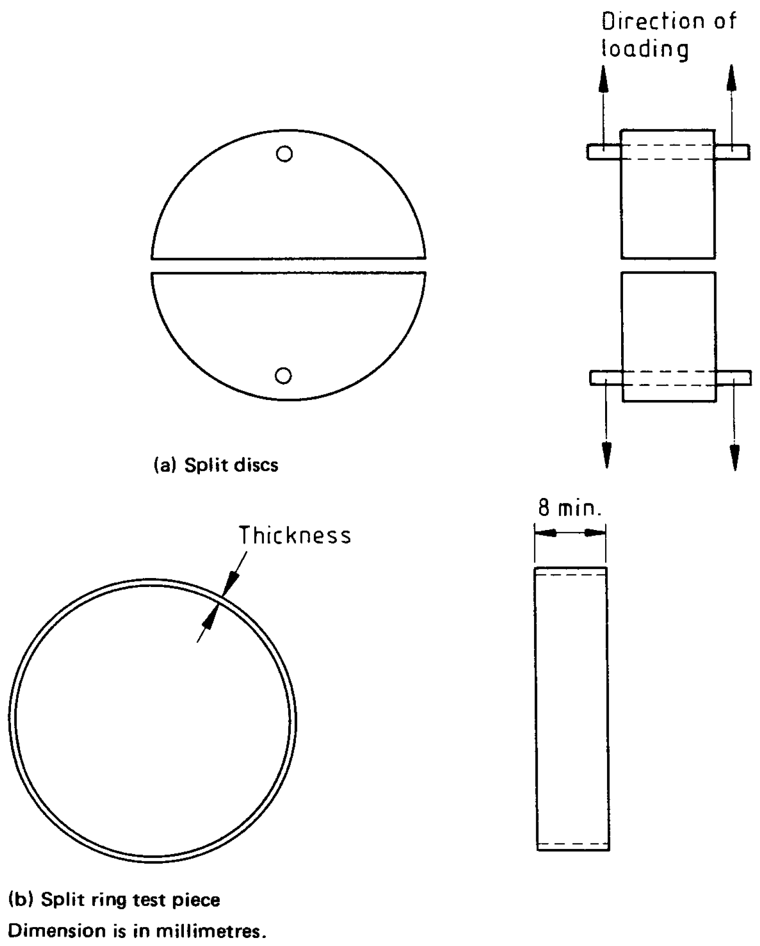


Figure 4 — Split discs and split ring test piece

D.4 Test conditions

Conduct the test at 15 ± 10 °C except in cases of dispute, in which case conduct the test at 23 ± 2 °C.

D.5 Procedure

D.5.1 Measure the width and thickness of the test piece at diametrically opposed points.

D.5.2 Mount the test piece on the outside periphery of the split disc test fixture with the points of measurement at the split.

D.5.3 Load the test piece by separating the mounts at a rate to ensure that failure occurs between 1 min and 3 min, and record the maximum force as the failure force, *F*, resisted by the test piece and the time to failure.

D.6 Calculation

For each test piece, calculate the initial circumferential tensile stress at failure using equation (6) or (7) according to the form of reinforcement.

If the test piece contains non-continuous glass fibre reinforcement only, determine the initial circumferential wall tensile stress at failure, $\sigma_{\phi i}$ (in MPa) using the following equation:

$$\sigma_{\phi i} = \frac{F}{2we} \tag{7}$$

where

F is the failure force (in N);

w is the mean width of the test piece (in mm);

e is the wall thickness of the test piece (in mm).

If the test piece contains continuous glass fibre reinforcement only, determine the initial circumferential glass tensile stress at failure, $\sigma_{\phi ig}$ (in MPa) using the following equation:

$$\sigma_{\phi ig} = \frac{F}{20wh \sin^2\theta} \tag{8}$$

where

F is the failure force (in N);

w is the average width of the test piece (in mm);

h is the actual cross-sectional area of continuous helical glass fibre reinforcement determined normal to the fibre, per millimetre length of pipe wall (in mm);

θ is the winding angle (i.e. the plane angle between circumferentially orientated reinforcement and the longitudinal axis of the pipe) (in degrees).

Depending upon the form of reinforcement, record the initial circumferential tensile strength $S_{\phi i}$ or $S_{\phi ig}$, as applicable, as equivalent to the average value for the tensile stress at failure $\sigma_{\phi i}$ or σ_{ig}, as applicable, for the set of test pieces.

D.7 Test report

The test report shall include the following.

a) The size and classification of the pipe and the manufacturer's code.

b) A reference to this method of test, i.e. Appendix D of BS 5480:1990.

c) The date of testing.

d) The mean width, *w*, and mean wall thickness, *e*, of the test piece.

e) The failure force, *F*, for each test piece.

f) The average initial circumferential wall tensile strength, $S_{\phi i}$, or the average initial circumferential glass tensile strength, $S_{\phi ig}$, as applicable.

g) The test temperature.

Appendix E Method for determination of long term circumferential tensile strength

E.1 Principle

The long term circumferential tensile strength for design service lives of up to 50 years is determined by extrapolation of failure data obtained from pipe samples hydro-statically pressurized to pressures that induce rupture or leakage in specified periods ranging from not less than 10 h to not less than 10 000 h.

E.2 Equipment

E.2.1 *Water tank(s),* comprising one or more tanks containing sufficient water to submerge the test piece(s) and associated fittings and capable of maintaining the water temperature within specified limits.

E.2.2 *Pressurization system,* capable of allowing a required hydrostatic pressure to be built up gradually and without shock to a specified level within each of a number of test pieces independently and to be subsequently maintained within ± 5 % throughout the test or until the moment of failure of the individual test piece(s).

NOTE 1 It is recommended that the pressure is applied to each test piece individually by means of compressed gas connected indirectly to the water-filled test pieces. The test pieces should then be isolated, except for periodic reconnection to maintain the pressure within the specified limits, unless the connection is via a non-return valve which would isolate the test piece at the moment of failure, i.e. before any other test pieces would be subjected to a pressure drop that would prevent compliance with **E.5.2**.

NOTE 2 Compliance with the specified pressure may be monitored by use of a pressure gauge associated with each individual test piece and capable of indicating the pressure therein to an accuracy of within ± 1 %.

E.2.3 *Timing device,* designed to register the duration of the pressure application until the moment when a pressure drop is induced by failure of individual test pieces.

E.2.4 *Fittings,* to provide a pressure-tight seal on one end of a test piece and a pressure-tight connection with the pressurization system at the other end. The fittings are to be one of two types, depending upon application (see **E.3**), as follows:

a) fittings carried by the test piece such that the test piece is subjected to the end thrust induced by the hydrostatic pressure within the test piece and that portion of the fitting corresponding to the bore of the test piece;

b) fittings supported such that the test piece can move longitudinally relative to the fitting without loss of internal pressure.

NOTE 1 In this case the pipe is not subjected to the hydrostatic end thrust applied to the fittings.

NOTE 2 Such fittings may comprise a pair of plugs or caps having ring seals bearing on the inner or outer surface respectively of the test piece to allow the test piece to slide longitudinally relative to the fittings, which typically are coupled via a coaxial rod or tube through which the hydrostatic pressure may be admitted.

E.3 Test pieces

Test pieces shall be lengths cut from pipes of the same classification. All test pieces shall be equal in length which shall be not less than that necessary to provide a clear length between the end seals of 1.5 times their nominal diameter. A minimum of 18 test pieces complete with fittings in accordance with **E.2.4** b) is required, except for pipes intended to withstand the end load resulting from internal pressure (marked LS) when a minimum of 18 additional test pieces complete with fittings in accordance with **E.2.4** a) is required.

E.4 Test temperature

Conduct the test at 15 ± 10 °C, except in cases of dispute, when the test shall be conducted at 23 ± 2 °C, unless the circumferential strength characteristics are required for an application involving temperatures higher than 30 °C, in which case conduct the test at the maximum service temperature.

E.5 Procedure

E.5.1 *Measurement of dimensions*

Mark or otherwise identify three positions spaced evenly around the circumference of the test piece along which to take measurements of thickness and diameter.

Measure the wall thickness to an accuracy of within ± 10 % at both ends of the test piece at three separate positions spaced evenly around the circumference. Determine and record the mean wall thickness, e, by taking the average of the six measured values.

Measure the internal diameter, D_i, and the external diameter, D_e, for every test piece at all three positions in the middle of the sample with an accuracy of within ± 1 mm or within ± 1.0 %, whichever is the lesser value, by means of calipers or an equivalent device.

NOTE In the case of external diameters, measurement by means of a circumferential tape (pi tape) of comparable accuracy is sufficient, thus it is not possible to obtain a different value for all three positions but only a mean value that incorporates those values.

Determine and record the average internal diameter and the average or mean external diameter.

E.5.2 *Pressure testing*

Seal each test piece, submerge it in a test tank controlled at the appropriate temperature, pressurize it to the selected pressure (see **E.5.3**), and, unless connected via a non-return valve (see note 1 to **E.2.2**), seal it off from the pressurizing source.

Monitor the pressure and adjust it periodically to keep it within ± 5 % of the selected test pressure until failure occurs, where failure is indicated by the transmission of the test fluid through the test piece wall in any manner, whether it be a wall fracture, localized leaking or weeping as evidenced by a continuous loss of pressure in excess of 0.2 % of the test pressure per hour.

Record the time, corrected to the nearest hour, between pressurization and failure for each test piece.

E.5.3 ***Test schedule***

Choose the pressure applied to each test piece so that failures occur in not less than 10 h and otherwise comply with the distribution pattern given in Table 5 as follows.

Table 5 — Failure point distribution

Failure time range	Minimum data point distribution
h	
⩾ 10 and < 1 000	4
⩾ 1 000 and < 6 000	3
⩾ 6 000 and < 10 000	3
⩾ 10 000	1
Total	11 + 7 others

On completion of each time band, if the minimum number of failure points shown in column 2 of Table 5 has not been achieved then test further test pieces until the applicable limit is satisfied.

To obtain the total of at least 18 data points required for **E.6.3**, include as valid those test pieces which at the conclusion of the schedule have not failed after being under test for more than 10 000 h, if the result increases the value of the extrapolated stress under the following condition.

First obtain the regression equation (25) in accordance with Appendix P for the results from the test pieces that failed. Then use the stress for each test piece that has been under test for more than 10 000 h and not failed, with the same regression equation, to estimate the time to failure in hours. If this time is less than or equal to the time the test piece has been on test then the result for the non-failed test piece can be included in the data analysis.

E.6 Calculation

E.6.1 For each test piece, calculate the circumferential tensile stress at failure using equation (9) or equation (10) according to the form of reinforcement.

If the test piece contains discontinuous glass fibre reinforcement only, determine the circumferential wall tensile stress at failure, σ_{ϕ} (in MPa), using the following equation:

$$\sigma_{\phi} = \frac{p\ (D_i + e)}{20e} \tag{9}$$

where

p is the internal pressure (in bar);

D_i is the mean internal diameter (in mm);

e is the mean wall thickness of pipe (in mm).

If the test piece contains continuous glass reinforcement only, determine the circumferential glass tensile stress at failure, $\sigma_{\phi g}$ (in MPa) using the following equation:

$$\sigma_{\phi g} = \frac{p\ (D_i + e)}{20h\ \sin^2\theta} \tag{10}$$

where

p is the internal pressure (in bar);

D_i is the mean internal diameter (in mm);

e is the mean wall thickness of the pipe (in mm);

h is the cross-sectional area of glass reinforcement determined normal to the fibre orientation per unit axial length of pipe wall (in mm);

θ is the winding angle (i.e. the plane angle between the helical class fibre reinforcement and the longitudinal axis of the pipe) (in degrees).

