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Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping —

Part 2: Qualification and manufacture

Industries du pétrole et du gaz naturel — Canalisations en plastique renforcé de verre (PRV) —

Partie 2: Conformité aux exigences de performance et fabrication

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14692-2 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

ISO 14692 consists of the following parts, under the general title *Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping*:

— *Part 1: Vocabulary, symbols, applications and materials*

— *Part 2: Qualification and manufacture*

— *Part 3: System design*

— *Part 4: Fabrication, installation and operation*

Introduction

The objective of this part of ISO 14692 is to enable the purchase of GRP components with known and consistent properties from any source. Main users of the document will be the principal and the manufacturer, certifying authorities and government agencies.

Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping —

Part 2: Qualification and manufacture

1 Scope

This part of ISO 14692 gives requirements for the qualification and manufacture of GRP piping and fittings in order to enable the purchase of GRP components with known and consistent properties from any source.

It is applicable to qualification procedures, preferred dimensions, quality programmes, component marking and documentation.

This part of ISO 14692 is intended to be read in conjunction with ISO 14692-1.

2 Normative references

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

ISO 834-1, *Fire-resistance tests — Elements of building construction — Part 1: General requirements*

ISO 1172, *Textile-glass-reinforced plastics — Prepregs, moulding compounds and laminates — Determination of the textile-glass and mineral-filler content — Calcination methods*

ISO 4901, *Reinforced plastics based on unsaturated polyester resin — Determination of residual styrene monomer content*

ISO 6721-1, *Plastics — Determination of dynamic mechanical properties — Part 1: General principles*

ISO 7822:1990, *Textile glass reinforced plastics — Determination of void content — Loss on ignition, mechanical disintegration and statistical counting methods*

ISO 10467:—[1], *Plastics piping systems for pressure and non-pressure drainage and sewerage — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin*

ISO 10639:—[1], *Plastics piping systems for water supply, with or without pressure — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin*

ISO 11357-2, *Plastics — Differential scanning calorimetry (DSC) — Part 2: Determination of glass transition temperature*

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1) To be published.

ISO 14692-1:2002, *Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping — Part 1: Vocabulary, symbols, applications and materials*

ASTM C177, *Standard test method for steady-state heat flux measurements and thermal transmission properties by means of the guarded-hot-plate apparatus*

ASTM D257, *Standard test methods for DC resistance or conductance of insulating materials*

ASTM D696, *Standard test method for coefficient of linear thermal expansion of plastics between* –*30 °C and 30 °C with a vitreous silica dilatometer*

ASTM D1598, *Standard test method for time-to-failure of plastic pipe under constant internal pressure*

ASTM D1599, *Standard test method for resistance to short-time hydraulic failure pressure of plastic pipe, tubing, and fittings*

ASTM D2105, *Standard test method for longitudinal tensile properties of "fiberglass" (glass-fiber-reinforced thermosetting-resin) pipe and tube*

ASTM D2143, *Standard test method for cyclic pressure strength of reinforced, thermosetting plastic pipe*

ASTM D2412, *Standard test method for determination of external loading characteristics of plastic pipe by parallel-plate loading*

ASTM D2583, *Standard test method for indentation hardness of rigid plastics by means of a barcol impressor*

ASTM D2925, *Standard test method for beam deflection of "fiberglass" (glass-fiber-reinforced thermosetting resin) pipe under full bore flow*

ASTM D2992, *Standard practice for obtaining hydrostatic or pressure design basis for "fiberglass" (glass-fiber-reinforced thermosetting-resin) pipe and fittings*

ASTM D3567, *Standard practice for determining dimensions of "fiberglass" (glass-fiber-reinforced thermosetting resin) pipe and fittings*

ASTM D4024, *Standard specification for machine made "fiberglass" (glass-fiber-reinforced thermosetting resin) flanges*

ASTM D5421, *Standard specification for contact molded "fiberglass" (glass-fiber-reinforced thermosetting resin) flanges*

ASTM E1529, *Standard test methods for determining effects of large hydrocarbon pool fires on structural members and assemblies*

ASTM E2092, *Standard test method for distorsion temperature in three-point bending by thermomechanical analysis*

API Spec 15HR, *Specification for high pressure fiberglass line pipe*

API Spec 5B 14th edition, *Gauging and inspection of casing, tubing, and line pipe threads*

IMO Resolution A 653(16), *Recommendation on improved fire test procedures for surface flammability of bulkhead, ceiling and deck finish materials*

IMO MSC.61(67) *International code for application of fire test procedures (FTP code)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14692-1 and the following apply.

3.1
fire endurance property
ability of an element of the structure or component to continue to perform its function as a barrier or structural component during the course of a fire for a specified period of time

3.2
fire reaction properties
material-related properties concerned with time to ignition, surface flame-spread characteristics including smouldering and post-fire-exposure flaming, and rate of heat, smoke and toxic gas release

4 Symbols and abbreviated terms

For the purposes of this part of ISO 14692, the symbols and abbreviated terms given in ISO 14692-1 apply.

5 Materials of construction and wall thickness limitations

5.1 General

Permissible materials of construction are identified in 5.2 to 5.4. These shall be qualified in accordance with the qualification programme given in Clause 6. Changes in materials of construction require components to be re-qualified in accordance with 6.2.8.

5.2 Fibre

The principal reinforcement material of the component wall shall be glass fibre, e.g. continuous and/or woven rovings. The application of this part of ISO 14692 to pipes manufactured with other reinforcement fibres shall be done with caution and in agreement with the principal.

Other types of fibre reinforcement, such as carbon or aramid fibre, may be used to provide local strengthening within fittings. Such components shall be qualified by survival tests according to 6.2.3.2.2. Use of low electrical resistivity fibres, e.g. carbon, for non-structural purposes to provide electrical conductivity shall be permitted.

NOTE 1 Glass fibre is the preferred reinforcement material because there is little information available about the long-term pressure retention, impact and fire performance of pipes manufactured from other reinforcement materials such as carbon or aramid fibre.

NOTE 2 If significant quantities of carbon are present, either as fibre or filler, it may be necessary to electrically insulate the surface of the component where it could come into contact with adjacent metal components with glass-fibre-reinforced material because of the risk of galvanic corrosion.

5.3 Resin

The manufacture of components shall be limited to thermosetting resins. Typical resins are epoxy, polyester, vinyl ester and phenolic.

NOTE 1 See ISO 14692-1:2002, Clause 6.

Caution shall be applied to the use of fillers within the resin, since these can result in differing properties compared to the base resin, which will affect the long-term performance of the pipe.

The resin shall have a glass transition temperature, T_g, that is greater than or equal to 95 °C. The T_g shall be 30 °C above the standard qualification temperature, which is 65 °C.

The qualification requirements given in this part of ISO 14692 are not applicable to pipe systems that incorporate internal thermoplastic or elastomeric liners.

NOTE 2 The use of a thermoplastic liner will result in change of the failure mode for pressure retention. Such liners also have an influence on the fire endurance and electrostatic properties of the pipe.

Thermosetting resins that incorporate fibres or other filler material may be used as a liner on the inside of the pipe to provide enhanced performance, e.g. wear resistance and electrical conductivity. The liner material shall be compatible with the service conditions.

External coatings may be used to provide thermal insulation, fire resistance or electrical conductivity. However, consideration shall be given to identifying how such coatings affect the ability to detect possible leakage paths through the wall of the component during hydrotesting, or the effect that the additional mass of external coating may have on the overall stress analysis.

5.4 Joints

5.4.1 General

The joints are often the greatest area of concern with regard to the overall integrity of the piping system. The principal types of joint are:

a) adhesive/resin for bonded/laminated joints; and

b) mechanical joints.

The requirements given in 5.4.2 and 5.4.3 apply. The manufacturer shall apply an equivalent level of qualification requirements to new jointing systems that may be developed in the future.

5.4.2 Adhesive/resin for bonded/laminated joints

The adhesive to be used in the factory or field shall be the same as that used in the qualification tests. The adhesive/laminating resin shall have properties suitable for field assembly and shall fulfil the following requirements.

a) The adhesive or laminating resin shall have a suitable viscosity for application at site temperature and humidity conditions.

b) The degree of cure shall be determined in accordance with the procedures given in 6.8.2. The following shall apply, depending on the method used to determine degree of cure:

— the glass transition temperature, T_g, of the cured adhesive or resin shall not be less than 95 % of the minimum value quoted by the manufacturer for the adhesive or resin system, as measured in accordance with 6.8.2.2;

— the styrene content shall be no more than 2 % (mass fraction) of resin content, as measured in accordance with 6.8.2.3;

— the Barcol hardness shall be at least 90 % of the minimum value quoted by the supplier and agreed with the principal, as measured in accordance with 6.8.2.4.

If an alternative method has been used to determine the baseline for degree of cure, then the acceptance criteria for quality control shall be in agreement with the principal.

c) The supplier shall record the test procedures used to determine the adhesive/resin properties.

5.4.3 Mechanical joints

The manufacturer shall ensure that the materials of construction of ancillaries such as O-rings, lubricants, gaskets, mastic and locking strips are suitable for the intended service conditions.

5.5 Wall thickness limitations

The structural calculations given in this part of ISO 14692 are only valid for thickness-to-diameter ratios that are in accordance with Equation (1).

$$\left(\frac{t_r}{D}\right) \leqslant 0{,}1 \qquad (1)$$

where

t_r is the average reinforced thickness of the wall, in millimetres, i.e. excluding liner and added thickness for fire protection;

D is the mean diameter, in millimetres, of the structural portion of the wall.

In order to provide sufficient robustness during handling and installation, the minimum total wall thickness, t_{min}, of all components shall be defined as:

$$\text{For } D_i \geqslant 100 \text{ mm: } t_{min} \geqslant 3 \text{ mm} \qquad (2)$$

$$\text{For } D_i < 100 \text{ mm: } \left(\frac{t_{min}}{D_i}\right) \geqslant 0{,}025 \text{ mm} \qquad (3)$$

where D_i is the internal diameter of the reinforced wall of the component, in millimetres.

For more onerous applications, for example offshore, consideration should be given to increasing the minimum wall thickness to 5 mm.

The minimum wall thickness of the pipe at the joint, i.e. at the location of the O-ring or locking-strip groove, shall be at least the minimum thickness used for the qualified pipe body. Depending on location, the system design pressure and other design factors can significantly increase the required wall thickness.

6 Qualification programme

6.1 General

The qualification programme consists of standard methods for quantifying component performance with respect to static internal pressure, elevated temperature, chemical resistance, electrostatic and fire performance properties, with optional methods for quantifying potable water, impact, low temperature and limited cyclic pressure performance.

The manufacturer is required to determine a qualified pressure p_q, see 6.2.1.1, which is related to the manufacturer's nominal pressure rating p_{NPR} by the expression given in Equation (4).

$$p_{NPR} = f_2 \cdot f_{3,man} \cdot p_q \qquad (4)$$

where

f_2 is a load factor (or safety factor);

$f_{3,man}$ is a factor to account for the limited axial load capability of GRP.

NOTE 1 See 7.2 and 7.10 of ISO 14692-3:2002 for further explanation.

The manufacturer shall provide the values of f_2 and $f_{3,\text{man}}$ used to develop a purchase quotation. Values of f_2 = 0,67 and $f_{3,\text{man}}$ = 0,85 are recommended as a default.

NOTE 2 $f_{3,\text{man}}$ is based on f_3 which is not a fixed parameter and is strongly dependent on the application and qualified pressure of the material.

Components that have been subjected to qualification testing shall not be used as part of a GRP pipeline or piping system.

The qualification programme also includes testing of components in order to provide data for

a) quality control,

b) system design.

NOTE 3 For flat regression curves (see 6.2.1.1) with a regression gradient of less than 0,03 it may not be possible, due to statistical uncertainty in extrapolation, to derive p_q.