E.6.2 If the pipes are intended to withstand the end load resulting from internal pressure, calculate the circumferential tensile stress at failure for test pieces sealed by means of devices that transmit the entire end load to the pipe wall separately from those sealed by means of devices that do not transmit end load to the pipe wall.

E.6.3 For at least 18 results obtained in accordance with **E.5** determine in accordance with Appendix P the correlation coefficient in accordance with **P.4.3** and the regression line in accordance with equation (39). Determine the mean values for the circumferential wall tensile stress $\sigma_{\phi L}$, or the circumferential glass tensile stress $\sigma_{\phi Lg}$, depending upon the form of reinforcement, for 50 years or, if different, the design service life, and the corresponding 95 % lower confidence limit value $\sigma_{\phi 95}$ or $\sigma_{\phi g95}$ in accordance with equations (42) and (41) respectively.

Depending upon the form of reinforcement, record the long term circumferential tensile strength $S_{\phi L}$ or $S_{\phi Lg}$, as applicable, as equivalent to the circumferential tensile stress $\sigma_{\phi L}$ or $\sigma_{\phi Lg}$ (in MPa), after 50 years or other design service life, as applicable, and the corresponding lower 95 % confidence limit value, $S_{\phi 95}$ or $S_{\phi g95}$.

E.7 Test report

The test report shall include the following.

a) The identity, date of manufacture, size, pressure class and stiffness of all pipes used to provide samples for the test.

b) A reference to this method of test, i.e. Appendix E of BS 5480:1990.

c) The date of testing.

d) The identity of all samples together with an indication as to what pipe they were removed from.

e) The start and finish dates of the test.

f) The test temperature (in °C).

g) The regression equation.

h) The correlation coefficient.

i) The minimum design life of the pipe.

j) The estimated mean long term circumferential tensile strength $S_{\phi L}$ or the long term circumferential glass tensile strength $S_{\phi Lg}$ without and, if applicable, (see **E.6.2**) with the effect of hydrostatic end load.

k) The 95 % lower confidence limit on the mean values of the long term circumferential tensile strength $S_{\phi 95}$ or long term circumferential glass tensile strength, $S_{\phi g95}$, as applicable.

Appendix F Methods for determination of strain corrosion resistance of pipes

F.1 Principle

The strain corrosion resistance of pipes is determined by extrapolation of the data obtained from constant deflection testing in the presence of 0.5 M sulphuric acid.

F.2 Materials

F.2.1 *Sulphuric acid*, as 0.5 M aqueous solution.

F.3 Apparatus

F.3.1 *Compression jig*, as shown in Figure 5 except that end dams fixed to the outside of the pipe may be used provided the edge of the test piece is sealed. The strain gauge equipment shall be capable of the determination of strain to 0.00005.

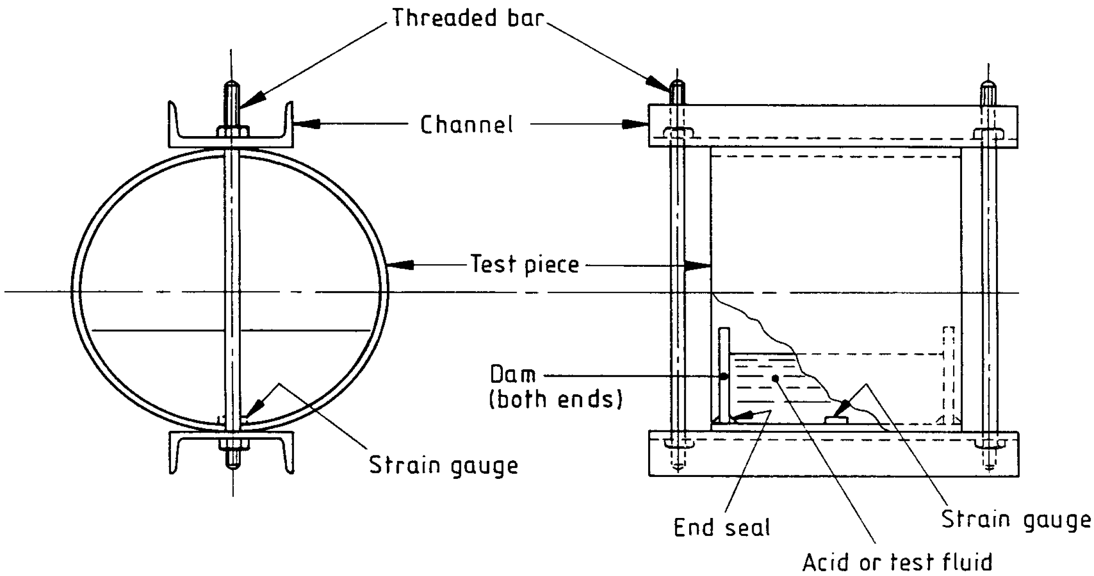


Figure 5 — Diagrammatic representation of apparatus for strain corrosion testing

F.3.2 *Testing machine*, capable of compressing individual test pieces mounted in accordance with **F.3.1** and of recording the resulting strain in accordance with **F.6.3.3**.

F.4 Test pieces

The test piece shall be a ring section at least 300 mm long, cut from a pipe. Sufficient test pieces are required to obtain at least 18 failures with a distribution in accordance with Table 7.

F.5 Test conditions

Conduct the test at 15 ± 10 °C except in the following two cases.

a) In case of dispute conduct the test at 23 ± 2 °C.

b) If the strain corrosion characteristics are required for an application involving sustained operating temperatures higher than 30 °C, conduct the test at this higher temperature.

F.6 Procedure

F.6.1 ***General***

Determine the internal circumferential strain using either an attached strain gauge in accordance with method 1 (see **F.6.2**) or a calibration curve in accordance with method 2 (see **F.6.3**).

F.6.2 ***Method 1***

Attach a strain gauge to the inside surface of the test piece such that it measures circumferential strain.

Place the test piece in the test rig as shown in Figure 5 with the strain gauge at the bottom. Deflect the test piece until the desired initial strain level is achieved and maintain this deflection for the duration of the test.

Proceed to **F.6.4**.

F.6.3 ***Method 2***

F.6.3.1 This method is only applicable to test pieces obtained from pipes of the same diameter, wall thickness, stiffness and pressure rating.

Where a calibration curve has been obtained from a series of test covering pipes of different diameters and wall thicknesses, then this may be used without repeating the procedures given in **F.6.3.2** to **F.6.3.4**, providing the pipe being tested falls within the proven limits of the curve.

F.6.3.2 Fit at least 3 test pieces from different pipes with a strain gauge mounted in accordance with **F.6.2**.

F.6.3.3 Using a testing machine, record circumferential strain as a function of pipe deflection for each of the test pieces such that data are obtained from increments of strain not greater than 0.02 % and until the maximum deflection is sufficient to produce a circumferential strain in excess of that to be applied in accordance with **F.6.3.5** and **F.7**.

F.6.3.4 Compare the calibration curves obtained at 0.3 % strain, the maximum strain, and 6 equally spaced intermediate levels of strain. If the deflections agree within 10 % then the data may be used to construct a mean curve.

If the curves do not agree, reject those that differ by more than 10 % and do not use samples from these pipes in the subsequent part of the test. For any new pipes from which samples will be taken, test at least one test piece for strain deflection measurements in accordance with **F.6.3.3**, and check that its deflection/strain relationship agrees to within 10 % of the mean curve prepared in accordance with this subclause. Otherwise use method 1.

F.6.3.5 Assemble the test piece into the testing rig as shown in Figure 5 and deflect the specimen as indicated from the calibration curve to obtain the required circumferential strain (see **F.7**), provided that this does not involve extrapolation beyond the measured limits used to establish the mean curve. Otherwise establish an acceptable mean curve or use method 1.

F.6.4 *Application of reagent.* Prepare chemically inert dams and bond them to the ends of the deflected test piece.

Fill the bore of the test piece between the dams to a depth of at least 0.2 diameters with 0.5 M sulphuric acid. Complete the bonding of the end dams and filling of the test pieces with acid within 24 h of deflecting the test piece. Once a week check, and if necessary correct, the concentration and level of the acid. Other acids or reagents may be used for specific applications.

F.6.5 *Inspection scheduling.* Using an inspection frequency in accordance with Table 6 in conjunction with a test schedule in accordance with **F.7**, note and record any failure with time of occurrence corrected to the nearest hour, where failure is defined as any cracking of the internal surface or leakage of acid through the pipe wall.

Where a failure occurs that is not due to strain corrosion, for example where failure occurs at a position remote from the acid or other corrosion reagent, this need not be taken as a failure point, but it may be used in accordance with **F.7** b) if that procedure is adopted.

Table 6 — Inspection schedule for strain corrosion testing

Stage of testing	Interval between inspections
h	h
⩾ 24 and < 40	⩽ 2
⩾ 40 and < 60	⩽ 4
⩾ 60 and < 100	⩽ 8
⩾ 100 and < 600	⩽ 24
⩾ 600 and < 6 000	⩽ 48
⩾ 6 000	⩽ 168

F.7 Test schedule

Choose the strain level applied to each test piece so that the distribution of failures complies with the distribution pattern given in Table 7.

Table 7 — Failure point distribution for strain corrosion testing

Failure time	Minimum data point distribution
h	
⩾ 24 and < 1 000	4
⩾ 1 000 and < 6 000	3
⩾ 6 000 and < 10 000	3
⩾ 10 000	1
Total	11 + 7 others

On completion of each time band, if the applicable minimum number of failure points shown in column 2 of Table 7 has not been achieved, adopt one of the following procedures as appropriate.

a) For pipes so highly resistant that strain corrosion failure points cannot be obtained in less than 1 000 h, repeat the test using ten test pieces. Subject five test pieces to ⩾ 1.25 % strain and record the number of failures before 3 000 h. Subject the other five test pieces to ⩾ 1.0 % strain and record the number of failures before 10 000 h.

b) Test further test pieces until the applicable limit is satisfied.

To obtain the total of at least 18 data points required for **F.8.2**, include as valid those test pieces which at the conclusion of the schedule have not failed after being under test for more than 10 000 h if the result increases the value of the extrapolated stress under the following condition.

First obtain the regression equation (25) in accordance with Appendix P for the results from the test pieces that failed. Then use the strain for each test piece that has been under test for more than 10 000 h and not failed with the same regression equation to estimate the time to failure in hours. If this time is less than or equal to the time the test piece has been on test then the result for the non-failed test piece can be included in the data analysis.

F.8 Calculation

F.8.1 For results obtained in accordance with **F.7** a), the strain corrosion resistance of the pipe shall be considered satisfactory if no failures are observed within the limits of 3 000 h at ⩾ 1.25 % strain and 10 000 h at ⩾ 1.0 % strain respectively.

F.8.2 For at least 18 results obtained in accordance with **F.7** use the method given in Appendix P to determine the following statistics and results assuming a design life of 50 years, unless the design life is other than 50 years, in which case determine the strain at the design life.

a) The correlation coefficient, *r*, calculated in accordance with **P.4.3**.

b) The regression equation calculated in accordance with **P.4.4**

c) The estimated mean long term strain, ϵ_L, at the design life of the pipe calculated using equation (42) in accordance with **P.4.6**.

d) The 95 % lower confidence limit, ϵ_{95}, on the value of ϵ_L calculated using equation (41) in accordance with **P.4.6**.

e) The strains ϵ_{24}, ϵ_{100}, and $\epsilon_{1\,000}$ together with their lower 95 % confidence limit at failure times of 24 h, 100 h and 1 000 h calculated using equations (41) and (42) in accordance with **P.4.6**.

NOTE Failure times of less than 24 h are not acceptable for inclusion in the calculation.