6.2 Qualification pressure and temperature

6.2.1 General

6.2.1.1 Pressure terminology and service conditions

Manufacturers shall assign all components a qualified pressure, p_q, expressed in megapascals[2)], as determined according to 6.2.2. The following service conditions apply.

a) The qualified pressure is based on a standard service life of 20 years at a temperature of 65 °C.

b) The effect of operation at other temperatures and chemical degradation from the transported medium shall be accounted for by partial factors A_1 and A_2 in accordance with 6.3.2 and 6.3.3.

c) A minimum test temperature of 65 °C is required for the regression tests and the 1 000 h survival tests.

6.2.1.2 Test requirements

The qualified pressure of all components shall be verified in accordance with the requirements described in 6.2.2. The manufacturer shall document the key factors that define the component to be qualified in accordance with 11.3. These include, but are not limited to:

a) materials of construction,

b) dimensions, including those of joints and ancillaries determined in accordance with ASTM D3567 or other suitable standard,

c) manufacturing processing conditions.

The objective of the qualification procedure is to verify the proposed qualified pressure of each component. Qualification tests are proof tests of specific representatives of a given product family and do not need to be repeated for each order or project. However, changes to any of the product family characteristics detailed in 6.2.8 shall require re-qualification.

The length of test pieces for qualification of pipes and joints shall be in accordance with ISO 10639:—, Table 14 and ISO 10467:—, Table 14.

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2) 1 bar = 0,1 MPa.

Components (fittings or joints) can be tested as either single units or, if appropriate, as assemblies made up with pipe sections in order that the combined integrity of the component and pipe are verified. All joints shall be made up in accordance with the manufacturer's instructions for field assembly as detailed in 11.5. The length of pipe needed to remove the influence of end-fittings when testing assemblies or spool pieces shall not be less than three times the mean structural diameter D of the pipe. For pipes and fittings where the diameter, D, to structural wall thickness, t_r, ratio is greater than 10, then pipe lengths shorter than three times the internal diameter may be used, with a minimum length of 150 mm. The length of pipe shall be determined from Equation (5):

$$L = \left(2 \times t_r \times D\right)^{0,5} \tag{5}$$

where

D is the mean structural diameter of the pipe, in millimetres;

t_r is the average reinforced wall thickness, in millimetres.

All qualification tests shall generally be conducted with unrestrained ends such that the full pressure-induced axial load is borne by the component. An exception is made for systems where the end loads are representative of field loadings, for example by supports. Such circumstances require special considerations, and qualification tests conducted with restrained ends shall be with agreement of the principal.

All tests specified shall be carried out by, or witnessed and certified by, an independent third-party agent approved by the principal. The qualification of each component shall be documented in both a qualification report and a summary as detailed in 11.3.2 and 11.3.3.

6.2.1.3 Component definitions

In order to keep the total test burden within acceptable limits but at the same time to control the use of test data beyond their limits of applicability, the concept of a product family and its subdivisions is used in this part of ISO 14692.

The definitions given in ISO 14692-1:2002 for **product family** (2.2.100)**, product family representative** (2.2.101), **product sector** (2.2.102)**, product sector representative** (2.2.103) and **component variant** (2.2.9) are used in order to rationalize the requirements for qualification testing.

The product family representative is the component that is taken to be representative of that particular product family, i.e. component type where all variants have the same function (e.g. plain pipe, pipe/joint, bend, etc.). For the purpose of this part of ISO 14692, product families shall include, but not be limited to

a) plain pipe,

b) pipe plus joint. The product family of pipe plus joint consists of one type of joint, to be chosen by the manufacturer. The following jointing systems shall be qualified as individual product sectors: adhesive, laminated, flange, elastomeric bell-and-spigot seal lock joint, threaded, and saddles,

c) elbows and reducers, each qualified as individual product sectors,

d) tees,

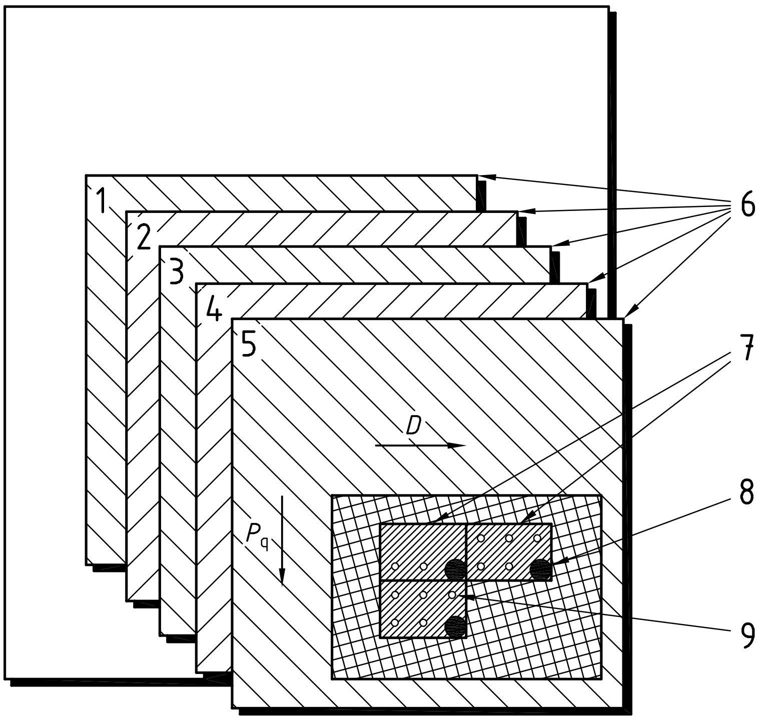
e) flanges,

f) fabrication processes used in the factory or on-site, that are not qualified as part of the process for manufacturing stock items.

A **product sector** is a subdivision of a product family, e.g. 50 mm to 150 mm diameter plain pipe or pipe/joint for pressures less than 5 MPa (50 bar), that groups plain pipes into specific diameter and pressure ranges. A description of the breakdown of a product family into its product sectors is given in Annex A. The size of each product sector shall be limited and should closely match the example given in Table A.1 to provide consistency of information for users. Other size ranges of product sectors with similar intervals between product sector representative diameters, e.g. as given in API Spec 15LR [12], are acceptable.

The **product sector representative** [e.g. 250 mm, 5 MPa (50 bar) pipe] for a product sector is the component variant taken to be representative of that sector and upon which the basic qualification testing is performed.

A **component variant** is an individual component [e.g. 80 mm/3 MPa (30 bar) bend, 100 mm/4 MPa (40 bar) pipe/joint, etc.].



Key

1 elbows
2 tees
3 flanges
4 joints (with pipes)
5 pipes (plain)
6 family representatives
7 product sectors
8 product sector representatives
9 component variants

Figure 1 — Breakdown of a product family into family representatives, product sectors, component variants and product sector representatives

Figure 1 schematically describes the breakdown of product range into the various definitions. A component in a product sector where the product sector representative has not been qualified may be considered qualified if the following criteria are satisfied:

a) the diameter is within 100 mm of a larger component in the adjacent product sector that has itself been qualified by testing, if the diameter of the component to be qualified is less than 400 mm;

b) the diameter is within 200 mm of a larger component in the adjacent product sector that has itself been qualified by testing, if the diameter of the component to be qualified is between 400 mm and 800 mm;

c) the diameter is within 300 mm of a larger component in the adjacent product sector that has itself been qualified by testing, if the diameter of the component to be qualified is between 800 mm and above;

d) the pressure is within 2,5 MPa (25 bar) of a component in the adjacent product sector that has itself been qualified, by testing, to a higher pressure.

6.2.2 Test methodology

The qualified pressure, p_q, for pipes, joints and fittings shall be determined in accordance with 6.2.3 to 6.2.7, where

6.2.3 describes the full qualification procedure, summarized in Table 1,

6.2.4 describes a restricted qualification procedure for low-pressure water applications,

6.2.5 describes qualification by design methods,

6.2.6 describes the further data from qualification tests required for system design (covered in ISO 14692-3),

6.2.7 describes how to translate qualified pressures from the standard design lifetime of 20 years to other design lifetimes.

The apparent ratio of the test pressure compared to the maximum possible design pressure of the component will depend on the method of qualification, see Annex B.

Table 1 — Full qualification procedure for pipes (plus joints) and fittings

Component	Product type	Qualification tests	Purpose
Plain pipe	Family representative[a]	**Full regression test** at 65 °C, or design temperature if higher (ASTM D2992:1996 – Procedure B)	Qualified pressure Qualified stress Gradient
Pipe plus joint, fittings and fabrication processes	Family representative[a]	**Full regression test** at 65 °C, or design temperature if higher (ASTM D2992:1996 – Procedure B) **or Default gradient**	Qualified pressure Baseline gradient for determining survival test pressure
	Product sector representative	Two 1 000-h survival tests at 65 °C, or design temperature if higher (ASTM D1598)	Qualified pressure
	Component variant	Two 1 000-h survival tests at 65 °C, or design temperature if higher (ASTM D1598) **or Scaling method** **or Design method** (in exceptional cases)	Qualified pressure

[a] Only one size of component diameter is required to be tested.

6.2.3 Full qualification procedure

6.2.3.1 Plain pipe qualification (family representative)

This regression qualification procedure determines the long-term hydrostatic pressure (p_{LTHP}) and lower confidence limit (p_{LCL}) in megapascals[1)] of the family representative for plain pipe based on a design life of 20 years. The gradient of the regression curve may also provide input to Table 2 if required. Only one size of pipe diameter is required to be tested. It is permissible for the manufacturer to test a pipe that includes a joint, of his choosing, since the gradient is likely to be more conservative than plain pipe. The qualified pressure, p_q, is equal to the p_{LCL}.

The qualified pressure p_q or p_{LCL} are related to p_{LTHP} through equation (6):

$$p_q = p_{LCL} = f_1 \cdot p_{LTHP} \quad (6)$$

where f_1 provides a measure of the degree of scatter in the long-term pressure tests and is the evaluation of the 97,5 % confidence limit from test data as defined in ASTM D2992:1996, Procedure B.

To generate the regression curve, test details and measurement data in accordance with ASTM D2992:1996 are required. The analysis of the regression data to generate the statistical parameters of the mean, variance of the curves and p_{LCL} should be carried out in accordance with annex K of this part of ISO 14692.

On agreement between the principal and manufacturer, the analysis of the regression data may also be carried out according to ASTM D2992:1996.

NOTE ASTM D2992:1996 contains an error in Equation A1.21 where a factor 2 is missing. The equation should read $\sigma_\varepsilon^2 = 2\lambda\sigma_\delta^2$.

Testing shall be carried out on product with a diameter of 50 mm or larger at, as a minimum, 65 °C or design temperature (if higher than 65 °C). Additional testing may be carried out at other temperatures as required (see 6.3.2). The test procedure to generate the regression curve for the family representative shall be performed or witnessed by a recognized third-party approved by the principal.

The manufacturer may carry out additional testing to determine the p_{LTHP} for the pipe under different combinations of hoop and axial stress to obtain a more comprehensive failure envelope. Further guidance of the procedure is given in Annex C.

The manufacturer shall assign a qualified stress, σ_{qs}, to the pipe in accordance with Equation (7).

$$\sigma_{qs} = p_q \times \frac{D}{2t_r} \text{ MPa} \quad (7)$$

where

p_q is the qualified pressure, in megapascals;

D is the mean structural diameter of the pipe, in millimetres;

t_r is the average reinforced wall thickness, in millimetres.

6.2.3.2 Pipe plus joint qualification

6.2.3.2.1 Family representative

This qualification procedure determines the gradient G, in megapascals per hour, of the family representative for pipe plus joint, see NOTE. The gradient G is used to determine the p_{LCL} based on a design life of 20 years for the product sector representative of the pipe plus joint (6.2.3.2.2). The qualified pressure, p_q, is equal to the p_{LCL}.

NOTE The primary purpose of the joint in this test is to provide a stress concentration on the parent pipe. Therefore the type of joint is less important than the presence of the joint itself.

Experience shows that failure usually occurs in the parent pipe material adjacent to the joint. Only failures in the parent pipe and not the joint shall be included in the regression analysis.