F.9 Test report

The test report shall include the following.

a) The size and classification of the pipe and the manufacturer's code.

b) A reference to this method of test, i.e. Appendix F of BS 5480:1990.

c) The dates between which the testing was conducted.

d) The limits of the test temperature range (in °C).

e) The fluid used.

f) The regression equation.

g) The correlation coefficient.

h) The design life of the pipe.

i) The estimated mean long term strain, ϵ_L, at the design life of the pipe.

j) The 95 % lower confidence limit, ϵ_{95}.

k) The strains ϵ_{24}, ϵ_{100} and $\epsilon_{1\,000}$ together with their lower 95 % confidence limit at the failure times of 24 h, 100 h and 100 h respectively.

l) In the case of pipes tested in accordance with **F.7** a), the two levels of strain applied and the incidence, if any, of failures within 3 000 h at ⩾ 1.25 % strain and/or within 10 000 h at ⩾ 1.0 % strain.

Appendix G Method for determination of ovality of a pipe after allowance for distortion by its own mass

G.1 Principle

The mean internal diameter, D_i, is determined as the average of measurements of the internal diameter at angular increments of 15° where half the diameters are measured while in the horizontal plane and the other half are measured coincidentally for the vertical plane.

The average deflection of the pipe, δ_v, because of its own mass, is determined from the data used to establish D_i, by subtracting from D_i the average value for the measurements of the internal diameter taken in the vertical plane.

The deviation from roundness of the pipe, γ, arising from effects other than its own mass, is determined from the differences between D_i and the maximum and minimum measured values for individual internal diameters after subtracting δ_v from each of those two overall differences.

NOTE GRP pipes having a low stiffness are usually sufficiently flexible to deflect noticably in response to their own mass when resting on a horizontal surface.

G.2 Apparatus

G.2.1 *Means for measuring an internal diameter* to an accuracy of ± 0.05 %.

G.3 Procedure

G.3.1 With the pipe resting horizontally, mark the horizontal and vertical diameters at each end of the pipe.

G.3.2 Measure and record the horizontal internal diameter, D_{H0}, and vertical internal diameter, D_{V0}, at each end of the pipe.

G.3.3 Rotate the pipe through 15° and record the new horizonal internal diameter, D_{H15}, and vertical internal diameter, D_{V15}.

G.3.4 Repeat **G.3.3** at 15° increments to obtain values for D_{H30} and D_{V30}, D_{H45}, and D_{V45} etc. up to and including D_{H165} and D_{V165}, i.e. for half the circumference of the pipe.

G.4 Calculation

Calculate the mean internal diameter, D_i (in mm) at each end of the pipe using the following equation:

$$D_i = \frac{(D_{HO} + D_{H15} + \ldots D_{H165}) + (D_{VO} + D_{V15} + \ldots D_{V165})}{24} \tag{11}$$

Calculate the vertical deflection of the pipe in response to its own mass, δ_v (in mm) using the following equation:

$$\delta_v = D_i - \frac{D_{VO} + D_{V15} + \ldots D_{V165}}{12} \tag{12}$$

Calculate the deviation from roundness of the pipe, γ, at any point, with the exception of deflection in response to its own mass, using the following equation:

$$\gamma = D_i - D_{Vn} - \delta_v \tag{13}$$

where

D_{Vh} is any vertical measurement.

For each end combine the highest positive and negative values of γ with the mean diameter D_i to obtain the range of the internal diameter of the pipe. Compare the range determined with the applicable limits for the work size of the pipe.

G.5 Report

The report shall include the following.

a) The size and classification of the pipe and the manufacturer's code.

b) A reference to this method of test, i.e. Appendix G of BS 5480:1990.

c) The date of testing.

d) The individual measurements of horizontal diameter, D_H and vertical diameter, D_V.

e) The mean internal diameter, D_i.

f) The vertical deflection of the pipe, δ_v,

g) The deviation from roundness, γ, at any point.

h) The limits on the work size diameter.

Appendix H Method for determination of initial specific stiffness and resistance to structural damage under ring deflection

H.1 Principle

A cut length of pipe is loaded along its length to compress it diametrically to within specified limits (2.5 % to 3.5 %) and after a limited period the relationship between load and deflection is determined by either of two methods as follows.

a) *Method A.* Following application of the load to achieve a required deflection, the load is kept constant for a period of time and the deflection is determined at the end of this period.

b) *Method B.* Following application of the load to achieve a required deflection, the deflection is kept constant for a period of time and the load being applied at the end of this period is determined.

The results obtained by either method are used to calculate the stiffness of the pipe per unit length in response to short term loading, i.e. the initial specific ring stiffness (see **H.8**).

Resistance to structural damage is assessed by applying a consecutive enhanced level of deflection within a specified period to a cut length of pipe which has been used for determination of initial specific stiffness. The test piece is then inspected for visible evidence of structural damage.

H.2 Apparatus

H.2.1 *Load application device,* capable of applying a compressive force, *F*, between parallel surfaces complying with **H.2.2**, sufficient to impart to a test piece (see **H.3**) without shock a deflection in accordance with **H.7.2** or **H.7.3**.

For testing in accordance with method A (see **H.1** and **H.7.2**), the device shall be capable of sustaining and indicating the applied force with a variation of not more than ± 1 % of the value to be sustained.

For testing in accordance with method B (see **H.1** and **H.7.3**), the device shall be a dynamometer capable of maintaining a deflection in accordance with **H.7.3** with a variation of not more than ± 1 % of the value to be sustained.

H.2.2 *Load application surfaces*

H.2.2.1 *Arrangement.* The surfaces shall comprise a pair of plates complying with **H.2.2.2** or a pair of rods complying with **H.2.2.3**, or a combination of one such plate and one such rod, mutually parallel and with their major axes at right angles to and centred on the direction of application of force, *F*, by the load application device, as shown in Figure 6.

H.2.2.2 *Bearing plates.* The plate(s) shall have a thickness of at least 5 mm, a length at least equal to the length of the test piece, a width of at least 100 mm and shall be made of a material such that bending or deformation of the plate(s) does not exceed 0.1 % of the maximum deflection of the test piece during the test.

The surface of the plate(s) to be in contact with the test piece shall be flat, smooth and clean.

H.2.2.3 *Bearing rods.* The rod(s) shall have a length at least equal to the length of the test piece and a cross section comprising at least one half of a circle. For testing pipes with a nominal size not greater than 300 the diameter of the rod(s) shall be 25 ± 5 mm. For testing larger pipes the diameter of the rod(s) shall be 50 ± 5 mm.

The rod(s) shall be made of a material such that bending or deformation of the rod does not exceed 0.1 % of the maximum deflection of the test piece during the test. The surface of the rod to be in contact with the test piece shall be smooth and clean.

H.2.3 *Means for measurement of dimensions.* The means shall be capable of measuring the dimensions (length, diameters, wall thickness) of the test piece to an accuracy of within ± 10 % and of determining the deflection, *y*, i.e. the change in the diameter of the test piece in the direction of the application of the force, *F*, during the test, to an accuracy of within 1.0 % of the maximum value of the change.

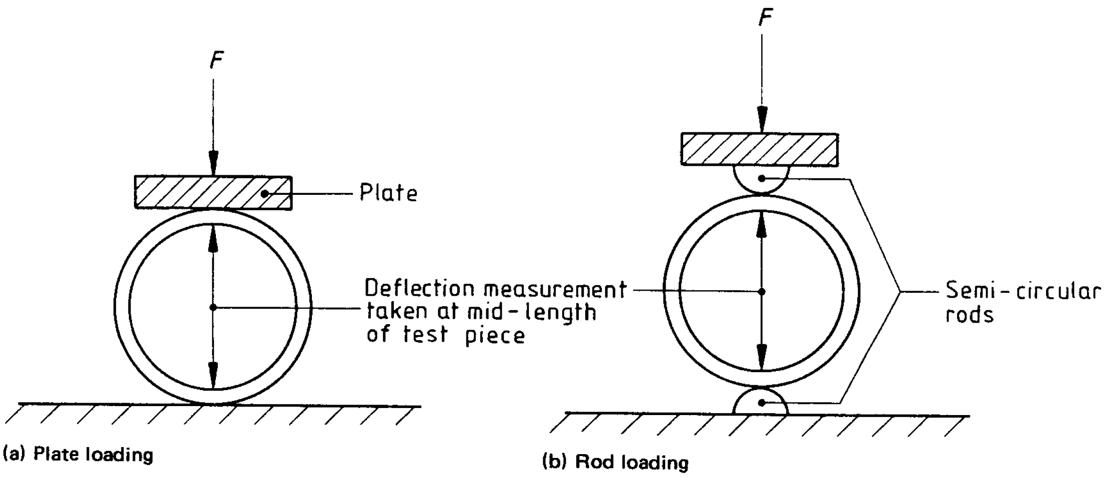


Figure 6 — Schematic diagram of the apparatus for determination of stiffness under ring deflection

H.3 Test piece

The test piece shall be a complete ring cut from the pipe to be tested. The length, l (in m), of the test piece (see **H.5.1**) shall be as follows, subject to a tolerance of ± 5 %:

a) for pipes with DN < 300, $l = 0.001$ (DN);

b) for pipes with $300 \leqslant$ DN < 1 500, $l = 0.3$;

c) for pipes with DN $\geqslant$ 1 500, $l = 0.002$ (DN);

where

DN is the nominal size of the pipe.

The cut ends shall be smooth and perpendicular to the axis of the pipe.

Locus lines comprising straight lines at 120° intervals around the pipe circumference shall be drawn on the inside and the outside along the length of the test piece.

H.4 Number of test pieces

The number of test pieces shall be one.

H.5 Determination of the dimensions of the test piece

H.5.1 ***Measurement of length***

Measure the length of each locus line on the test piece (see **H.3**) to an accuracy of within ± 1.0 %. Calculate the mean length, l, of the test piece as the average of the lengths of the locus lines.

H.5.2 ***Measurement of wall thickness***

Measure the thickness of the test piece on each locus line at each end. Calculate the mean wall thickness as the average of these 6 measurements.

H.5.3 ***Measurement of diameters***

H.5.3.1 Measure the internal diameter, D_i, at mid-length on each locus line to an accuracy of within ± 1.0 %, or measure the external diameter, D_e, at mid-length on each locus line to an accuracy of within ± 1.0 %, e.g. by means of calipers.

NOTE When a circumferential tape is used for the measurement of the external diameter, it is not possible to give a different value for all three positions.

H.5.3.2 Determine the mean diameter, D_m, by calculation using the averaged values obtained for wall thickness and either the internal diameter or the external diameter for the mid-points of the 3 locus lines.

H.6 Conditioning

In cases of dispute, condition the test pieces at 23 ± 2 °C for at least 24 h before testing.

H.7 Procedure

H.7.1 ***General***

H.7.1.1 *Control of temperature.* In cases of dispute, conduct the test at 23 ± 2 °C.

H.7.1.2 *Positioning of the test piece.* Place the test piece on the lower bearing plate or rod with one of the locus lines in contact with the upper bearing plate or rod.

Ensure that the contact between the test piece and the bearing plate or rod is as uniform as possible.

H.7.1.3 *Repetition of test.* Using either method A (see **H.1** and **H.7.2**) or method B (see **H.1** and **H.7.3**), determine the force/deflection relationship at the mid-point of each of the three locus lines in turn. Allow the test piece to recover elastically between each test. In case of dispute, allow 15 minutes between each determination.

H.7.2 ***Method A (using constant force)***

Apply a compressive force at a constant rate or in three equal increments so that a percent relative deflection 100 δ/D_m of between 2.5 % and 3.5 % is reached in 60 ± 10 s.

Maintain this force for 2 min and determine the force and the deflection for the locus under load at the end of this period.

For pipes having an initial specific stiffness less than 1 250 N/m^2, after having sustained the force for 2 min at the third locus position, increase the force at a rate that will induce in not more than 6 min a relative deflection of 15 % or three times the maximum permissible deflection recommended by the manufacturer, whichever applies the greater deflection, and inspect the test piece for visible evidence of structural damage in the form of cracking, delamination or rupture of the pipe wall.

Note the load and deflection at which any such damage occurs. Stop the test when the required deflection is attained or if and when the rate of deflection is sustained without an increase in force, whichever occurs first.

For pipes manufactured to a minimum initial specific stiffness not less than 1 250 N/m^2, after having sustained the force for 2 min at the third locus position, increase the force at a rate that will induce in not more than 6 min a deflection of three times the maximum long term ring deflection recommended by the manufacturer and inspect the test piece for visible evidence of structural damage in the form of cracking, delamination or rupture of the pipe wall.

Note the load and deflection at which any such damage occurs. Stop the test either when the required deflection is attained or if and when the rate of deflection is sustained without an increase in force, whichever occurs first.

H.7.3 ***Method B (using constant deflection)***

Apply a compressive force at a substantially constant rate or in three equal increments so that a percent relative deflection 100 δ/D_m of between 2.5 % and 3.5 % is reached in 60 ± 10 s.

Maintain the deflection constant for 2 min and determine the deflection and the force at the end of this period.

For pipes of minimum initial specific stiffness less than 1 250 N/m^2, after having sustained the deflection for 2 min at the third locus position, increase the force at a rate that will induce in not more than 6 min a relative deflection of 15 % or three times the maximum permissible deflection recommended by the manufacturer, whichever applies the greater deflection, and inspect the test piece for visible evidence of structural damage in the form of cracking, delamination or rupture of the pipe wall.

Note the load and deflection at which any such damage occurs. Stop the test when the required deflection is attained or if and when the rate of deflection is sustained without an increase in force, whichever occurs first.

For pipes manufactured to a minimum initial specific stiffness not less than 1 250 N/m^2, after having sustained the deflection for 2 min at the third locus position, increase the force at a rate that will induce in not more than 6 min a deflection of three times the maximum permissible long term ring deflection recommended by the manufacturer and inspect the test piece for visible evidence of structural damage in the form of cracking, delamination or rupture of the pipe wall.

Note the load and deflection at which any such damage occurs. Stop the test either when the required deflection is attained or if and when the rate of deflection is sustained without an increase in force, whichever occurs first.

NOTE An estimate of the probable compressive force required to achieve a relative deflection of 3 % can be made from knowledge of the specific stiffness (SN). This will enable a substantially constant rate of loading to be achieved.

H.8 Calculation

Calculate the initial specific ring stiffness, S_o (in N/m^2) using the following equation:

$$S_o = \left[0.0186 + \frac{0.025\bar{\delta}}{D_m}\right] \frac{\bar{F}}{l\bar{\delta}} \quad (14)$$

where

$\bar{\delta}$ is the average value (in m) of the three deflection measurements obtained in accordance with **H.7.1.3**;

D_m is the mean diameter (in m) of the pipe, e.g.

$D_m = D_i + e$

where

D_i is the internal diameter (in m) of the pipe;

e is the minimum wall thickness (in m) of the pipe;

$\bar{F}$ is the average value (in N) of the three levels of force used or measured in accordance with **H.7.1.3**;

l is the mean length (in m) of the test piece.

H.9 Test report

The test report shall include the following information.

a) A full identification of the pipe tested.

b) A reference to this method of test, i.e. Appendix H of BS 5480:1990.

c) The dimensions of the test piece.

d) The positions in the pipe from which the test piece was obtained.

e) The test method used (A or B), equipment details and whether rods or plates were used.

f) The individual values for forces and deflections.

g) The temperature during testing.

h) The initial specific ring stiffness, S_o.

i) A description of the test pieces after testing, i.e. any evidence of visible structural damage.

j) The date of testing.

Appendix J Method for determination of impact resistance

J.1 Principle

A number of test pieces are each subjected to a blow by a striker of specified mass falling vertically from a variety of heights depending upon whether or not the test pieces exhibit damage, specifically cracking of the internal surface. The results obtained are used to estimate the drop height, H_{50}, from which the specified striker would cause damage to 50 % of such test pieces.

J.2 Apparatus

J.2.1 *Falling weight apparatus,* incorporating a rigid frame supporting a guide in the form of rails or a perforated tube vertical to within 1°.

J.2.2 *Striker,* which can fall freely subject to the guide, has a mass of 515 ± 5 g and provides a hemispherical striking surface of 50 mm radius.

J.2.3 *Test piece support,* comprising a 120° vee-block of length at least equal to the length of the pipe test piece and so positioned on a rigid base that the projection of the path of the centre of the hemispherical striking surface is aligned with the centre of the face of the vee-block to within 2.5 mm or 1 % of the outside diameter of the cross section to be struck, whichever is the greater. The vee-block and its underlying support or foundation shall not sensibly deform or move in response to the impact on the test piece.

J.3 Reagents

J.3.1 *A penetrant dye,* of contrasting appearance to the test piece and of sufficiently low viscosity to penetrate any superficial crack.

J.4 Test pieces

A test piece shall comprise a complete section of pipe length equivalent to three times its diameter of 1.5 m, whichever is the shorter.

NOTE A minimum of 11 test pieces is required, depending upon the results obtained (see **J.5**).

J.5 Procedure

NOTE The procedure is split into two parts, with a preliminary test to determine an appropriate drop height for commencing the main test.

J.5.1 ***Preliminary test***

Select a drop height where cracking of the internal surface is not expected to occur. Subject a sample of pipe to a single blow by the falling striker and inspect the internal surface for any cracks, using a dye penetrant to aid their detection if in doubt.

If there is no sign of damage, increase the drop height by 100 mm and repeat the test. Continue in this manner until damage occurs to the internal surface. Note as H_s the greatest drop height used which did not cause damage, then proceed to **J.5.2**.

If the initial drop height chosen produces damage to the internal surface, then reduce the drop height by 100 mm and repeat the test. Continue reducing the drop height until no damage occurs to the internal surface. Note as H_s the first drop height that did not cause damage, then proceed to **J.5.2**.

J.5.2 ***Main test***

In case of dispute, conduct the following "main test" procedure at 23 ± 2 °C. Otherwise, note the ambient temperature range in which the main test was conducted.

Take H_s as the starting drop height for this part of the procedure and consider the result which produced it as an initial pass in the calculation of the result.

Add 100 mm to this height and use it to test the first of a minimum of 9 further test pieces. Check the internal surface for damage. If it is undamaged then count that result as a pass and add a further 100 mm to the drop height and test the next test piece. If, however, the test piece shows any cracking of the internal surface, count it as a failure and reduce the drop height by 100 mm before testing the next test piece. Continue this procedure until all the test pieces have been tested.

J.6 Calculation

Estimate the drop height H_{50} (in m), that would cause 50 % of such test pieces to fail, using the following equation:

$$H_{50} = (\Sigma H_p + \Sigma H_F)/2000 \qquad (15)$$

where

ΣH_p is the sum of the drop heights (in mm) of all passed test pieces divided by the number of passed test pieces;

ΣH_F is the sum of the drop heights (in mm) of all failed test pieces divided by the number of failed test pieces.

J.7 Test report

The test report shall include the following.

a) The identity, date of manufacture, size and classification of the pipe and the manufacturer's code.

b) A reference to this method of test, i.e. Appendix J of BS 5480:1990.

c) The date of testing.

d) The number of test pieces used for the main test.

e) The test temperature range (in °C).

f) The results obtained from both the preliminary and main parts of the test.

g) The estimated mean failure drop height, H_{50} (in m).

Appendix K Method of test for leaktightness of pipes and their joints by hydrostatic pressure testing

K.1 Principle

The leaktightness of pipes and their joints is determined using a hydrostatic pressure test at 1.5 times the working pressure of the pipe for pressure applications and otherwise at 1.5 bar.

NOTE References to pressure relate to gauge pressure unless otherwise stated.

K.2 Apparatus

K.2.1 For pipes that are not intended to resist longitudinal end loads developed by internal pressure, the apparatus shall consist of a pair of end seals suitably restrained so that no axial force is applied to the pipe other than that exerted through the gasket. It shall be provided with a means of measuring the hydrostatic pressure at the top of the pipe to an accuracy of ± 2 %.

K.2.2 For pipes intended to resist longitudinal end loads developed by internal pressure, the apparatus shall consist of a pair of end seals that transmit the axial force to the pipe and it shall be provided with a means of measuring the hydrostatic pressure at the top of the pipe to an accuracy of ± 2 %.

K.2.3 If supports are used, these shall not interfere with observation of the pipe surface.

K.3 Test pieces

The test piece shall be a length of pipe and joint as manufactured.

K.4 Test conditions

Conduct the test at ambient temperature, except in cases of dispute, in which case conduct the test at 23 ± 2 °C.

K.5 Test pressure

Unless otherwise required by the product specification, the test pressure shall be either 1.5 bar for pipes or joints intended for non-pressure applications or 1.5 times the maximum sustained working pressure of the pipe or joint if intended for pressure applications.

K.6 Procedure

K.6.1 Assemble the pipe in the test apparatus.

K.6.2 Seal the ends by suitable devices (see **K.2.1** and **K.2.2**) that have joints similar to those that will normally be used on the pipe.

K.6.3 Fill the pipe with water, taking care to expel all air.

K.6.4 Apply the test pressure (**K.5**) at a rate not exceeding 1 bar per second and maintain the pressure for a period of 5 min or a period sufficient to enable visual inspection of the pipe, whichever is the longer.

K.6.5 Examine the pipe surface during the test period and record any failure.

K.7 Test report

The test report shall include the following.

a) The identification, size and classification of the pipe and the manufacturer's code.

b) A reference to this method of test, i.e. Appendix K of BS 5480:1990.

c) The test pressure.

d) The test temperature.

e) Confirmation that the test piece or joint was leaktight or otherwise a description of the type of failure.

f) The date of the test.

Appendix L Method for determination of long term specific ring stiffness and creep factor under ring deflection

L.1 Principle

A cut length of pipe is loaded along its length to compress it diametrically within specified limits. It is immersed in water at a given temperature and its deflection in response to a constant load is measured at intervals. The long term deflection is estimated by extrapolation. From that deflection and the load, the long term specific ring stiffness under wet conditions is calculated. The creep factor under wet conditions is determined as the ratio between the initial specific stiffness and long term specific ring stiffness of the same test piece.

L.2 Apparatus

L.2.1 *Load application devices.* Devices capable of applying a compressive force, F, between parallel surfaces complying with **H.2.2**, sufficient to impart to a test piece without shock a deflection in accordance with **L.6.3**. The apparatus shall be capable of applying the force to a test piece submerged in a water bath without the force being influenced by any change of water level during the test.

L.2.2 *Water bath.* A water bath of sufficient size to allow a test piece (see **L.3**) to be completely immersed. The bath shall contain potable water with a pH of between 5 and 9 at a specified test temperature.

L.2.3 *Means for measurement of dimensions.* These shall comply with **H.2.3** and, for determining the change in diameter of the test piece, shall be applicable to the submerged test piece.

L.3 Test pieces

Use three test pieces, each of which shall be in accordance with **H.3**.

L.4 Determination of the dimensions of the test pieces

For each test piece, determine its length, wall thickness and internal, external and mean diameters in accordance with **H.5**.

L.5 Conditioning

In cases of dispute, condition the test pieces at 23 ± 2 °C for at least 24 h before testing.

L.6 Procedure

L.6.1 ***Temperature***

In cases of dispute conduct the test at 23 ± 2 °C.