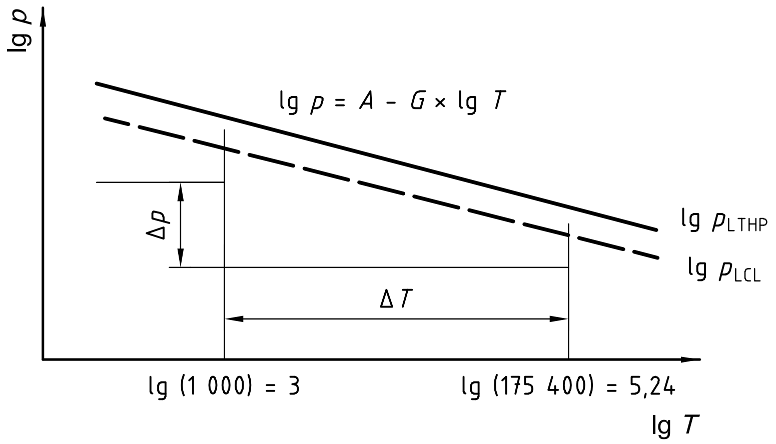
To generate the regression curve, the test details and measurement should be in accordance with 6.2.3.1. In the absence of data for the product family representative, a conservative or default gradient, $G_{default}$, may be used. Default gradients are listed in Table 2 and are based on experience and amount of relevant material data. The default gradient shall only be used for design temperatures up to 65 °C.

Table 2 — Default gradients

$G_{default}$ Plain pipe having regression line with a slope < 0,06	$G_{default}$ Plain pipe having regression line with a slope > 0,06 but < 0,075	$G_{default}$ Plain pipe having regression line with a slope > 0,075
0,075	0,100	0,125
NOTE The unit of gradient is pressure per time. Since the scale is logarithmic, whether the units of measurement are in bar or MPa does not affect the value.		

6.2.3.2.2 Product sector representative

This qualifying procedure permits qualification of the p_{LCL} of the product sector representative based on a design life of 20 years for pipe plus joint based on a 1 000 h survival test. Each type of jointing system shall be qualified as individual product sector, i.e. adhesive, laminated, flange, elastomeric bell-and-spigot seal lock joint, threaded, saddles, etc. The objective of this procedure is to demonstrate that the product sector representative's performance is equal, or superior, to that of the family representative. The qualified pressure, p_q, is equal to the p_{LCL}.



$\lg (T_{P1\,000}) = \Delta p + \lg (p_{LCL})$

$T_{P1\,000} = p_{LCL} \times 10^{\Delta p}$

$\Delta p = G \times \Delta T$

$= G \times [\lg (175\,400) - \lg (1\,000)]$

$= 2{,}24 \times G$

$T_{P1\,000} = p_{LCL} \times 10^{2{,}24 \times G}$

NOTE 20 years is approximately equivalent to 175 400 h.

Figure 2 — Calculation procedure for the 1 000 h test pressure

The 1 000 h test pressure is calculated using either the gradient, G, of the family representative as described in 6.2.3.1, or the default gradient, $G_{default}$, as determined in 6.2.3.2.1. Two replicate samples of the product sector representative shall be selected at random and pressure-tested in accordance with ASTM D1598 at 65 °C or design temperature if higher. The product sector representative is qualified if it survives the test duration, i.e. does not leak, weep, and lose test pressure or structural integrity during the test duration. Figure 2 presents the graphical calculation of test pressure using the regression line for the product family representative. The test duration shall be 1 000 h, but the manufacturer may carry out testing to a longer test duration and lower test pressure commensurate with the calculation procedure given in Figure 2.

NOTE A longer test duration may be desirable if the gradient of the component is significantly steeper than that of the plain pipe.

The 1 000 h test pressure, $T_{P1\,000}$, in megapascals, is calculated from G and is given by Equation (8):

$$T_{P1\,000} = p_{LCL} \times 10^{\,2,24 \times G} \tag{8}$$

If the default gradient, $G_{default}$, is used to determine the 1 000 h test pressure, then the ratio between the 1 000 h test pressure and the p_{LCL} is given in Table 3.

Table 3 — Ratio of $T_{P1\,000}$ hour test to p_{LCL}

$T_{P1\,000/pLCL}$		
$G_{default}$ **= 0,075** MPa (bar)/h	$G_{default}$ **= 0,1** MPa (bar)/h	$G_{default}$ **= 0,125** MPa (bar)/h
0,147 (1,47)	0,167 (1,67)	0,191 (1,91)
NOTE See Table 2 for explanation of default gradient		

6.2.3.2.3 Component variant

This qualifying procedure permits qualification of the p_{LCL} of a component variant for pipe plus joint (same joint type as the product sector representative) based on either a 1 000 h survival test or scaling methods. The objective of this procedure is to demonstrate that the component variant's performance is equal or superior to that of both the product sector representative and the family representative. The qualified pressure, p_q, in megapascals, is equal to the p_{LCL} based on a design life of 20 years.

It is the responsibility of the manufacturer to quote the qualified pressure, p_q, i.e. the p_{LCL} of the component variant, and verify through 1 000 h survival testing that quoted value. The 1 000 h test pressure procedure calculated using either the gradient, G, or the default gradient, $G_{default}$, is described in 6.2.3.2.2. Alternatively, the component variant may be qualified by scaling the results of the product sector representative using the mean diameter of reinforced wall and the reinforced wall thickness of the pipe. However, only components that have a smaller diameter than the product sector representative shall be scaled using this method.

The $(p_q)_{cv}$ of the component variant is given by Equation (9):

$$(p_q)_{cv} = (p_q)_{psr} \times \left(\frac{D}{t_r}\right)_{psr} \times \left(\frac{t_r}{D}\right)_{cv} \tag{9}$$

where

$(p_q)_{cv}$ is the qualified pressure of the component variant, in megapascals;

$(p_q)_{psr}$ is the qualified pressure of the product sector representative, in megapascals;

D is the mean diameter of the reinforced wall of the component, in millimetres;

t_r is the average reinforced wall thickness of the component, in millimetres.

6.2.3.3 Fittings and qualification of other fabrication processes

6.2.3.3.1 Family representative

This qualification procedure determines the gradient G of the family representative for the fitting, e.g. bend, tee, reducer or site-fabrication process. Alternatively, the gradient G of the pipe and joint as described in 6.2.3.2.1 may be used. The minimum gradient for fittings or other site-fabrication processes is set to 0,03 irrespective of the gradient of the pipe and joint.

NOTE The latter option assumes that the joint is the most likely source of failure of the fitting during regression testing.

The qualified pressure, p_q, is equal to the p_{LCL} based on a design life of 20 years. To generate the regression curve, the test details and measurement should be in accordance with 6.2.3.1. In the absence of data for the product family representative, a conservative or default gradient, $G_{default}$ may be used. Default gradients are listed in Table 2. The default gradient shall only be used for design temperatures up to 65 °C.

6.2.3.3.2 Product sector representative

This qualifying procedure permits qualification of the p_{LCL} of the product sector representative for the component based on a 1 000 h survival test. The qualified pressure p_q is equal to the p_{LCL} based on a design life of 20 years. The objective of this procedure is to demonstrate that the product sector representative's performance is equal, or superior, to that of the family representative. It is the responsibility of the manufacturer to quote the p_{LCL} of the product sector representative and verify that quoted value through 1 000 h survival testing in accordance with the procedure given in 6.2.3.2.2. The 1 000 h test pressure shall be calculated using either the gradient, G, of the family representative or the default gradient, $G_{default}$, as described in 6.2.3.3.1.

6.2.3.3.3 Component variant

This qualifying procedure permits qualification of the p_{LCL} of a component variant (same type as the product sector representative) based on either a 1 000 h survival test or scaling methods. The qualified pressure, p_q, is equal to the p_{LCL} based on a design life of 20 years. The objective of this procedure is to demonstrate that the component variant’s performance is equal, or superior, to that of both the product sector representative and the family representative.

It is the responsibility of the manufacturer to quote the qualified pressure p_q, i.e. the p_{LCL} of the component variant, and verify through either 1 000 h survival testing or design calculations that quoted value. The 1 000 h test pressure procedure calculated using the default gradient, $G_{default}$, is described in 6.2.3.2.2. Alternatively, the scaling method qualification procedure may be used as described in 6.2.3.2.3.

6.2.3.3.4 Flanges

Flanges shall be qualified according to either of the following:

— procedures given in 6.2.3.3.1, 6.2.3.3.2 and 6.2.3.3.3 using higher rated gaskets and seals as applicable, provided they are of the same type as specified during service;

— ASTM D4024 for reinforced-thermosetting-resin flanges other than contact-moulded flanges or ASTM D5421 for contact-moulded flanges.

The method of qualification shall be agreed with the principal.

6.2.4 Restricted qualification procedure for low-pressure water applications

For low-pressure water service applications, the following qualification procedure based on the short-term burst tests may be applied. Low pressure based on the qualified pressure is defined as a function of diameter in Table 4.

Table 4 — Low-pressure application as a function of diameter

Pipe diameter mm	Qualified pressure MPa (bar)
25 to 600	1,2 (12)
600 to 1 200	0,6 (6)
$>$ 1 200	0,3 (3)

This procedure permits qualification of a product sector representative or component variant's qualified pressure p_q based on its p_{STHP}.

The option makes a conservative estimate of the qualified pressure p_q based on the p_{STHP} and an empirical de-rating factor, Z. The p_{STHP}, in megapascals, of the component variant shall be determined using either of the following two methods:

a) by testing five replicate samples in accordance with ASTM D1599. The p_{STHP} of the representative product shall be taken as the lower deviated (two standard deviations) value of the five replicate samples;

b) by taking 85 % of the lower of two replicate samples tested in accordance with the test procedures given in ASTM D1599.

Testing shall be at SLT (Standard Laboratory Temperature). The rated temperature for a component qualified by this option shall not exceed 65 °C. See also 5.3 with respect to minimum required resin T_g.

NOTE Experience shows that burst-testing at SLT gives a conservative result as compared to that at 65 °C.

The qualified pressure, p_q, in megapascals, shall satisfy the criterion in Equation (10):

$$p_q = \frac{p_{STHP}}{Z} \tag{10}$$

Values of Z shall be taken from Table 5. These values are based on experience, manufacturing process, amount of relevant material data and chosen default regression gradient. See Table 2 to determine default gradient.

Table 5 — Values for empirical factor Z (up to 65 °C only)

$G_{default}$ **= 0,075**	$G_{default}$ **= 0,1**	$G_{default}$ **= 0,125**
2,68	3,35	4,02

6.2.5 Qualification using design methods

For certain component variants, it may be impractical to qualify the component using the test methods given in 6.2.3 and 6.2.4 because of the proportionally high unit cost of the component.

For limited applications, components may be qualified using design methods proposed by the manufacturer. Design methods shall be checked and approved to the satisfaction of the principal.

6.2.6 Further data required for system design

For pipes, joints and fittings, the manufacturer shall assign a value r for the short-term biaxial strength ratio to the family representative. This value of r is required for system design in ISO 14692-3 and is defined as:

$$r = 2 \times \frac{\sigma_{sa(0:1)}}{\sigma_{sh(2:1)}} \tag{11}$$

where

$\sigma_{sh(2:1)}$ is the short-term hoop strength, in megapascals, which shall be calculated according to Equation (12):

$$\sigma_{sh(2:1)} = p_{STHP} \times \frac{D}{2t_r} \tag{12}$$

where

D is the mean diameter of the reinforced wall of the family representative, in millimetres;

t_r is the average reinforced wall thickness of the family representative, in millimetres;

p_{STHP} is the short-term hydrostatic test pressure, in megapascals, determined in accordance with the method given in 6.2.4;

$\sigma_{sa(0:1)}$ is the short-term axial strength in megapascals, of the component, manufactured with no liner, determined using either of the following two methods:

a) by testing five replicate samples in accordance with ASTM D2105 at SLT. The $\sigma_{sa(0:1)}$ of the family representative shall be taken as the lower deviated (two standard deviations) value of the five replicate samples;

b) by taking 85 % of the lower of two replicate samples tested in accordance with the test procedures given in ASTM D2105 at SLT.