L.6.2 ***Positioning of the test piece***

Place the test piece in the apparatus with a measured diameter (see **H.5.3**) in the vertical position. Ensure that the contact between the test piece and the bearing plates or rods is as uniform as possible. Place the whole apparatus in the water bath, so that the test piece is completely immersed.

L.6.3 ***Application of load***

For each test piece, determine its initial specific ring stiffness in accordance with Appendix H. Estimate from the initial specific ring stiffness, S_o, the load required to compress the test piece to between 98.0 % and 98.5 % (inclusive) of its average diameter (this load may include the mass of the upper plate or rod). Apply the compressive load so that the deflection is reached within 2 min. Note the deflection achieved.

L.6.4 ***Measurement of deflection***

Measure to within ± 1.0 % of the measured value the deflection at the mid-length of the test piece after time intervals since loading of 1, 3, 10, 24, 100, 300, 1 000, 3 000 and 10 000 h.

L.7 Calculation

Determine in accordance with Appendix P the regression line and the lower 95 % confidence limit for the change in deflection (δ_1/δ_2) with time, derived from the deflection data obtained in accordance with **L.6.3** and **L.6.4** where

δ_1 is the initial deflection (in mm) determined in accordance with **L.6.3**;

δ_2 is the deflection (in mm) determined after a given time interval in accordance with **L.6.4**.

Calculate the long term specific stiffness after 50 years, S_{50}, or other design life, as applicable, by multiplying the initial specific stiffness by the creep factor, i.e. the extrapolated 50 year value of δ_1 divided by δ_2.

L.8 Test report

The test report shall include the following information.

a) The size and classification of the pipe and the manufacturer's code.

b) A reference to this method, i.e. Appendix L of BS 5480:1990.

c) The dimensions of each test piece.

d) The test temperature range.

e) The initial specific ring stiffness, S_o, of each test piece.

f) The range of pH of the water during the test.

g) The load applied to each specimen.

h) The measured deflection versus the time for each specimen.

i) The calculated long term specific ring stiffness, S_{50}, of each test piece.

j) The dates between which the tests were conducted.

k) The creep factor.

Appendix M Methods of test for leaktightness of flexible joints

WARNING. Attention is drawn to the need for adequate precautions against the possible effects of lateral forces generated in jointed pipework subjected to a combination of angular deflection and internal pressure.

M.0 Introduction

The methods in this appendix are technically equivalent to the corresponding methods given in ISO/DIS 8639:1985. If ISO/D1S 8639 is published and implemented as a British Standard, consideration will be given to cross-reference to the international standard in place of the text which follows.

M.1 General

This appendix describes methods of test applicable to flexible spigot and socket joints, including double socket joints, of glass reinforced plastics (GRP) with elastomeric sealing rings for above ground and buried pipeline applications. The methods are intended for the joint only, to prove the design of the joint for pressure or non-pressure applications, while subject to draw with angular deflection or misalignment and, in the latter position, to negative pressure.

NOTE References to pressure relate to gauge pressure unless otherwise stated.

M.2 Equipment

M.2.1 *End sealing devices*, of size and design appropriate to the pipe system under test and anchored to take the total end thrust without otherwise supporting the joint.

M.2.2 *Means* for applying a controlled amount of angular deflection (see Figure 7) and draw (see Figure 8 and Figure 9) or draw in conjunction with misalignment (see Figure 10) while subject to support (see **M.2.3**).

M.2.3 *Supports or cradles* depending on the conditions of the test as follows.

For tests involving draw and angular deflection, supports or cradles shall be provided either side of the joint as shown in Figure 11. For tests involving misalignment, the pipe having the collar or socket of the joint being tested shall have two supports and the pipe having the spigot shall have one support. Two straps or cradles, each 100 mm to 200 mm wide, shall provide support for a 180° arc of the pipe barrel or outside diameter of the joint, as applicable, where one is located under the collar and the other is located 900 mm ± 10 mm from the joint as shown in Figure 12. The strap or cradle nominally located 900 mm from the joint shall be used to apply the additional force, F_m, necessary in accordance with equation (16) to produce the total shear force, F_r, required on the joint [see **10.2.2** c)]. Except for the load-applying strap or cradle, all supports or cradles shall be anchored to a fixed base. The supports or cradles shall not have any detrimental effect on the test pieces.

Calculate the additional force, F_m (in N) using the following equation.

$$F_m = \frac{F_r L_r - 4.9 m_r L_r^2}{L_r - 0.9} \qquad (16)$$

where

F_r is the total shear force (in N);

L_r is the distance (in m) between the centres of the supports (see Figure 12);

m_r is the mass per unit length (in kg/m) of the pipe and its contents.

M.2.4 *Source of hydrostatic pressure, and a means of achieving a vacuum in the test piece,* capable of satisfying the conditions given in **M.4** and Table 8 such that each specified pressure is achieved or maintained as applicable with a permissible deviation of ± 5 %.

M.2.5 *Pressure gauges,* to measure the positive and negative pressures at the top of the pipe cross section with an accuracy of ± 2 %.

M.3 Test pieces

The joint under test shall be located in a test assembly having a total length of not less than 2.9 m and not more than 10 m, including end sealing devices, and assembled in accordance with the manufacturer's recommendations.

M.4 Procedure

M.4.1 ***General***

While maintaining the temperatures within and surrounding the test assembly at 23 ± 15 °C, test the joint in accordance with **M.4.2** or **M.4.3**, and Table 8, as applicable.

M.4.2 ***Joints for pressure applications***

M.4.2.1 *Initial pressure test.* Apply to the joint the maximum total draw including maximum angular deflection for which the joint is intended.

Fill the test piece with water and vent carefully.

Apply and maintain a hydrostatic pressure of 0.05 bar (0.005 MPa) for 15 min.

Inspect the joint for leaktightness and for damage to the joint components.

Depressurize and if the joint is satisfactory proceed to **M.4.2.2**.

M.4.2.2 *Static pressure test with draw.* Check that the maximum total draw conditions are still applied.

Raise the hydrostatic pressure at a rate not exceeding 1 bar per min (0.1 MPa per min) to twice the nominal pressure rating of the joint and maintain it for 2 h.

Inspect the joint for leaktightness and for damage to the joint components.

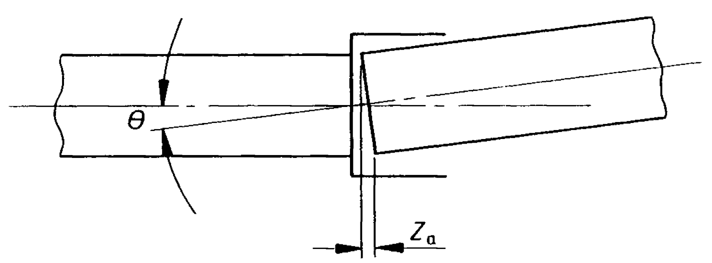
Depressurize and if the joint is satisfactory proceed to **M.4.2.3**.

M.4.2.3 *Cyclic and static pressure test with misalignment and draw.* Set the recommended total draw to the joint.

Fill the test piece with water and vent carefully.

Apply a load to the pipe (see **M.2.3**) such that the specified total shear force F_r [see **10.2.2** c)] is achieved.

Apply an initial pressure of 0.05 bar (0.005 MPa) for 15 min and inspect the joint for leaktightness. If the joint is leaking, discontinue the test, record the failure and reassemble the joint. Repeat **M.4.2.3** thus far until either a satisfactory seal is achieved or the test is abandoned.



NOTE Angular deflection causes a longitudinal movement Z_a.

Figure 7 — Angular deflection

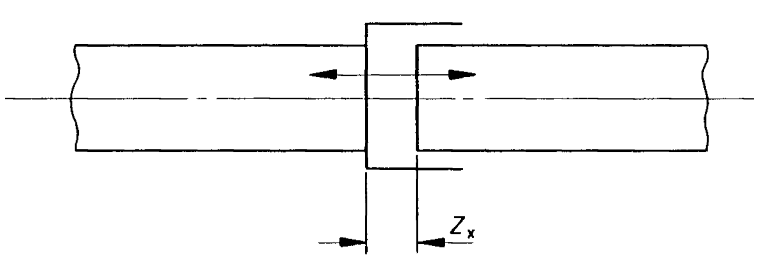
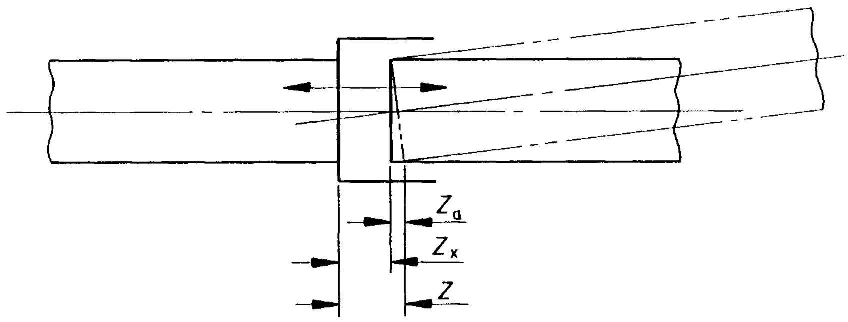


Figure 8 — Draw



NOTE Total draw Z is the sum of Z_a and Z_x.