For some fittings, it is not practicable to determine a value of r by testing, and the manufacturer should assign a value according to the principles given in 7.11.4 of ISO 14692-3:2002.

6.2.7 Design lifetimes other than 20 years

The standard or default lifetime of components for this part of ISO 14692 is 20 years. To convert the qualified pressure, p_{LCL} (20 years), as derived in this qualification procedure to a qualified pressure at a different lifetime, p_{LCL} at T years, use is made of Equations (13) and (14):

$$p_{LCL}\text{ (20 years)} = p_{LCL}\text{ (}T\text{ years)} \times 10^{\Delta p} \tag{13}$$

$$\Delta p = G \times [1{,}3 - \lg(T)] \tag{14}$$

where G is the appropriate gradient of the regression line, megapascals per hour, for the component variant of interest.

6.2.8 Requalification

6.2.8.1 General

Changes to a component by an amount beyond that agreed with the principal shall invalidate the component's previous qualification, as defined in accordance with 6.2.1.2 and 6.2.1.3. Examples of changes in component design which require requalification are defined in Table 6.

Components shall be requalified in accordance with the requirements of 6.2.3.2.2, 6.2.8.2 and 6.2.8.3. If the performance is outside limits, then the modified component shall be deemed to be a new product and it shall be qualified in accordance with 6.2.3. If components have been qualified by short-term burst testing, the requalification shall be in accordance with 6.2.4 in place of 6.2.3.2.2. The p_{STHP} of the requalified component shall not be less than the p_{STHP} established in qualification testing.

The qualification reports and summaries of each such revalidated variant shall be amended to include reference to this revalidation and details.

6.2.8.2 Systematic changes to all product sectors

If a change as defined by Table 6 has been made systematically to all product sectors, then the qualification of those product sectors shall be group-revalidated by requalifying a single product sector representative for each product family, e.g. bend or joint, to be proposed by the manufacturer and agreed with the principal in accordance with 6.2.3.2.2.

6.2.8.3 Changes to a single product sector

If a change as defined by Table 6 has been made systematically to all previously qualified component variants of a particular type in a product sector, then the qualification of those variants may be group-revalidated by requalifying the product sector representative (i.e. of that type and product sector) in accordance with 6.2.3.2.2.

Table 6 — Changes in component design requiring requalification

Reinforcement	— reinforcement manufacturer — reinforcement manufacturing process — reinforcement type and composition — reinforcement finish (sizing) — filament diameter — tow tex
Resin and adhesive	— resin/adhesive manufacturer — curing system supplier — quantity and type of fillers and additives, e.g. for electrical conductivity — curing temperature — curing schedule — resin/adhesive grade — curing system type
Internal surface	— composition — curing schedule/temperature — thickness
Design	— geometry and dimensions, including that of the jointing detail — winding angle (> ± 5 %) — reinforcement mass — mass fraction (> ± 5 %)
Manufacturing plant	— transfer of manufacture of a qualified product from one plant to another

6.3 Effect of temperature and chemical resistance

6.3.1 General

The manufacturer shall provide partial factors, A_1 and A_2, which respectively account for the reduction in performance capability caused by long-term exposure to temperatures above 65 °C and chemicals other than water.

The procedures for determining A_1 and A_2 are given in 6.3.2 and 6.3.3.

6.3.2 Partial factor for temperature

The manufacturer shall provide partial factor A_1 as a function of temperature. This shall take account of the effect of temperature on ancillaries such as O-rings, locking strips, etc. where applicable.

Generally pipe components qualified in accordance with 6.2 shall be qualified for operation at all temperatures, up to and including 65 °C, and A_1 shall be equal to 1,0.

If additional regression data measured in accordance with ASTM D2992 are available at temperatures other than 65 °C, it shall be permissible to interpolate between the two sets of data to determine the partial factor A_1.

NOTE Under some circumstances, for example where data are obtained at temperatures less than 65 °C, it may be possible for A_1 to exceed 1,0.

The maximum allowable design temperature shall be less than the T_g of the resin used in the qualified component. The difference between allowable design temperature and T_g is specified in 6.8.2.2.

Guidance on alternative means for determining partial factor A_1 is given in Annex D. The method for determining partial factor A_1 shall be agreed with the principal.

6.3.3 Partial factor for chemical resistance

A suitable means for quantifying the reduction in performance is by carrying out regression testing according to ASTM D2992 with the chemical medium at the design temperature. However, this may not be practicable; if so, partial factor A_2 has to be determined by other means. Guidance on alternative means for determining partial factor A_2 is given in Annex D. The method for determining partial factor A_2 shall be agreed with the principal.

6.4 Optional qualification requirements

6.4.1 General

In addition to the qualification requirements of 6.2, components shall also be qualified for the following requirements when specified by the principal.

6.4.2 Potable water certification

Piping shall comply with the requirements of the national health or certifying authorities in the country of use.

6.4.3 Impact resistance

The manufacturer shall demonstrate that the pipe is capable of withstanding the impact from a low velocity 5 J impact representative of a dropped tool. There shall be no leakage of water when the pipe is subject to a 1 000 h survival test.

The size of the pipe shall be the same as that of the family representative originally qualified. The test shall be carried out under the following conditions:

a) 1 m length of empty pipe, i.e. not filled with liquid, laid on a firm flat surface;

b) a weight of 0,5 kg with a hemispherical indentor geometry of radius 12 mm shall be dropped from 1 m height;

c) the pipe shall then be subjected to the 1 000 h survival test in accordance with 6.2.3.2.2.

6.4.4 Low temperature performance

The manufacturer shall demonstrate that the pipe is capable of performing satisfactorily at low temperatures. Both qualification as well as additional mechanical tests should be considered and agreed with the principal.

6.4.5 Limited cyclic qualification testing (7 000 cycles)

The ability of components nominally qualified for static pressure ratings to also withstand limited cyclic service shall be demonstrated by limited cyclic pressure-testing of their representative product.

In this qualification test, two replicate samples shall be tested under nominally identical pressure loadings. Testing shall be at SLT (23 °C ± 2 °C). The test fluid may be water. The results may be reported alone, or included in the qualification report.

Wherever practicable, the standard cycling rate of (25 ± 2) cycles per minute as per ASTM D2143 shall be used. If this cannot be maintained then a slower rate is acceptable, so long as the actual rate used is monitored and recorded in the qualification test report. Each test pressure cycle shall range between not more than 10 % and not less than 90 % of the qualified pressure, p_q, agreed with the principal. A failure within 7 000 pressure cycles is unacceptable.

6.5 Fire performance

6.5.1 General

Fire performance is characterized in terms of the following properties:

a) fire endurance (see 3.1);

b) fire reaction (see 3.2).

All fire testing, if required, shall be conducted on each piping material system. If appropriate, the testing shall take account of the effect of weathering and ageing on the fire performance of the pipe, particularly if coatings are used to provide fire protection.

The performance of piping systems shall be qualified in accordance with the procedures given in 6.5.5 and 6.5.6 and assigned a classification code in accordance with 6.5.2. The fire testing shall be performed at a nationally accredited laboratory that is acceptable to the authority having jurisdiction to verify that the results for all the relevant performance parameters have achieved the defined test standards.

6.5.2 Fire classification code

The fire performance of a pipe system shall be defined according to the fire classification code A-B-C/xxx-(D-E), see also F.7 of ISO 14692-3:2002, in terms of service conditions, severity of fire threat and duration.

The fire endurance classification code is designated by a three-field number A - B - C as given in Table 7, where service function A, fire type B and integrity C are assigned prescribed levels in decreasing order of severity. For completeness, the fire classification code includes some service conditions, A, which may be outside the scope of this part of ISO 14692.

The /xxx parameter is the duration over which the pipe is qualified to function under the fire and service conditions.

The fire reaction classification code is designated by a two-field number as given in Table 8, where spread of fire and heat release D, and smoke and toxicity E, are assigned prescribed levels in decreasing order of severity.

6.5.3 Manufacturer and system identification

Any testing performed shall include the full description of the manufacturer's name and unique product code, including any details of fire protection applied.

6.5.4 Requalification

Changes to the design pressure, joint or fitting design and other generic properties of a component, e.g. fire-protection coating, resin type, wall thickness, fibre volume fraction, lay-up angle, etc. as defined in Table 6 shall invalidate the component's previous qualification.

Such components shall require requalification in accordance with 6.5.5 or 6.5.6.

6.5.5 Fire endurance tests

Pipe components shall be tested in accordance with Annex E at an independent third-party laboratory, acceptable to the authority having jurisdiction. This applies to all pipe, fittings, system joints intended to be used (including joints between non-metal and metal pipes and fittings), methods of joining, and any internal or external liners, coverings and coatings required to comply with the performance criteria.

The test conditions and size of pipe components to be tested shall be in agreement with the principal and authority having jurisdiction. Further guidance on size of pipe component to be tested and the factors that determine fire test requirements is given in E.7 and Annex F of ISO 14692-3:2002.

Tested components shall be assigned a fire classification code in accordance with Table 7.

NOTE The fire test procedures given in Annex E are consistent with the IMO type testing requirements given in [1].

6.5.6 Fire reaction tests

6.5.6.1 General

If GRP systems are fabricated from a generic type of material, it is sufficient to test the material rather than complete assemblies. Pipe components shall be tested at an independent third-party laboratory, acceptable to the authority having jurisdiction. Testing need not be conducted on every pipe size.

Testing should be conducted on piping sizes with the maximum and minimum wall thicknesses intended to be used. This will qualify all piping sizes for a specific piping material, provided that the wall thickness falls within the tested range.

6.5.6.2 Surface spread of flame and heat release

Surface spread of flame and heat release shall be evaluated in accordance with IMO Resolution A653(16) modified in the manner of F.1 to take account of the curved surface of the pipe.

6.5.6.3 Smoke obscuration and toxicity

Smoke emission, obscuration and toxicity shall be evaluated in accordance with Annex 1, Part 2 of IMO MSC.61(67) modified in the manner of F.2 to take account of the curved surface of the pipe.

Table 7 — Classification code for fire endurance properties

A: Service (Fluid or fluid state)		B: Fire type		C: Integrity/Duration see Notes 1 and 2	
DE	Dry or empty.	JF	Jet Fire	EA	Capable of maintaining the test pressure without leakage during or after test.
DF	Initially dry/empty for minimum of 5 min followed by flowing water (linear velocity ⩽ 1 m/s)	HF	Hydrocarbon Pool Fire	EB	No leakage during fire test except a slight weeping may be accepted. Capable of maintaining the test pressure after cooling without significant leakage, i.e. not exceeding 0,2 l/min for a minimum of 15 min.
ST	Stagnant water	IF	Impinging flame	EC	Minimal or no leakage (⩽ 0,5 l/min) during fire test. Capable of maintaining the test pressure after cooling with known leakage (leakage rate per metre length of pipe to be quantified in each case)
SF	Initially stagnant for minimum of 5 min followed by flowing water (linear velocity ⩽ 1 m/s)	CF	Cellulosic fire	ED	Leakage permitted (⩾ 0,5 l/min) during fire test. Capable of maintaining the test pressure after cooling with known leakage (leakage rate per metre length of pipe to be quantified in each case)
WF	Flowing water (linear velocity ⩽ 1 m/s)			EE	Leakage permitted (⩾ 0,5 l/min) during fire test. Pressure that can be maintained after cooling with known leakage to be quantified.
FG	Flammable gas			EF	No endurance required
HL	Hydrocarbon liquid				
OC	Other chemical				

NOTE 1 The indicator for duration shows the test period in minutes, e.g. / 120: greater than 2 h.

NOTE 2 The test pressure shall be the design pressure p_d. Where p_d is not known, the test pressure shall be $p_{d,\ max}$ which is $0{,}67 \times p_q$, where p_q is the qualified pressure.

Table 8 — Classification code for fire reaction properties

D: Spread of fire and heat release		E: Smoke and toxicity	
1	No spread of fire permitted	1	No emissions of smoke or toxicity permitted
2	Representative of confined areas where spread of flame is required to be limited and satisfy: IMO Resolution A.653(16) $Q_{\text{CFE}} > = 20{,}0$ kW/m^2, $Q_{\text{sb}} > = 1{,}5$ MJ/m^2 $Q_{\text{t}} < = 0{,}7$ MJ, $q_{\text{p}} < = 4{,}0$ kW	2	Representative of confined areas where levels are required not to exceed: IMO MSC.61(67) (Part 2 of Annex 1) $D_{\text{m}} < 400$ CO $< 1\,450$ µg/g, HCl < 600 µg/g, HCN < 140 µg/g, HF < 600 µg/g, $NO_x < 350$ µg/g, HBr < 600 µg/g, $SO_2 < 120$ µg/g
3	Representative of areas where spread of flame is required to be limited and quantified using the procedures in: IMO Resolution A.653(16)	3	Levels are required to be quantified and acceptable within evacuation time IMO MSC.61(67) (Part 2 of Annex 1)
4	No spread of fire requirement	4	Representative of open-area levels where there is no requirement for smoke obscuration or toxicity
Where Q_{CFE} is the critical heat flux at extinguishment Q_{sb} is the heat for sustained burning Q_{t} is the total heat release q_{p} is the peak heat release		Where D_{m} is the average optical density	

6.6 Electrical conductivity and electrostatic dissipative properties

6.6.1 General

This subclause provides the requirements for determining the electrical conductivity and electrostatic dissipative properties of GRP pipe components.

NOTE This information is used by the system designer to determine the distance between earth-bonding points and to demonstrate that charge cannot accumulate on the pipe to produce an incendive discharge. The factors determining the requirements for electrical conductivity, electrostatic dissipative properties and resistance to earth of GRP piping components are discussed in Annex G of ISO 14692-3:2002.

All testing, if required, shall be carried out on each piping material system. If appropriate, the testing shall take account of the effect of weathering and ageing on the electrical properties of the pipe. The effect of coatings for fire protection and insulation, etc. which may have different electrical properties shall also be taken into account.

Components shall satisfy one or more of the requirements given in 6.6.3.1 to 6.6.3.6 and be assigned a classification code in accordance with 6.6.2. The electrical properties shall be effective over the design life and shall not be impaired by normal service, handling or installation. The testing of at least one product sector representative of each product family shall be performed at a nationally accredited laboratory that is acceptable to the authority having jurisdiction to verify that the results for all the relevant performance parameters have achieved the defined test standards. The choice of product sector shall be agreed with the principal and authority having jurisdiction. Other product sectors may be tested in-house in the presence of an independent third party acceptable to the principal and authority having jurisdiction.

6.6.2 Classification code for electrical conductivity and electrostatic dissipative properties

The electrical properties for pipe system components shall be defined according to the following two-field classification code, X/Y, in which performance, X, is assigned prescribed levels in decreasing order of conduction properties as shown in Table 9. The Y indicator has a value of 1 if the joint can be demonstrated to satisfy the continuity requirements defined in G.6, and a value of 0 (zero) if continuity cannot be satisfied.

For example, the code C3/0 means that the component meets the C3 classification requirement but there is no continuity of conduction across the joint. A C1/1 code means that the pipe meets the C1 classification requirement and is electrically conductive across the joint. The effect of pipe construction on the electrical properties is discussed in 6.6.4.

GRP pipe system components that are designed to be electrically conductive should meet the classification code requirements of C1a, C2a or C3. Codes C4, C5 and C6 provide performance parameters that can be used as input to a risk assessment and are intended for use with GRP pipe system components that were not designed to be electrically conductive. The classification codes C7 and C8 allow the use of pipe components that do not meet the requirements of C1 to C6 on a case-specific basis if agreed with the principal and authority having jurisdiction.

Some components may have more than one classification code, e.g. C3 and C6. Those components complying with codes C1 and C2 will automatically comply with the requirements for codes C3, C4, C5 and C6.

6.6.3 Test requirements

6.6.3.1 The component shall have a resistance per length not to exceed 1×10^5 Ω/m when tested from the outside to outside-surface or earth-bonding clamp mode of the component at 100 V or less, in accordance with G.2. If components are homogeneously conducting within a layer at constant radius and can be shown to satisfy the requirements of this clause without the use of grounding clamps, it shall not be necessary to carry out tests 6.6.3.3, 6.6.3.4 or 6.6.3.5 and the material shall be classified as C2a. If components can be shown to satisfy the requirements of this clause only with the use of grounding clamps, the material shall be classified as C4. If components can only achieve a C2 classification between 100 V and 1 000 V, the component shall be classified as C2b.

NOTE A maximum voltage of 100 V or less ensures that only resin coatings on the outside that are intended to be conductive pass the test. The C2b classification at 1 000 V takes into account the benefit to be gained from voltage breakdown of thin resin coatings at 1 000 V or more for installed components, as allowed in 5.5.4.4 of ISO 14692-4:2002.

6.6.3.2 The component shall have a resistance per length not to exceed 1×10^5 Ω/m when tested in the inside to outside-surface or earth-bonding clamp mode of the component at 100 V or less, in accordance with G.2. If components are homogeneously conducting within a layer at constant radius and can be shown to satisfy the requirements of this clause, it shall not be necessary to carry out test 6.6.3.3 and the material can be classified as C1a. If components can only achieve a C1 classification between 100 V and 1 000 V, the component shall be classified as C1b.

NOTE A maximum voltage of 100 V or less ensures that only resin coatings on the inside that are intended to be conductive pass the test. The C1b classification at 1 000 V takes into account the benefit to be gained from voltage breakdown of thin resin coatings at 1 000V or more for installed components, as allowed in 5.5.4.4 of ISO 14692-4:2002.

6.6.3.3 The component shall have a maximum induced voltage on the exterior surface of the pipe not to exceed 2 % of the supply voltage when tested in accordance with G.3 (charge-shielding test). An alternative acceptance criterion is acceptable if agreed with the principal and authority having jurisdiction. Components satisfying this criterion and having a resistance per length not exceeding 1×10^5 Ω/m when tested with or without earthing clamps shall be classified as C3.

Pipes that cannot meet C1a but can meet C1b shall be re-classified as C1a if it is not possible to sustain the 1 000 V charge inside the pipe because of conduction to earth through the pipe wall.

Table 9 — Classification code of electrical properties

Code	Required electrical properties
C1 a	resistance per length less than 1×10^5 Ω/m when tested in the inside to outside-surface or earth bonding clamp mode at 100 V or less in accordance with G.2 (see 6.6.3.2) **and** meets the requirements for C3
C1 b	resistance per length less than 1×10^5 Ω/m when tested in the inside to outside-surface or earth bonding clamp mode at 1 000 V or less in accordance with G.2 (see 6.6.3.2) **and** meets the requirements for C3
C2 a	resistance per length less than 1×10^5 Ω/m when tested in the outside to outside-surface mode at 100 V or less in accordance with G.2 (see 6.6.3.1)
C2 b	resistance per length less than 1×10^5 Ω/m when tested in the outside to outside-surface mode at 1 000 V or less in accordance with G.2 (see 6.6.3.1)
C3	maximum induced voltage on the exterior surface of the pipe of less than 2 % of the supply voltage when tested in accordance with G.3 (see 6.6.3.3) **and** meets the requirements for C4
C4	resistance per length less than 1×10^5 Ω/m when tested in the earth-bonding clamp to earth-bonding clamp mode at 100 V or less in accordance with G.2 (see 6.6.3.1)
C5	surface resistivity less than 1×10^9 Ω when determined accordance with ASTM D257 (see 6.6.3.5)
C6	surface charge decay properties shall meet requirements of G.4 (see 6.6.3.4)
C7	quantified conductivity data available that do not fully comply with C1 to C6
C8	quantified conductivity data available that do not comply with C1 to C6
C9	non-conductive

NOTE This test addresses the situation where the source of charge generation is on the inside of the pipe, for example due to flow of a fluid of low conductivity within the pipe. It is an alternative to 6.6.3.2 for components that do not have a radial conducting path through the wall of the pipe. The intent of the test is to demonstrate that a voltage of no more than 1 kV can be induced on the outside of the pipe. For the purposes of the test, it is assumed that the maximum voltage that can be generated by flow inside the pipe is 50 kV.

6.6.3.4 Components shall satisfy the charge-decay classification C6 if either of the following criteria is met when the test piece is tested in accordance with G.4 (charge-decay test).

— The absolute peak voltage on the surface of the pipe is less than 1 kV or 1 % of the absolute corona voltage, whichever is smaller;

or

— the decay time, initial peak voltage to 1/e (37 % of this), is less than 0,5 s.

An alternative acceptance criterion is acceptable if agreed with the principal and authority having jurisdiction. When determining an alternative decay-time criterion, the charge-decay rate should be faster than the charge-accumulation rate.

NOTE This test determines whether the outside of the pipe component is electrostatically dissipative.

6.6.3.5 The component shall have a surface resistivity less than 1×10^9 Ω when determined in accordance with ASTM D257. Components satisfying this criterion shall be classified as C5.

6.6.3.6 If the continuity at the joint has not already been demonstrated in accordance with G.2, the continuity of the electrical path at joints shall be demonstrated according to the procedure given in G.6. If the joint can be demonstrated to satisfy the continuity requirements defined in G.6 the Y indicator of the classification code shall have a value of 1. Otherwise, the Y indicator shall have a value of 0.

6.6.4 Effect of pipe construction on testing requirements

The electrical properties of the piping system are determined by the construction detail of the individual components. Components may be of four types:

— plain GRP where no additional measures have been taken to enhance the electrical conduction or electrostatic dissipative properties;

— components that incorporate a network of discrete conductive elements within the wall of the pipe;

— components that have a conductive resin through the wall of the pipe;

— components that have a conductive coating painted on the outside.

If discrete conductive elements are used to provide electrical conductivity, they shall be uniformly distributed around the circumference and length of the pipe component. There should be no electrically isolated conductors such that they cannot be connected to earth in the normal manner using a grounding clamp. In particular, there shall be no direct-current path from the inside to the outside of the pipe by electrically isolated conductive filaments. The number of product sectors for each component required to be qualified will be influenced by the spacing apart of the conductive filaments in the wall of the component. A single test may qualify all sizes of each component type that have the same or smaller spacing of conductive filaments. Additional tests should be carried out on components that have the conductive filaments spaced further apart.

NOTE Components that incorporate a network of conductive filaments may have a surface layer with high electrical resistivity that prevents the component from satisfying the requirements of 6.6.3.1.

If a coating is applied on the outside, the manufacturer shall provide evidence of the durability of the coating.

Some GRP materials may take on a permanent increase in electrical conductivity properties when exposed to a marine environment. If required, G.5.3 includes provision to enable the change in electrical properties to be determined after the specimen has been immersed in seawater for up to 12 months.

If components have a conductive coating painted on the outside, the maximum uncoated area on the painted surface applied under factory conditions shall be 10 cm^2. The coating shall be effective over the design life and shall not be impaired by normal service, handling or installation.

6.7 Additional component properties

If applicable, the manufacturer shall perform one or more of the following tests in order to determine values for the following properties for each plain pipe family product representative:

a) long-term failure envelope of pipe, determined in accordance with Annex C at 65 °C or higher;

NOTE If data for the plain pipe are not available, data for pipe/joint may be used instead.

b) short-term axial strength, determined in accordance with ASTM D2105 at SLT;

c) axial tensile modulus, determined in accordance with ASTM D2105 at SLT;

d) axial bending modulus, determined in accordance with ASTM D2925 at SLT;

e) hoop tensile modulus and Poisson's ratio, determined in accordance with API 15HR at SLT;

f) hoop bending strength and modulus, determined in accordance with ASTM D2412 at SLT;

g) Poisson's ratio for an axial tensile load and the resulting hoop contraction, determined in accordance with ASTM D2105 at SLT but modified in order to measure hoop contraction;

h) thermal coefficient of expansion in the axial direction, determined in accordance with ASTM D696;

i) thermal conductivity of component and protective coatings, determined for the radial direction in accordance with ASTM C177;

j) density of component.