Figure 9 — Total draw

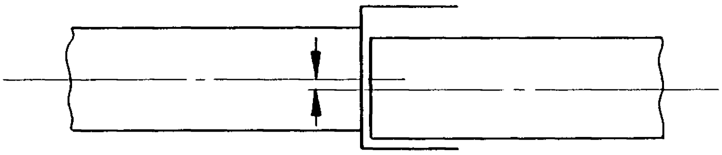


Figure 10 — Misalignment

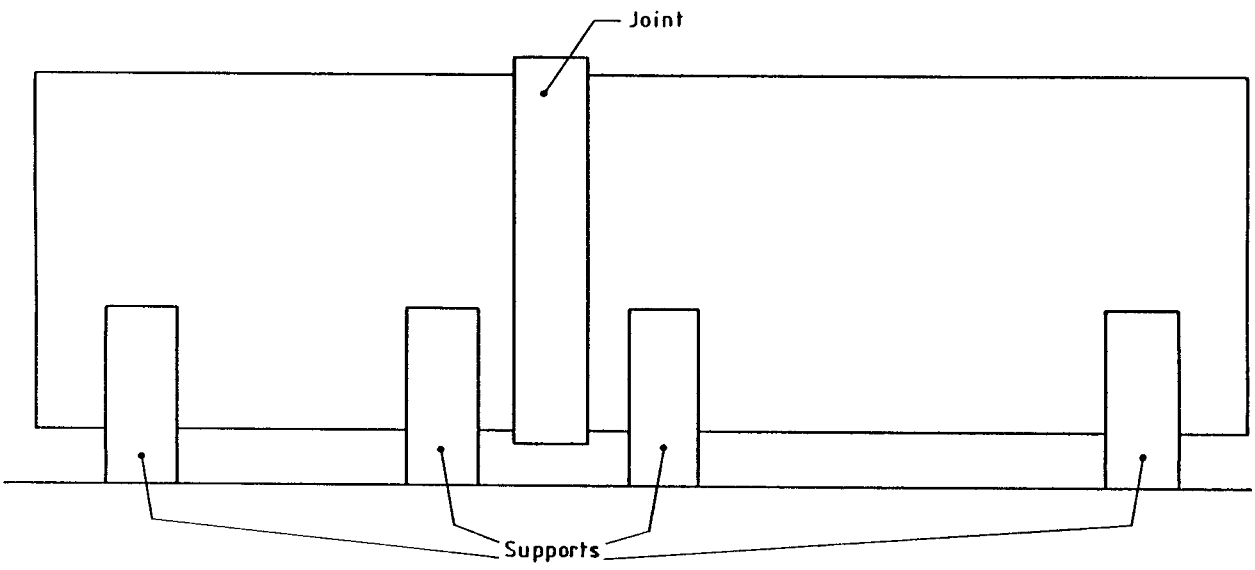
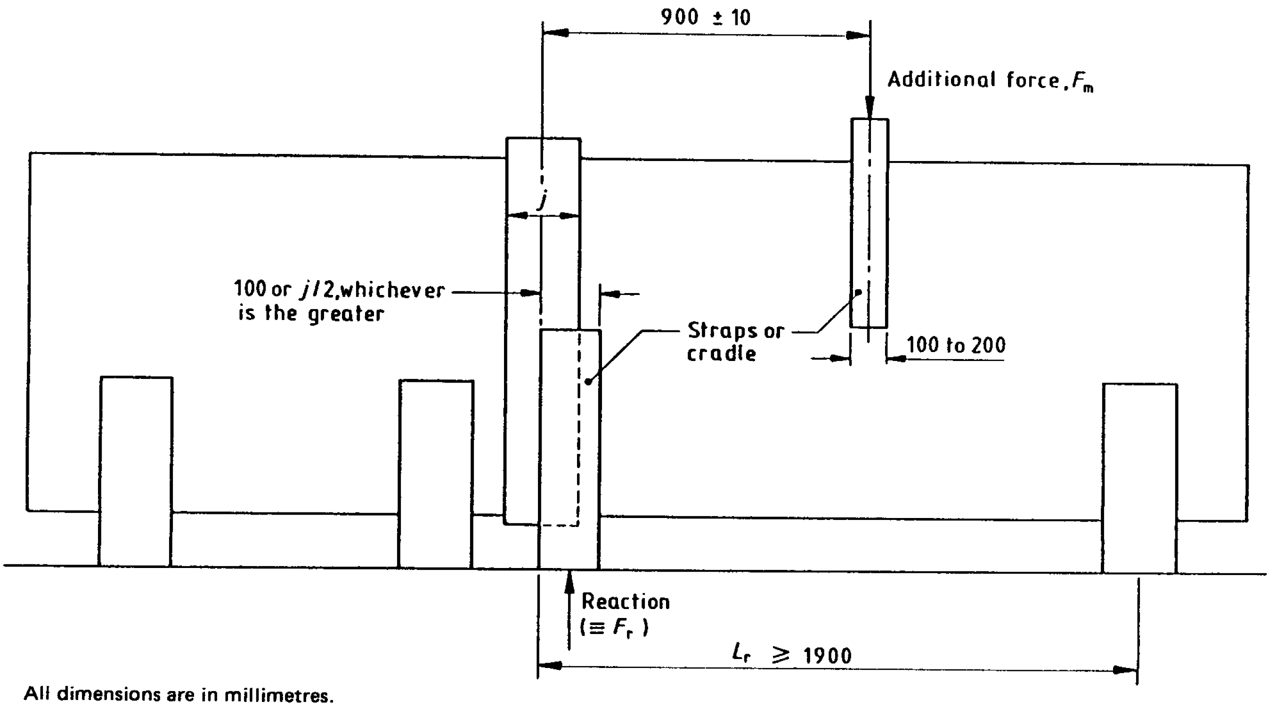


Figure 11 — Sketch of support conditions for testing flexible joints subject to draw and/or angular deflection



NOTE For DN $\leqslant$ 1 800, F_r = 20 × (DN) N;
for DN > 1 800, F_r = 36 kN;
for F_m, see **M.2.3**.

Figure 12 — Support and cradle or strap arrangement for testing flexible joints subject to misalignment

If the joint is leaktight, increase the pressure to twice the nominal pressure rating of the joint and maintain the pressure for 2 h. Inspect the joint for signs of leakage. If leaking occurs, discontinue the test and record the failure; otherwise continue as follows.

Reduce the pressure to 0 gauge. In a period of 5 ± 3 min, raise the pressure to 1.5 times the nominal pressure of the joint and then reduce to 0 gauge.

Repeat this 5 ± 3 min pressure cycle a further 9 times and during the last of these, before lowering the pressure, inspect the joint for leaktightness and damage to the joint components.

If the joint is satisfactory proceed to **M.4.2.4**

M.4.2.4 *Negative pressure test with draw.* Whilst maintaining the total draw condition in accordance with **M.4.2.3**, empty the joint of water, apply a vacuum to – 0.8 bar (– 0.08 MPa) gauge, [i.e. 0.2 bar absolute (0.02 MPa absolute)], seal and leave for 1 h. Check for any pressure change greater than 0.08 bar (0.008 MPa) during this period.

Inspect the joint for leaktightness and for damage to the joint components.

Restore to atmospheric pressure (0 gauge).

M.4.3 ***Joints for non-pressure applications***

NOTE If a joint intended for both pressure and non-pressure applications has been tested in accordance with **M.4.2** for satisfactory compliance with the requirements for pressure applications, it is not necessary to also test it in accordance with **M.4.3**, the conditions of which are not more stringent than those of **M.4.2**.

M.4.3.1 *Initial pressure test.* Carry out the test procedure given in **M.4.2.1**. If the joint is leaktight and undamaged proceed to **M.4.3.2**.

M.4.3.2 *Static pressure with total draw.* Carry out the test as in **M.4.2.2** but using a pressure of 0.5 bar (0.05 MPa) for 15 min. If the joint is leaktight and undamaged proceed to **M.4.3.3**

M.4.3.3 *Static pressure test with misalignment and draw.* Proceed in accordance with **M.4.2.3** to set the joint, fill the pipe and apply the shear force and then apply an initial pressure of 0.05 bar (0.005 MPa) for 15 min. If the joint is leaktight, increase the static pressure to 0.5 bar (0.05 MPa) for 15 min. Inspect the joint for leaktightness and for damage to the joint components. Depressurize and, if the joint is leaktight and undamaged, proceed to **M.4.3.4**.

Table 8 — Test conditions for flexible joints

Joint condition	Test	Joints for pressure pipe applications			Joints for non-pressure pipe applications		
		Clause reference	Test pressure (gauge)[a]	Test period	Clause reference	Test pressure (gauge)[a]	Test period
Angular deflection for maximum total draw	Initial pressure	**M.4.2.1**	0.05 bar (0.005 MPa)	15 min	**M.4.3.1**	0.05 bar (0.005 MPa)	15 min
	Positive static pressure	**M.4.2.2**	2 × nominal pressure	2 h	**M.4.3.2**	0.5 bar (0.05 MPa)	15 min
Misalignment and draw	Initial pressure	**M.4.2.3**	0.05 bar (0.005 MPa)	15 min	**M.4.3.3**	0.05 bar (0.005 MPa)	15 min
	Positive static pressure	**M.4.2.3**	2 × nominal pressure	2 h	**M.4.3.3**	0.5 bar (0.05 MPa)	15 min
	Positive cyclic pressure	**M.4.2.3**	0 to 1.5 × nominal pressure	10 cycles of 5 ± 3 min each	None	Not required	—
	Negative pressure	**M.4.2.4**	– 0.8 bar (– 0.08 MPa) [0.2 bar absolute (0.02 MPa absolute)]	1 h	**M.4.3.4**	– 0.8 bar (– 0.08 MPa) [0.2 bar absolute (0.02 MPa) absolute]	1 h

[a] Test pressure to be achieved and maintained within ± 5 %.

M.4.3.4 *Negative pressure test with misalignment and draw.* Whilst maintaining the draw and misalignment force conditions specified in **M.4.3.3**, empty the joint of water, apply a vacuum to – 0.8 bar (0.08 MPa) gauge [0.2 bar absolute (0.02 MPa absolute)], seal and leave for 1 h. Check for any pressure change greater than 0.08 bar (0.008 MPa) during this period.

Inspect the joint for leaktightness and for damage to the joint components.

Restore to atmospheric pressure (0 gauge).

M.5 Test report

The test report shall include the following.

a) The nominal size of joint tested.

b) The nominal pressure and stiffness class of pipe used in the test.

c) The intended use, i.e. pressure and/or non-pressure application.

d) The manufacturer's code.

e) A reference to this method, i.e. Appendix M of BS 5480:1990.

f) The test temperature.

g) The total draw applied to the joint.

h) The angular deflection applied to the joint.

i) The positive pressure applied at each stage.

j) The total shear force, F_r, applied to the joint (see **M.2.3**).

k) The negative pressure applied.

l) Any observations on performance of the joint.

m) The date of the test.

Appendix N Methods of test for leaktightness of rigid joints

N.1 Principle

The tests are identical to the corresponding tests for flexible joints (see Appendix M) except that the components are not subjected to angular deflection or draw.

N.2 Equipment

The equipment shall comply with Appendix M (see **M.2**), except for the end sealing devices (**M.2.1**) which shall comply with **N.3**, and excluding means for the application of angular deflection and draw (i.e. as specified in **M.2.2**).

N.3 Test piece

The joint under test shall be located in the middle of a test assembly having a total length in millimetres of not less than 10 times the nominal size with a minimum of 1 m and a maximum of 10 m, including end sealing devices which will transmit the end load to the joint, and assembled in accordance with the manufacturer's recommendations.

N.4 Procedure

Subject to disregarding instructions in **M.4** to impart or maintain angular deflection and/or draw to the joint under test, conduct the test procedure in accordance with Appendix M (see **M.4**).

N.5 Test report

The test report shall include the following.

a) The size(s) and classification of the joint component(s) under test and their manufacturer's code.

b) A reference to this method, i.e. Appendix N of BS 5480:1990.

c) The intended use, i.e. pressure and/or non-pressure applications.

d) The test temperature.

e) The positive pressure applied at each stage.

f) The negative pressure applied.

g) Any observations on the performance of the joint.

h) The date of testing.

Appendix P Method for statistical analysis of long term data from GRP pipes and fittings

P.1 General

The analysis is based on the relationship

$$y = a + bx \qquad (17)$$

where

y is one variable;

x is the other variable;

b is the slope of the line;

a is the intercept on the y axis.

A linear functional relationship analysis (sometimes called "covariance analysis") is used, subject to tests for the sign (i.e. "+" or "–") of the slope and the coefficient of correlation for the quantity of data available. The relevant equations are given together with example data and results, on the basis of which any other statistical computing package may be used subject to validation by agreement with the example results to within the indicated limits.

For the purposes of this appendix, a design service life of 50 years has been assumed, as applicable.

The long-term properties of GRP pipe for which this analysis is considered applicable include the following:

a) circumferential tensile strength;

b) strain corrosion resistance;

c) specific ring stiffness;

d) creep factor under ring deflection.

P.2 Procedure for analysis of data

Use a linear functional relationship analysis in accordance with **P.3** and **P.4** or equivalent (see **P.1**), as applicable to analyse *n* pairs of data values [as *y* and *x* (see **P.3**)] to obtain the following information:

a) the slope of the line, *b*;

b) the intercept on the *y* axis, *a*;

c) the correlation coefficient, *r*;

d) the predicted mean and/or lower 95 % confidence limit on the mean value for the following properties:

1) circumferential tensile strength ($S_{\phi L}$ or $S_{\phi Lg}$, as applicable), using data obtained in accordance with **4.1** and Appendix E;

2) strain corrosion resistance, using data obtained in accordance with **4.2** or **8.2**, as applicable, and Appendix F;

3) specific ring stiffness, using data obtained in accordance with **8.3** and Appendix L;

4) creep factor under ring deflection, using data obtained in accordance with **8.3** and Appendix H and Appendix L.

P.3 Assignment of variables

For the properties listed in **P.2**, let *x* be $\log_{10}$ time, in hours, and let *y* be $\log_{10} V$, where *V* is the applicable variable for the property being determined.