Full background data for all the tests shall be made available upon request.

6.8 Component data for quality control baseline

6.8.1 General

The manufacturer shall generate, from the qualification programme, baseline values including acceptance criteria for the fabrication and installation quality control programme.

6.8.2 Degree of cure

6.8.2.1 General

The preferred method for determining the degree of cure of either the base resin or component is by measurement of the glass transition temperature in accordance with 6.8.2.2. The degree of cure may also be determined in accordance with 6.8.2.3 or 6.8.2.4. The manufacturer may propose an alternative procedure for assessing the state of cure subject to agreement with the principal, for example from the deflection temperature under load determined in accordance with ISO 75. The choice of procedure and whether a component or the base resin is used shall seek to provide the most appropriate baseline for assessing the degree of cure of produced components during quality control.

If the baseline is taken from a component, three samples shall be taken from three locations situated 120° apart in the same component variant cross-section. The samples used to determine the degree of cure shall be taken from a component variant used in the qualification test programme, 6.2.

6.8.2.2 Glass transition temperature (T_g)

The glass transition temperature (°C) shall be determined by one of the following means as appropriate:

— DSC (differential scanning calorimetry) according to ISO 11357-2;

— MDSC (modulated differential scanning calorimetry) as agreed between the manufacturer and principal;

— DTMA (dynamic mechanical thermal analysis) according to ISO 6721-1;

— HDT (heat distortion temperature according to ASTM E2092.

The T_g shall be more than 30 °C above the maximum design temperature if measured by DSC, MDSC or DTMA.

The T_g shall be more than 20 °C above the maximum design temperature if measured by HDT.

6.8.2.3 Residual styrene monomer content

For polyester and vinyl ester-based products, the residual styrene monomer content for joints in components used in qualification testing may be determined. The measurement shall be performed according to ISO 4901. The residual styrene content shall not be above 2 % (mass fraction) of the resin content.

6.8.2.4 Barcol hardness

Barcol hardness testing shall be carried out in accordance with ASTM D2583. It is recommended that a minimum of ten readings be taken on each sample. The two highest and two lowest readings may be discarded, with the remaining six to be used to calculate an average reading.

NOTE Because the material being tested is a composite, it is not uncommon for there to be a wide range between high and low readings. Factors that can affect the Barcol hardness reading include whether the tester impacts reinforcing glass, whether the tester impacts a topcoat of resin or wax or if it impacts gelcoat. A low reading may be obtained if the tester impacts surfacing veil.

6.8.3 Optional short-term burst tests

Short-term burst tests provide an alternative means for monitoring component quality.

The principal and manufacturer shall agree on the type of specimen chosen to be representative of the qualified component. As a minimum similarity, the specimen shall be manufactured using the same reinforcement and resin of the qualified component that is required to be monitored.

The baseline pressure p_{STHP} of the specimen shall be determined according to the procedure given in 6.2.4.

6.8.4 Glass, void and water contents

The glass content (percentage of fibreglass reinforcement) of the reinforced wall thickness of the qualified component shall be determined in accordance with ISO 1172. Three samples shall be taken from three locations situated 120° apart in the same component variant cross-section. The samples used to determine the glass content shall be taken from a component variant used in the qualification test programme, 6.2.

The void content and water content of phenolic resin qualified components shall also be determined in accordance with procedures agreed with the principal.

6.8.5 Key component dimensions

The manufacturer shall establish the following baseline dimensions of the qualified component in accordance with ASTM D3567:

a) internal diameter, d_{ID};

b) outside diameter, d_{OD};

c) mass;

d) minimum wall thickness, t_{min};

e) average of the reinforced wall thickness, t_{r};

f) laying length.

7 Preferred dimensions

7.1 Nominal diameters

The nominal diameter, in millimetres, of pipes and fittings should be chosen from the sizes listed in Table 1 of ISO 7370:1983 or as agreed between the manufacturer and principal.

7.2 Bend radii

The standard bend radius should be 1,5 times the nominal diameter, but other sizes are acceptable with agreement of the principal.

7.3 Fitting lengths

The preferred maximum overall length of fittings (bends, tees and reducers) denoted as L_{max} in Figure H.1 should be in accordance with Table H.1 and Table H.2. Longer lengths, for example for high-pressure applications, are acceptable with agreement of the principal.

8 Quality programme for manufacture

8.1 General requirements

The piping manufacturer shall have a suitable and accredited quality assurance (QA) and quality control system.

The supplier shall identify manufacturing processes and activities that affect component performance and shall ensure that these processes and activities are adequately controlled. Critical processes or activities for which procedures should be developed and maintained include, but are not limited to, the following:

a) acceptance of raw material (including ancillaries) (raw materials shall not be used prior to passing acceptance tests);

b) storage of raw material (including ancillaries);

c) resin mixing;

d) control of temperature and relative humidity;

e) component fabrication;

f) restart after production stops;

g) curing (including monitoring of time and temperature);

h) component variant identification;

i) training and certification of workforce personnel;

j) training and certification of inspectors;

k) marking, packing, handling and transportation.

NOTE The requirements for pipe bonder and inspector certification for installation are given in ISO 14692-4:2002, 5.4.1.

In addition, a quality plan and flow diagram shall be produced (drawn in the context of a factory plan, showing all the proposed tests and inspections during component fabrication).

All records, documents and procedures shall be made available for inspection upon request by the principal.

It shall be the responsibility of the manufacturer to maintain copies of the relevant records, documents and procedures for a minimum of five years from the date of commissioning acceptance.

8.2 Quality control equipment

All inspection, measuring and testing equipment shall be maintained and calibrated.

Test-pressure measuring devices shall be either pressure gauges or pressure transducers with a full-scale range of no more than two times the test pressure, and shall be accurate to at least $\pm$ 0,5 % of full-scale range. A dead-weight testing device shall be available at the manufacturer's facility to calibrate gauges. All pressure-measuring devices shall be calibrated with a deadweight pressure tester or other suitable device every two months.

8.3 Quality control tests

8.3.1 General

Pipe and fittings furnished to this part of ISO 14692 shall be tested in accordance with 8.3.2 to 8.3.10. The frequency of quality control testing is based on a specific percentage of continuous production. Continuous production is defined as:

a) for continuous winding processes, the period in which there is no change in fibre type, resin, diameter and wall thickness;

b) for winding on fixed mandrels, the period in which there is no change in fibre type, resin or cleaning of the resin bath.

8.3.2 Mill hydrostatic test

8.3.2.1 General

After full curing, a proportion of the produced components shall be hydrostatically tested by the manufacturer according to the requirements given in 8.3.2.2 to 8.3.2.4.

Hydrostatic test pressure shall be maintained for a minimum of 2 min in order to ascertain there is no leakage. If practicable, test components shall have unrestrained ends. Test temperature shall be at ambient conditions.

8.3.2.2 Component variants

5 % of the continuous production of the component variant shall be hydrostatically tested. For high-pressure systems [$>$ 3,2 MPa (32 bar)], the testing frequency shall be 100 %.

For components of nominal diameter $\leqslant$ 600 mm, the test pressure shall be 0,89 times the qualified pressure.

NOTE 1 0,89 is the f_2 factor for occasional loads, see ISO 14692-3:2002, 7.6.2.2.

For components of nominal diameter $>$ 600 mm, the test pressure may be reduced to 0,75 times the qualified pressure.

NOTE 2 The lower test pressure for large-diameter components takes into account the additional axial stresses caused by self-mass during testing.

8.3.2.3 Spoolpieces

If practicable, 100 % of spoolpieces shall be hydrostatically tested to 1,5 times the design pressure or 0,89 times the qualified pressure, whichever is lower. For components of nominal diameter $\geqslant$ 600 mm, the test pressure may be reduced to 0,75 times the qualified pressure.

When it is impossible to test the spool, it should be agreed between the principal and the manufacturer that yearly production QA audits and procedures can be used as sufficient evidence of acceptable quality control.

8.3.2.4 Retesting

In the event of failure, retests on two additional components shall be performed. If both of the retests are successful, then the previously produced components, up to the last successful hydrotest sample, shall be accepted. If one or both of the retests fail, then the previously produced components, up to the last successful hydrotest sample, shall be rejected.

8.3.3 Degree of cure

The degree of cure shall be determined with the same procedure used to determine the degree of cure for the baseline component, as defined in 6.8.2, at a frequency of 1 % of continuous production. If the baseline was determined from a component rather than the base resin, three samples shall be taken from three locations situated 120° apart in the same component variant cross-section. The following shall apply, depending on the method used to determine degree of cure:

— if the glass transition temperature is less than 95 % of the minimum value measured, in degrees Celsius, on the baseline component in 6.8.2.2, then the previously produced components, up to the last successful test sample, shall be rejected, subject to the retest option of 8.3.11;

— if the styrene content is more than 2 % (mass fraction) of resin content measured in accordance with 6.8.2.3, then the previously produced components, up to the last successful test sample, shall be rejected, subject to the retest option of 8.3.11;

— if the Barcol hardness is less than 90 % of the minimum value measured on the baseline component in 6.8.2.4, then the previously produced components, up to the last successful test sample, shall be rejected, subject to the retest option of 8.3.11.

If an alternative method has been used to determine the baseline for degree of cure, then the acceptance criteria for quality control shall be agreed by the principal.

8.3.4 Optional short-term burst tests

If agreed as an optional requirement, see 6.8.3, the manufacturer and principal should agree the frequency of manufacture of specimens that are required for quality control purposes. The manufacturer and principal should also agree the frequency of these required for p_{STHP} testing.

The p_{STHP} should be determined in accordance with ASTM D1599 at SLT. If the p_{STHP} is less than the baseline p_{STHP} established in qualification testing, see 6.8.3, then the previously produced components, up to the last successful p_{STHP} test, should be rejected.

8.3.5 Ongoing pressure tests

Pressure testing of all component variants shall be based on continuous production schedule rather than specific project orders.

A minimum of six 1 000 h tests taken from at least two product sectors shall be performed each year in accordance with 6.2.3.2.2 on a continuous basis from the production unit, irrespective of qualified pressure, diameter and wall thickness. The range of component variants shall not be limited to plain pipe, but should include all component variant types within the product family range.

If any of the 1 000 h tests fails, then an inspection of the plant production process and quality control procedures shall be required. Also, the previous production batch shall be rejected, subject to the retest option of 8.3.11.

Components that have been subjected to these tests shall not be used as part of a GRP pipeline or piping system.

8.3.6 Glass, water and void contents

The glass content (percentage of glass-reinforcement) of the reinforced wall shall be determined in accordance with ISO 1172 at a frequency of 1 % of continuous production. The range of component variants shall not be limited to plain pipe, but should include all component variant types within the product family range.

If required by the principal, the void content shall be measured according to ISO 7822 or a procedure agreed with the principal.

If required by the principal, the void content and water content of phenolic resin components shall be measured according to procedures agreed with the principal.

The samples used to determine the glass, void and water contents, if applicable, shall be taken from the same location as the baseline component.

Unless otherwise agreed by the principal, the glass content (mass fraction) shall be as shown in either Table 10 or Table 11.

Table 10 — Glass content (option 1)

Pipe/fitting type	Glass content[a] % (mass fraction)
Filament-wound pipe	70 to 82
Filament-wound fittings	65 to 75
Hand-lay-up fittings	50 to 65

[a] The percentage glass content refers to the reinforced wall thickness. The range is wide to take into account the variability between samples found in normal manufacture.

Table 11 — Glass content (option 2)

Pipe/fitting type	Glass content[a] % (mass fraction)
Filament-wound pipe	± 6 % of quoted mean by supplier
Filament-wound fittings	± 6 % of quoted mean by supplier
Hand-lay-up fittings	± 7,5 % of quoted mean by supplier

[a] The percentage glass content refers to the reinforced wall thickness.

If the glass content is not within the limits given in Table 10 or Table 11, then the previously produced components, up to the last successful test sample, shall be rejected, subject to the retest option of 8.3.11.

If the void content is greater than the maximum value agreed with the principal, then the previously produced components, up to the last successful test sample, shall be rejected, subject to the retest option of 8.3.11.

8.3.7 Inspection

8.3.7.1 General

All pipe and fittings shall be visually inspected for compliance with the requirements stated in 8.3.7.2 and 8.3.7.3 and, if appropriate, either repaired or rejected.

8.3.7.2 Probable defects and selection of NDE methods

NDE methods recommended for use in detecting those defects most likely to occur during the manufacture of GRP piping systems are given in Table 12, along with possible causes. Visible defects are listed in Table A.1 of ISO 14692-4:2002.

8.3.7.3 Acceptance criteria and remedial action

The acceptance criteria and recommended corrective actions are listed in Table 12.

The principal shall be notified of all repairs. On agreement between the principal and the manufacturer, a mill hydrostatic test in accordance with 8.3.2 on all minor repaired items shall be performed.

8.3.8 Dimensions and wall thickness

8.3.8.1 General

All dimensions shall be compared with the baseline values determined in 6.8.5.

No component shall have excessive resin, adhesive or foreign matter on the internal wall which could provide a flow disturbance or hinder the passage of specialized equipment, for example pigs. The maximum height of adhesive bead shall be limited to 10 mm or 5 % of the internal diameter, whichever is smaller.

8.3.8.2 Pipe and pipe plus joints

The following dimensions shall be determined in accordance with ASTM D3567 for at least 1 % of continuous production:

a) internal diameter, d_{ID};

b) outside diameter, d_{OD};

c) mass;

d) minimum total wall thickness;

e) reinforced wall thickness determined from minimum total wall thickness less the nominal liner thickness.

Total wall thickness shall be determined by calliper on every pipe joint.

The tolerance for minimum reinforced wall thickness shall be as specified in Table 13; any out-of-tolerance components shall be rejected. The measurement location on the component shall be the same as that used to determine the baseline value.

Table 12 — General description of defects that potentially could occur during manufacture

Manufacturing defects	Cause(s)	Consequence(s)	Recommended NDT method(s)	Criteria	Corrective action
Incorrect dimensions	Incorrect design input Spool design drawings not correctly verified Incorrect manufacture	Joint cannot be sealed Laminate overstressed if joint pulled up	Measurement to verify documented dimensions Ultrasonic (wall thickness)	In accordance with 6.8.5.	Replace
Visible (major and minor) defects	QA procedures not followed	Weepage or failure if major defect Typically none for minor defects	Visual inspection, with internal light source if appropriate	In accordance with Table A.1 of ISO 14692-4:2002	Replace per Table A.1 of ISO 14692-4:2002 (major defect) Repair per Annex A of part 4 (minor defect)
Incorrect: lamination (e.g. wrong lay-up) filament winding (e.g. incorrect fibre orientation)	QA procedures not followed Incorrect raw materials used	Weepage Joint or pipe failure if strength not adequate	Visual inspection, with light source inside pipe if appropriate, followed by radiography as agreed by the principal and manufacturer	In accordance with agreed manufacturer's specifications	Replace per Table A.1 of ISO 14692-4:2002 (or repair if agreed by manufacturer and principal)
Inadequate curing of the resin	Incorrect formulation Out-of-date components Incorrect curing cycle Excessive ambient humidity	Poor laminate quality	In accordance with 6.8.2	In accordance with agreed resin supplier's specification	Replace per Table A.1 of ISO 14692-4:2002 (major defect) Post-cure (minor defect)
Impact, wear or abrasive damage	Incorrect transport Incorrect handling	Weepage or pipe failure	Visual inspection, with light source inside pipe	In accordance with Table A.1 of ISO 14692-4:2002	Replace (major defect) Repair (minor defect)

Table 13 — Tolerances for reinforced wall thickness t_r based on qualification values

Diameter range D_i mm	Tolerance[a] mm
< 600	< 3
600 to 1 200	< 4,5
> 1 200	< 6

[a] The tolerance on reinforced wall thickness for fittings should refer to the spot having the minimum wall thickness.

8.3.8.3 Fittings

The following dimensions shall be determined in accordance with ASTM D3567 for each fitting:

a) internal diameter, d_{ID};

b) maximum outside diameter, d_{OD};

c) mass;

d) minimum wall thickness;

e) reinforced wall thickness determined from minimum total wall thickness less the nominal liner thickness;

f) laying length according to ASTM D3567.

The manufacturer shall also determine the dimensions of critical connection detail, such as the O-ring groove, taper angle, etc.

The tolerance for minimum reinforced wall thickness shall be as specified in Table 13; any out-of-tolerance components shall be rejected. The location on the component shall be the same as that used to determine the baseline value. The tolerance for laying length shall be as specified in Table 14.

Table 14 — Tolerances for fitting laying length per joint

Diameter range D_i mm	**Tolerance** mm			
	adhesive taper/taper joint	adhesive concentric cylindrical joint	elastomeric bell-and-spigot sealed joint	laminated joint
⩽ 400	$^{0}_{-25}$	± 3	± 6	± 5
400 to 1 200	$^{0}_{-25}$	—	± 12	± 10

8.3.8.4 Spoolpieces

The individual components from which the spoolpiece is fabricated shall have been previously measured in accordance with 8.3.8.2 and 8.3.8.3.

The following dimensions shall be determined in accordance with ASTM D3567 for each spoolpiece:

a) internal diameter, d_{ID};

b) maximum outside diameter, d_{OD};

c) reinforced wall thickness, determined from minimum total wall thickness less the nominal liner thickness;

d) relevant dimensions as described in Figure 1 of ISO 14692-4:2002;

e) mass.

The dimensions shall be compared with the baseline quoted by the manufacturer and agreed with the principal. Any out-of-tolerance components shall be rejected.

8.3.9 Thread dimensions

Threads shall be gauged in accordance with API Spec 5B or to a manufacturer-produced procedure agreed with the principal. The minimum frequency of gauging shall be 1 % of continuous production. For moulded threads, the first article from a new mould shall also be checked.

8.3.10 Conductivity

If piping is required to have conductive electrical properties, the following shall apply.

a) If the electrical properties have been specified in terms of electrical resistance and the electrical conductivity properties can be achieved without the aid of earth-bonding clamps, the electrical resistance properties of at least 10 % of continuous production pipe and fittings and 100 % of produced spoolpieces shall be tested according to 6.6.3.1 and 6.6.3.2 as appropriate, and shown to be less than 10^5 Ω/m;

b) If the electrical properties have been specified in terms of electrical resistance and the electrical conductivity properties can only be achieved with the aid of earth-bonding clamps, the electrical resistance properties shall be tested according to 6.6.3.1 and 6.6.3.2 as appropriate, and shown to be less than 10^5 Ω/m. Since this may require abrasion to the surface and the permanent attachment of the grounding clamp to the component, the frequency of testing shall be agreed with the principal;

c) If the electrical properties have been specified in terms of the charge-decay properties, the charge-decay properties shall be tested according to 6.6.3.4. Since this may require the permanent attachment of a section of pipe and/or grounding clamp to the component, the frequency of testing shall be agreed with the principal;

d) if the electrical properties have been specified in terms of the charge-shielding properties, the charge-shielding properties shall be tested according to 6.6.3.3. Since this may require the permanent attachment of a section of pipe and/or grounding clamp to the component, the frequency of testing shall be agreed with the principal;

e) if the electrical properties have been specified in terms of the surface resistivity properties, the surface resistivity properties of at least 10 % of continuous production pipe and fittings and 100 % of produced spoolpieces shall be determined in accordance with ASTM D257 and shown to be less than 1×10^9 Ω. The use of a suitable portable surface resistivity meter shall be acceptable, since this is likely to produce a conservative result on account of the reduced contact area caused by the curved and undulating surface of the GRP.

If the electrical properties exceed the specified requirements, then the previously produced components, up to the last successful test sample, shall be rejected subject to the retest option of 8.3.11.

8.3.11 Retest

If any specimen fails to conform to any of the specified requirements of 8.3.3 to 8.3.10, it shall be rejected. The manufacturer may elect to make retests, on agreement with the principal, on two additional replicate samples selected at random from the previous production batch until the last successful test sample. If all the retest samples conform to the requirements, then the remainder of the previously produced components, up to the last successful test, shall be accepted. If any retest specimen fails to conform, then the previous production batch shall be rejected.

8.4 Quality control records

8.4.1 Purpose

The quality control records are required to substantiate that all components manufactured to this part of ISO 14692 conform to the specified requirements.

8.4.2 Records control

Quality control records required by this part of ISO 14692 shall be:

a) legible, identifiable, retrievable and protected from damage, deterioration or loss;

b) retained by the manufacturer for a minimum of five years following the date of commissioning acceptance;

c) signed and dated.

8.4.3 Records to be maintained by manufacturer

The manufacturer shall maintain the following records for a minimum of 5 years:

a) test results in accordance with 8.3;

b) any records related to manufacturer's process documentation.

8.4.4 Prefabrication documentation

Raw material certificates shall be available for review by the principal prior to the start of manufacture.

8.4.5 Production quality control reports

The manufacturer shall prepare a set of quality control reports for the supplied components. These reports shall demonstrate that the delivered components have been manufactured in accordance with the requirements listed herein.

The quality control report shall

a) identify the components (including type, nominal diameter and qualified pressure), their date of manufacture, production identification information code and the manufacturing procedure used for their production,

b) reference the prefabrication documentation of 8.4.4,

c) report the quality control tests of 8.3.2 to 8.3.10.

9 Component marking

9.1 General

Pipe and fittings manufactured in accordance with this part of ISO 14692 shall be marked by the manufacturer as specified in 9.2. Additional project-related markings as desired by the manufacturer or as requested by the principal may be included. Markings shall be applied by paint or ink stencil, decal or both, as agreed upon between the principal and manufacturer. Markings shall be permanent, shall not overlap, and shall be applied in such manner as not to damage the pipe or fittings. Markings shall be applied on the pipe and fittings within 1 m of the end.

9.2 Requirements

All pipes and fittings shall be permanently marked with

a) manufacturer's name,

b) product line designation,

c) qualified pressure,

d) temperature at which qualified pressure was determined (default is 65 ^{o}C),

e) system design pressure (if known),

f) system design temperature (if known),

g) nominal diameter,

h) manufacturer's identification code,

i) limitations or reference to installation requirements: permissible bolt torques, potable water (yes/no), electrical conductivity and fire performance classification.

10 Handling, storage and transportation

The handling, storage and transportation of GRP components shall be in accordance with Annex B of ISO 14692-4:2002.

11 Documentation

11.1 General

The following subclauses provide a checklist of documentation required for the order and supply of components in accordance with this part of ISO 14692.

11.2 Purchase order documentation

The principal shall provide the manufacturer, in the invitation to tender, with the minimum following information:

a) design internal pressure and design external pressure;

b) details of media to be transported (i.e. chemical composition, erosive nature, etc.);

c) ambient and fluid temperatures (maximum and minimum);

d) anticipated flow conditions (i.e. velocity, particulates, turbulence and shock loads);

e) potable water service requirements (if any);

f) external service environment requirements;

g) electrical conductivity requirements;

h) fire performance requirements;

i) requirements for internal resin-rich liners to provide additional protection against chemical attack;

j) requirements for the supervision of installation by the manufacturer.

A sample enquiry sheet (to be completed by the principal and transmitted to the manufacturer) is provided in Annex I.

11.3 Qualification documentation

11.3.1 General

The manufacturer shall provide the principal with proof of compliance with the qualification requirements of Clause 6. The following sections summarize the requirements. Examples of suitable report layout are given in Annex J.