P.4 Functional relationship equations and method of calculation

P.4.1 ***Basic statistics and symbols***

The following basic statistics and symbols are used:

n is the number of pairs of observed data values (V_i, t_i);

y_i is the $\log_{10}$ of V_i where V_i is, for example, the stress at failure (in MPa) of observation *i; i* = 1, . . . *n*;

x_i is the $\log_{10}$ of t_i where t_i is the time to failure (in h) of observation *i*; *i* = 1, . . . *n*;

$\bar{y}$ is the arithmetic mean of all y_i values

$$= \frac{1}{n} \Sigma_{i=1}^{n} y_i; \qquad (18)$$

$\bar{x}$ is the arithmetic mean of all x_i values

$$= \frac{1}{n} \Sigma_{i=1}^{n} x_i; \qquad (19)$$

P.4.2 ***Relevant sums-of-squares***

Calculate the following sums-of-squares and cross-products.

$$S_{xy} = \Sigma_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y}) \qquad (20)$$

If $S_{xy} > 0$, consider the data unsuitable for evaluating the material; otherwise calculate also

$$S_{xx} = \Sigma_{i=1}^{n} (x_i - \bar{x})^2; \qquad (21)$$

$$S_{yy} = \Sigma_{i=1}^{n} (y_i - \bar{y})^2; \qquad (22)$$

P.4.3 ***Correlation of data***

Calculate the coefficient of correlation, r, from the following relationship

$$r = \frac{S_{xy}}{\sqrt{(S_{xx} \cdot S_{yy})}} \qquad (23)$$

If the value of r is less than the applicable minimum value given in Table 9 as a function of n, reject the data; otherwise proceed to **P.4.4**.

Table 9 — Minimum values for the coefficient of correlation, *r*, for acceptable data from *n* pairs of data

$(n - 2)$	r minimum	$(n - 2)$	r minimum
11	0.8010	25	0.5974
12	0.7800	30	0.5541
13	0.7603	35	0.5189
14	0.7420	40	0.4896
15	0.7246	45	0.4648
16	0.7084	50	0.4433
17	0.6932	60	0.4078
18	0.6787	70	0.3799
19	0.6652	80	0.3568
20	0.6524	90	0.3375
21	0.6402	100	0.3211
22	0.6287		
23	0.6177		
24	0.6074		

P.4.4 ***Functional relationships***

To find a and b for the functional relationship line $y = a + bx$ [equation (17)], first set

$$\lambda = \frac{S_{yy}}{S_{xx}} \qquad (23)$$

and then put

$$b = -\sqrt{\lambda} \qquad (24)$$

and

$$a = \bar{y} - b\bar{x} \qquad (25)$$

NOTE 1 In general, b takes the sign of S_{xy}.

NOTE 2 Since $y = \log_{10}V$ and $x = \log_{10}t$, hence $V = 10^y$, $t = 10^x$ and the implied relationship for V in terms of t is therefore

$$V = 10^{(a + b \cdot \log_{10} t)}$$

P.4.5 ***Calculation of variances***

If t_L is the applicable time to failure, then set

$$x_L = \log_{10}t_L \qquad (26)$$

Calculate, in turn, the following sequence of statistics.

For $i = 1$ to $i = n$, the best fit, ξ_i, for true x, the best fit, Y_i, for true y and the error variance, $\sigma_\delta{}^2$, for x using equations (27), (28) and (29) respectively.

$$\xi_i = \{\lambda x_i + (Y_i - a)b\}/2\lambda \qquad (27)$$

$$Y_i = a + b\xi_i \qquad (28)$$

$$\sigma_\delta{}^2 \ \{\Sigma(y_i - Y_i)^2 + \lambda\Sigma(x_i - \xi_i)^2\} / \{\lambda(n - 2)\}. \qquad (29)$$

Calculate the following quantities:

$\tau = b\sigma_{\delta}{}^{2}/2S_{xy}$; (30)

$D = 2\lambda b\sigma_{\delta}{}^{2}/nS_{xy}$; (31)

$B = -D\bar{x}(1 + \tau)$. (32)

Calculate the following variances:

the variance, C, of b using the formula

$C = D(1 + \tau)$; (33)

the variance, A, of a using the formula

$$A = D\left\{\bar{x}^2(1 + \tau) + \frac{S_{xy}}{b}\right\};\quad (34)$$

the variance, $\sigma_{\eta}{}^{2}$, of the fitted line at x_L using the formula

$\sigma_{\eta}{}^{2} = A + 2Bx_L + Cx_L{}^{2}$; (35)

the error variance, $\sigma_{\varepsilon}{}^{2}$, for y using the formula

$\sigma_{\varepsilon}{}^{2} = \lambda\sigma_{\delta}{}^{2}$; (36)

the total variance, $\sigma_y{}^2$, for future values, Y_L, for y at x_L using the formula

$\sigma_y{}^2 = \sigma_{\eta}{}^{2} + \sigma_{\varepsilon}{}^{2}$ (37)

Calculate the estimated standard deviation, σ_y, for y_L using the equation

$\sigma_y = (\sigma_{\eta}{}^{2} + \sigma_{\varepsilon}{}^{2})^{0.5}$ (38)

and the predicted value, y_L, for y at x_L using the relationship

$y_L = a + b\,x_L$ (39)

where a and b have the values obtained in accordance with equations (24) and (25).

P.4.6 *Calculation of confidence limits*

Calculate the lower 95 % confidence limit, $Y_{L\,0.95}$, predicted for Y_L using the equation

$y_{L\,0.95} = y_L - t_v\,\sigma_y$ (40)

where

y_L is the value obtained in accordance with equation (39) when x_L is, as applicable, the value in accordance with equation (26) appropriate to a design life of, for example, 50 years [i.e. x_L = 5.6415 (in h)] or to a time at which it is desired to predict with 95 % confidence the minimum value for the next observation of V;

σ_y is the value obtained in accordance with equation (38);

t_v is the applicable value for Student's t for v = n – 2 degrees of freedom, as given in Table 10 which gives the upper 2½ % points.

Calculate the corresponding lower 95 % confidence limit for V using the relationship

$V_{L\,0.95} = 10^{Y_{L\,0.95}}$ (41)

Similarly, the predicted mean value of V at time t_L, i.e. V_L, is given by the relationship

$V_L = 10^{Y_L}$ (42)

where

Y_L is the value obtained in accordance with equation (39).

Table 10 — Percentage points of Student's t distribution
(upper 2½ % points or two-sided 0.05 level of significance or t_v,0.975)

Degrees of freedom $(n-2)$	Student's "t" value t_v	Degrees of freedom $(n-2)$	Student's "t" value t_v	Degrees of freedom $(n-2)$	Student's "t" value t_v
1	12.7062	46	2.0129	91	1.9864
2	4.3027	47	2.0117	92	1.9861
3	3.1824	48	2.0106	93	1.9858
4	2.7764	49	2.0096	94	1.9855
5	2.5706	50	2.0086	95	1.9853
6	2.4469	51	2.0076	96	1.9850
7	2.3646	52	2.0066	97	1.9847
8	2.3060	53	2.0057	98	1.9845
9	2.2622	54	2.0049	99	1.9842
10	2.2281	55	2.0040	100	1.9840
11	2.2010	56	2.0032	102	1.9835
12	2.1788	57	2.0025	104	1.9830
13	2.1604	58	2.0017	106	1.9826
14	2.1448	59	2.0010	108	1.9822
15	2.1315	60	2.0003	110	1.9818
16	2.1199	61	1.9996	112	1.9814
17	2.1098	62	1.9990	114	1.9810
18	2.1009	63	1.9983	116	1.9806
19	2.0930	64	1.9977	118	1.9803
20	2.0860	65	1.9971	120	1.9799
21	2.0796	66	1.9966	122	1.9796
22	2.0739	67	1.9960	124	1.9793
23	2.0687	68	1.9955	126	1.9790
24	2.0639	69	1.9949	128	1.9787
25	2.0595	70	1.9944	130	1.9784
26	2.0555	71	1.9939	132	1.9781
27	2.0518	72	1.9935	134	1.9778
28	2.0484	73	1.9930	136	1.9776
29	2.0452	74	1.9925	138	1.9773
30	2.0423	75	1.9921	140	1.9771
31	2.0395	76	1.9917	142	1.9768
32	2.0369	77	1.9913	144	1.9766
33	2.0345	78	1.9908	146	1.9763
34	2.0322	79	1.9905	148	1.9761
35	2.0301	80	1.9901	150	1.9759
36	2.0281	81	1.9897	200	1.9719
37	2.0262	82	1.9893	300	1.9679
38	2.0244	83	1.9890	400	1.9659
39	2.0227	84	1.9886	500	1.9647
40	2.0211	85	1.9883	600	1.9639
41	2.0195	86	1.9879	700	1.9634
42	2.0181	87	1.9876	800	1.9629
43	2.0167	88	1.9873	900	1.9626
44	2.0154	89	1.9870	1 000	1.9623
45	2.0141	90	1.9867	∞	1.9600

P.5 Example calculation

P.5.1 *Basic data*

The data given in Table 11 together with the example results given in this appendix are for use to verify that any other statistical procedure(s) being used will produce results similar to those obtained from the equations given in **P.4**. Because of rounding errors, it is unlikely that the results will agree exactly, so for the calculation procedure to be acceptable, the results obtained for *r, b, a, V* (mean) and $V_{L\ 0.95}$ shall agree to within ± 0.1 % of the values given in **P.5.3**, **P.5.4** or Table 12, as applicable. The values of other statistics are provided to assist checking of the procedure.

P.5.2 *Sums of squares* (see **P.4.2**)

S_{xx} = 25.53983

S_{yy} = 0.02811

S_{xy} = – 0.79478

P.5.3 *Coefficient of correlation* (see **P.4.3**)

r = – 0.93808 (see **P.5.1**)

Table 11 — Basic data for example calculation and statistical analysis validation

n	*V*	*Y* ($\log_{10}V$)	*t*	*x* ($\log_{10}t$)
			h	h
1	30.8	1.4886	5 184	3.7147
2	30.8	1.4886	2 230	3.3483
3	31.5	1.4983	2 220	3.3464
4	31.5	1.4983	12 340	4.0913
5	31.5	1.4983	10 900	4.0374
6	31.5	1.4983	12 340	4.0913
7	31.5	1.4983	10 920	4.0382
8	32.2	1.5079	8 900	3.9494
9	32.2	1.5079	4 173	3.6204
10	32.2	1.5079	8 900	3.9494
11	32.2	1.5079	878	2.9435
12	32.9	1.5172	4 110	3.6138
13	32.9	1.5172	1 301	3.1143
14	32.9	1.5172	3 816	3.5816
15	32.9	1.5172	669	2.8254
16	33.6	1.5263	1 430	3.1553
17	33.6	1.5263	2 103	3.3228
18	33.6	1.5263	589	2.7701
19	33.6	1.5263	1 710	3.2330
20	33.6	1.5263	1 299	3.1136
21	35.0	1.5441	272	2.4346
22	35.0	1.5441	446	2.6493
23	35.0	1.5441	466	2.6684
24	35.0	1.5441	684	2.8351
25	36.4	1.5611	104	2.0170
26	36.4	1.5611	142	2.1523
27	36.4	1.5611	204	2.3096
28	36.4	1.5611	209	2.3201
29	38.5	1.5855	9	0.9542
30	38.5	1.5855	13	1.1139
31	38.5	1.5855	17	1.2304
32	38.5	1.5855	17	1.2304
Means: $\bar{y}$ = 1.5301; $\bar{x}$ = 2.9305.				

P.5.4 ***Functional relationships*** (see **P.4.4**)

$\lambda = 0.00110$

$b = -0.0331732$ (see **P.5.1**)

$a = 1.62731$ (see **P.5.1**)

P.5.5 ***Calculated variances*** (see **P.4.5**)

$D = 1.51394 \times 10^{-7}$

$B = -4.439287 \times 10^{-7}$

C (the variance of b) $= 1.514858 \times 10^{-7}$

A (the variance of a) $= 4.926316 \times 10^{-6}$

σ_{σ}^2 (the error variance for x) $= 5.27109 \times 10^{-2}$

σ_{ε}^2 (the error variance for y) $= 5.800616 \times 10^{-5}$

P.5.6 ***Confidence limits for estimated values*** (see **P.4.6**)

$n = 32$

$t_v = 2.0423$

The estimated mean values and confidence limits for V at various times are given in Table 12.

Table 12 — Estimated[a] mean values and confidence limits for *V*

Time h	V (mean)	$V_{L\ 0.95}$	$V_{U\ 0.95}$
0.10	45.7597	44 0705	47.5136
1.00	42.3945	40.8421	44.0060
10.00	39.2768	37.8469	40.7608
100.0	36.3884	35.0682	37.7584
1 000	33.7124	32.4905	34.9803
10 000	31.2333	30.0996	32.4095
100 000	28.9364	27.8822	30.0304
438 000	27.5527	26.5453	28.5984

[a] See **P.5.1**.

Appendix Q Guidance on quality control testing and associated sampling

Q.1 General

The following guidance on the nature of the requirements and test methods specified in this standard is provided to assist in the preparation of quality plans for the manufacture of GRP pipes, fittings or joints in accordance with this standard.

Each requirement is classified in Table 13 as being considered particularly suitable for type test and/or inspection test purposes.

Type tests are intended to prove the suitability and performance of the materials and method of construction and the design and size of a GRP pipe, fitting or joint. Such tests should be performed whenever a change is made in any of these characteristics, and without exception for any alteration of the design basis or laminate construction, but they may be performed more frequently by incorporation into a plan for monitoring the consistency of manufacture. A recommended basis for organizing type testing is given in **Q.2**.

Inspection tests are carried out during and/or following manufacture to monitor the quality of product pipes or fittings. Certain test methods and associated requirements have been included because of the practicability and speed with which they may be performed in conjunction with a production process in comparison with some of the type tests. A recommended basis for applying inspection testing is given in **Q.3**.

Table 13 — Applicability of requirements and test methods

Property	Clause	Method	Test type	
			Type test	Inspection test
Material	**3**	Appropriate specification	×	
Effect on potable water	**3.5**	BS 6920	×	
Pipe design limits	**4**	Appendix A, Appendix B, Appendix C, Appendix D, Appendix E and Appendix F	×	
Dimensions				
Diameters	**5.2**, **7.2.1**	Appendix G; BS 2782:1101A	×	×
Lengths	**5.3**	Appendix G; BS 2782:1101A	×	×
Out-of-squareness	**5.4**	Appendix G; BS 2782:1101A	×	
Straightness	**5.5**	Appendix G; BS 2782:1101A		×
Wall thickness	**7.2.2**		×	×
Stiffness	**6.3**	Appendix H	×	×
Appearance	**7.1**	**7.1**	×	×
Initial longitudinal unit tensile strength	**7.3**	Appendix A or Appendix B	×	×
Impact resistance	**7.4**	Appendix J	×	×
Leaktightness	**8.1.1**, **8.1.2**	Appendix K	× ×	× ×
Strain corrosion resistance	**8.2**	Appendix F	×	
Long term specific ring stiffness and creep factor under ring deflection	**8.3**	Appendix L	(×)	
Performance of fittings	**9.1.1**		(×)	
Longitudinal and circumferential tensile strength of fittings	**9.1.2**		×	
Geometrical tolerances for fittings	**9.1.4**		×	×
Effect of joints on potable water	**10.1**	BS 6920	×	
Design performance of flexible joints	**10.2.1**		(×)	
Leaktightness of flexible joints	**10.2.2**	Appendix M	×	×
Design performance of rigid joints	**10.3.1**		(×)	
Leaktightness of rigid joints	**10.3.2**	Appendix N	×	×
Elastomeric joint rings	**10.4**	BS 2494	(×)	
Marking	**11**	—		×

NOTE (×) indicates by inspection of information: no practical test is included in this standard.

Some of the requirements in this standard are relevant to both type and inspection testing, e.g. those for dimensions. Attention is drawn to guidance given in **4.14** of BS 5750-5:1981 concerning possible use of alternative inspection procedures and equipment for production quality control purposes to the methods required by a British Standard specification for establishing the properties of the final product under the conditions specified in the standard. For example, for monitoring of performance properties, measurements of the strain induced by internal pressure may largely suffice (see **Q.3.2**).

Recommendations for arrangements for inspection by or on behalf of the purchaser are given in **Q.4**. Guidance in respect of certification is given in **Q.5** and in the foreword.

Q.2 Type testing

The conduct of type testing may be rationalized by dividing the range of pipework components and joints within the scope of this standard into groups based on the categories given in Table 14, which are selected from the nominal sizes complying with Table 1, pressure ratings in compliance with **6.2** and stiffness classifications in compliance with **6.3**.

A type test group can be any combination selected from each of the 3 categories given in Table 14, e.g.

$100 \leqslant DN \leqslant 800/4 < PN \leqslant 12½/2\ 500 < SN \leqslant 20\ 000$

For groups applicable to the product range, the manufacturer should conduct type tests on pipes representative of each group, the respective results being applicable only to the group from which they are derived.

Q.3 Inspection testing

Q.3.1 ***General***

For pipes for use under pressure, inspection testing should be conducted in accordance with **Q.3.2**, which also describes 3 stages in the establishment of supporting information and a basis for grouping samples by the nominal size unless the results are found to be independent of such groupings. If the components are intended to be suitable for use with septic sewage or aggressive industrial wastes, seel also **Q.3.4**.

For pipes for use with gravity, inspection testing should be conducted in accordance with **Q.3.3**, with reference to **Q.3.2** and **Q.3.4**, as applicable.

For pipes intended for use with septic sewage or aggressive industrial wastes, inspection testing for strain corrosion resistance should be conducted in accordance with **Q.3.4**.

NOTE For fittings fabricated from complete pipes or portions of straight pipe, attention is drawn to **9.1.2**.

Q.3.2 ***Inspection testing for pressure pipes***

Q.3.2.1 *Non-destructive testing.* Every pipe should be checked for the following properties.

a) Wall thickness: all individual pipes for their sentencing as being in or out of specification, and as a control datum (see stage 2 of **Q.3.2.2**).

b) Increase in the outside diameter under a test pressure corresponding to the pressure rating for use as a means of quality control subject to limits determined in accordance with stage 2 of **Q.3.2.2**.

c) Leaktightness: all pipes including joints for their sentencing as being in or out of specification.

Where joints are tested with the pipes and the joint fails, the pipe may be retested with a new joint.

Q.3.2.2 *Stages for establishment of background data.* Three stages are listed as follows.

Stage 1. Determination of the dependence of physical characteristics on internal pressure

The following relationships should be determined.

a) The relationship between glass content, designed strain and measured increase in diameter when subjected to a test pressure of 1.5 times the rated pressure for different groupings of pipes based on Table 14.

b) The relationship of diameter change with pressure according to the different groupings (as in stage 2) with regard to changes in wall thickness.

c) The effect of changes in stiffness of a pipe with the same glass content when subjected to the same test pressure.

Stage 2. Setting of control limits

Limits of control should be set for wall thickness and circumferential strain based on a statistical analysis of data using a minimum of 20 consecutive results. Limits should be capable of being substantiated using normal statistical methods.

Control limits should be reviewed on a regular basis based on the immediately previous production test data using a minimum of 20 and a maximum of 200 results. These reviews should be regular and should not normally be less frequent than monthly subject to 20 results being available and with regard to destructive test results.

Table 14 — Categories for basis of type test sampling groups

Category 1 Nominal size (metric) (DN)	Category 2 Pressure rating (PN)	Category 3 Minimum initial specific stiffness (SN)
	bar	N/m^2
⩾ 100 to ⩽ 800	⩽ 4	⩽ 2 500
> 800 to ⩽ 1 600	> 4 to ⩽ 12½	> 2 500 to ⩽ 20 000
> 1 600 to ⩽ 2 600	> 12½ to ⩽ 25	> 20 000
> 2 600 to ⩽ 4 000		

Confirmatory destructive tests should be made in accordance with stage 3.

It is essential that the upper action limits for strain be within the applicable design limit for strain.

Regular appraisals of the control limits and the performance of the product when subjected to the confirmatory destructive testing should be made.

Stage 3. Confirmatory destructive testing

Destructive tests for performance criteria, stiffness, burst and tensile properties should be performed weekly, to confirm performance. For this purpose, the pipe selected for test should be representative of production, i.e. of the type(s) and class(es) (see Table 14) produced most, and taken at random, subject to the following conditions.

a) Where it can be proven by analysis of the data that the relationship between diameter changes and pressure is not affected by changes across the size classes stated, then the manufacturer may class and batch the pipes in a way convenient to their production process.

b) Quantities of less than 20 pipes can be carried forward to count with the next week's production. However, at least one in every 50 pipes produced should be tested, and at least one pipe in a month's production.

For example, if the production from 1 week provides 50 pipes from group A, 40 pipes from group B and 18 pipes from group C, test those from groups A and B that week, but carry group C's production forward to count with the next week's production. Should any item fail one or more destructive tests, then isolate the batch and test for the property(ies) failed by sampling in accordance with method S of BS 6002, at 2.5 % AQL when using inspection level S-4.

Q.3.3 ***Inspection testing for gravity pipe***

Q.3.3.1 *Non-destructive testing.* Every pipe should be checked for wall thickness for their sentencing as being in or out of specification and as a control datum (see stage 2 of **Q.3.2.2**).

Leaktightness tests at 1.5 bar hydraulic pressure coupled with measurement of strain in accordance with stages 1 and 2 of **Q.3.2.2** should be made weekly on a sampling basis in accordance with BS 6001 or BS 6002 using an AQL of 6.5 % and at inspection level S-3, subject to the following conditions:

a) gravity pipe should be treated separately to pressure pipe;

b) the samples should be representative of the groups given in Table 14;

c) a batch should be one week's production subject to a maximum of 20 pipes being allowed to be carried forward to count with the next week's production for the same class.

Q.3.3.2 *Confirmatory destructive testing.* The testing should be carried out in accordance with stage 3 of **Q.3.2.2**.

Q.3.4 *Inspection testing for strain corrosion resistance*

Pipes intended for use with septic sewage or aggressive industrial wastes should be tested in accordance with Appendix F using one test piece for each lower 95 % confidence limit strain level at the 24 h, 100 h and 1 000 h failure time, as calculated in accordance with **P.4.6**. For the product to be satisfactory there should be no visible internal surface cracking or leakage of fluid before the relevant test period of 24 h, 100 h or 1 000 h has elapsed.

Q.4 Inspection

In addition to the manufacturer's own inspection and supervision, the purchaser or his appointed inspecting authority, should have access at all reasonable times, by arrangement with the manufacturer, to those parts of the works engaged in the manufacture and testing of the pipes to be supplied and all the relevant test records.

Q.5 Certification

The manufacturer should, on request, furnish to the purchaser or purchaser's representative, duplicate copies of a signed certificate stating that the design, construction and testing of the pipes comply with the requirements specified in this standard. If required by the purchaser, the test results or a suitable summary should be provided with the certificate.

In cases of dual responsibility for inspection and testing of pipes, signed documentary evidence of the results of all the completed inspections and tests should be forwarded to the inspecting authority.

NOTE Attention is drawn to information given in the foreword concerning certification.

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[5] Referred to in the foreword only.

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