11.3.2 Qualification reports

Qualification reports, as detailed below, shall be produced for each product sector, and shall be supplied by the manufacturer if so requested by the principal:

a) manufacturer's identification of products;

b) T_g data on all test samples, if specified;

c) glass content of all test samples;

d) date of manufacture and identification number of test samples;

e) reference to manufacturing procedure, including version number and issue date used for production of test samples;

f) constituent material details, including types, manufacturer/supplier, delivery/batch data;

g) such additional information, including dimensions of samples, required by the test procedure specified for each qualification test method;

h) copy of, or reference to, manufacturer's instructions for field assembly;

i) specific requirements for the qualification option used;

j) report of the testing carried out to establish the published values detailed in 11.6. The testing may be reported in detail in the qualification report, or reported separately and referenced therein.

SI units shall be used in all qualification reports.

11.3.3 Qualification summaries

Qualification summaries, containing selective information from the qualification report, shall be produced for each component variant, and shall be supplied by the manufacturer if so requested by the principal.

An example of a qualification summary is given in Annex J.

11.3.4 Potable water approval certificates

Potable water approval certificates shall be provided if specified by the principal.

11.4 Production quality control documentation

11.4.1 General

The manufacturer shall provide the principal with proof of compliance with the quality control requirements of Clause 8. The following subclauses summarize the requirements.

11.4.2 Manufacturing procedure

A manufacturing procedure, in accordance with 8.1, shall be available for each component variant to be supplied. The manufacturing procedure shall be provided, if requested by the principal, prior to the start of manufacture.

11.4.3 Raw material certificates

Raw material (including ancillaries) certificates, in accordance with 8.1, shall be available for the raw materials of all components to be supplied. The certificates shall be provided, if requested by the principal, prior to the start of manufacture.

11.4.4 Production quality control reports

Production quality control reports, in accordance with 8.4, shall be provided for all supplied components within five working days, or other agreed period, after delivery of the complete order or part thereof.

11.5 Installation documentation

The manufacturer shall provide the principal with the following documentation to facilitate the proper assembly and installation of his products:

a) instructions for field assembly of all joint types supplied;

b) instructions for the installation of the piping system supplied;

c) instructions for the field repair of damage to pipe and fittings, if this is permitted in accordance with Table 12.

11.6 Published values

11.6.1 Product families and product sectors

The manufacturer shall identify the name of the product family for each pipe component and size of each product sector within that product family.

11.6.2 Properties

If applicable, the manufacturer shall publish values for the following properties for each product family, determined in accordance with Clause 6:

a) qualified pressure, p_{q};

b) rated temperature;

c) biaxial stress ratio, r;

d) ASTM D2992 regression data;

e) short-term burst pressure p_{STHP};

f) thermal conductivity;

g) coefficient of axial thermal expansion;

h) hoop tensile modulus;

i) axial tensile modulus;

j) axial bending modulus;

k) Poisson’s ratio; axial/hoop, and hoop/axial;

l) electrical classification code;

m) fire classification code.

11.6.3 Dimensions

11.6.3.1 Pipes

Manufacturers shall publish the following information for each qualified component. The following dimensions, with tolerances if applicable, shall be given:

a) pipe inside and outside diameters;

b) minimum total wall thickness;

c) average structural wall thickness;

d) liner thickness;

e) overall pipe length;

f) effective pipe length;

g) inside and outside diameters of the end;

h) length of joint;

i) form of spigot and socket;

j) spigot and socket taper angle.

11.6.3.2 Fittings

Manufacturers shall publish the following information for each qualified component. The following dimensions, with tolerances if applicable, shall be given:

a) fitting inside and outside diameters;

b) minimum total wall thickness;

c) minimum structural wall thickness;

d) average structural wall thickness;

e) liner thickness;

f) overall fitting length;

g) effective fitting length;

h) length of joint;

i) form of spigot and socket;

j) spigot and socket taper angle;

k) elastomeric bell-and-spigot seal lock joint features;

l) bend radius (if appropriate);

m) tee centreline-to-branch face length.

11.6.3.3 Flanges

Manufacturers shall publish the following information for each qualified component and identify whether it complies with a recogized standard, e.g. ISO 7005-3 and ASME B16.5, etc. The following dimensions, with tolerances if applicable, for flanges shall be given:

a) thickness of flange;

b) bolt hole circle and diameter;

c) flange inside diameter;

d) effective length;

e) overall length;

f) joint configuration.

11.6.3.4 Pipe spools

Manufacturers shall publish the following information for each qualified component. The following dimensions, with tolerances if applicable, shall be given:

a) face to face;

b) centreline to face;

c) centreline to centreline;

d) flange offset;

e) flange face alignment.

Annex A
(informative)

Examples of component requirements for qualification

A.1 Product sectors

Examples of product sectors are shown in Table A.1. The product sector representative is the component variant that has the largest nominal diameter and highest pressure rating in that specific sector. Assuming that the product range consists of pipes, elbows, flanges and joints, in diameters up to 250 mm and pressures up to 5 MPa (50 bar), the product sector representative (PSR) in product sector “A” would be:

a) 250 mm 5 MPa (50 bar) pipe;

b) 250 mm 5 MPa (50 bar) elbow and reducer;

c) 250 mm 5 MPa (50 bar) flange;

d) 250 mm 5 MPa (50 bar) joint;

e) 250 mm 5 MPa (50 bar) saddle.

If a product family does not include variants with nominal diameters and pressure ranges that coincide with the product sector boundaries, then the product sector representative is identified by selecting first on nominal diameter, then on pressure rating.

Table A.1 — Product sectors

Diameter mm	**Pressure range** MPa (bar)			
	0 to 5 (0 to 50)	**5 to 10 (50 to 100)**	**10 to 15 (100 to 150)**	**⩾ 15 (⩾ 150)**
25 to 250	A	H	N	S
250 to 400	B	I	O	T
400 to 600	C	J	P	
600 to 800	D	K	Q	
800 to 1 200	E	L	R	
1 200 to 2 400	F	M		
> 2 400	G			

A.2 Example of component qualification

Table A.2 provides an example of the breakdown of the qualification requirements of a material take-off (MTO) for a typical pipe system. Note that only one size of pipe is required for qualifying the product family representative. In this particular example, the number of components requiring qualification by testing can be summarized according to Table A.3. Note that it is possible for the default gradient or just a single regression curve for a pipe and joint to be used as the family representatives for all the components listed. All product variants can be qualified using scaling methods and do not require testing.

Table A.2 — Example of component qualification — Breakdown in product family representatives, product sector representatives and component variants

No.	Component list		Product family representative			Product sector representative			Product variant		
	Type	ID mm	Type	ID mm	Qualification	Type	ID mm	Qualification	Type	ID mm	Qualification
1	Pipe	300	Pipe	100	ASTM D2992	Pipe + elastomeric seal lock joint	400	ASTM D1598 (1 000 h)	Pipe	300	Design
2	Pipe + elastomeric seal lock joint	300	Pipe + joint[a]	100	ASTM D2992 or default	Pipe + elastomeric seal lock joint	400	ASTM D1598 (1 000 h)	Pipe + elastomeric seal lock joint	300	Design
3	Elbow	300	Elbow or pipe + joint[a]	100	ASTM D2992 or default	Elbow	400	ASTM D1598 (1 000 h)	Elbow	300	Design
4	Flange	300	Flange or pipe + joint[a]	100	ASTM D2992 or default	Flange	400	ASTM D1598 (1 000 h)	Flange	300	Design
5	Tee	300 × 200	Tee or pipe + joint[a]	100 × 100	ASTM D2992 or default	Tee	400 × 400	ASTM D1598 (1 000 h)	Tee	300 × 200	Design
6	Reducer	300 × 200	Elbow or pipe + joint[a]	100	ASTM D2992 or default	Reducer	400	ASTM D1598 (1 000 h)	Reducer	300 × 200	Design
7	Pipe	200	Pipe	100	ASTM D2992	Pipe	250	ASTM D1598 (1 000 h)	Pipe	200	Design
8	Pipe + adhesive-bonded joint	200	Pipe + joint[a]	100	ASTM D2992 or default	Pipe + adhesive-bonded joint	250	ASTM D1598 (1 000 h)	Pipe + adhesive-bonded joint	200	Design
9	Elbow	200	Elbow or pipe + joint[a]	100	ASTM D2992 or default	Elbow	250	ASTM D1598 (1 000 h)	Elbow	200	Design
10	Flange	200	Flange or pipe + joint[a]	100	ASTM D2992 or default	Flange	250	ASTM D1598 (1 000 h)	Flange	200	Design

NOTE Short-term pressure-testing in accordance with ASTM D1599 is an alternative for qualifying product sectors for low-pressure components.

[a] The type of joint may be of the manufacturer's own choosing.

Table A.3 — Summary of qualification testing requirements

Component	Family representative	Product sectors
Plain pipe	1	2
Pipe plus joint	1	2
Elbow	1	2
Flange	1	2
Tee	1	2
Reducer	1	same as elbow

Annex B
(informative)

Pressure qualification test ratios

B.1 General

This annex shows how the ratio T_{TD} of the test pressure to the maximum possible design pressure depends on the method used to qualify the component. A comparison of the magnitude of possible ratios can be derived as follows.

The maximum design pressure, $p_{d,max}$, in megapascals for the GRP pipe and joint/fitting is given by Equation (B.1):

$$p_{d,max} = f_2 \cdot f_3 \cdot p_q \qquad (B.1)$$

where

p_q is the qualified pressure, in megapascals;

f_2 is the part factor for loading (safety factor);

f_3 is the part factor to account for the limited axial load capability of GRP.

NOTE The actual magnitudes of f_2 and f_3 may be different from the values given in the following cases, but will be the same for each case. Therefore the results of Table B.1 will scale accordingly depending on the actual values of f_2 and f_3.

B.2 Case 1 — Full regression testing as per 6.2.3.1 or 6.2.3.2

This applies if the p_{LCL} (in accordance with ASTM D2992) is known.

$$p_q = p_{LCL} \qquad (B.2)$$

Taking values of f_2 and f_3 as:

f_2 = 0,67

f_3 = 1,0 (maximum value which would normally only be applicable to a straight run, below-ground application).

The T_{TD} ratio of $p_{LCL}/p_{d,max}$ is:

$$T_{TD} = 1,0 /(f_2 \times f_3) = 1,0/0,67 = 1,5 \qquad (B.3)$$

B.3 Case 2 — 1 000-h survival testing as per 6.2.3.2.2

This applies if the medium term (1 000 h) test pressure ($T_{P1\ 000}$) is known.

From Equation (8):

$$T_{P1\ 000} = p_q \times 10^{2,24G} \qquad (B.4)$$

Taking the default values of f_2 and f_3 as:

f_2 = 0,67

f_3 = 1,0

The T_{TD} ratio of $T_{P1\,000}/p_{d,max}$ is equal to:

$$T_{TD} = 10^{2,24G}/(f_2 \cdot f_3) \quad \text{(B.5)}$$

= 2,19 (pipes with G = 0,075)

= 2,49 (fitting with G = 0,10)

= 2,85 (fitting with G = 0,125)

B.4 Case 3 — Short-term burst testing as per 6.2.4

This applies if the short-term burst pressure (p_{STHP}) is known.

Using equation (10), the equivalent p_{LTHP} in accordance with the short-term burst test is given by:

$$p_{STHP} = p_q \cdot Z \quad \text{(B.6)}$$

Taking the default values of f_2 and f_3 as:

f_2 = 0,67

f_3 = 1,0

The T_{TD} ratio of $p_{STHP}/p_{d,max}$ is equal to

T_{TD} = $Z/(f_2 \cdot f_3)$ (B.7)

T_{TD} = 4,00 (For Z = 2,68)

T_{TD} = 5,00 (For Z = 3,35)

T_{TD} = 6,00 (For Z = 4,02)

Table B.1 shows a comparison of the T_{TD} ratios. This shows that for values of f_2 = 0,67 and f_3 = 1,0 (possible for a below-ground application), the T_{TD} ratio can range between 1,5 and 6,0 depending on the method of qualification.

Table B.1 — Comparison of the ratio of the test pressure and maximum design pressure if f_3 = 1,0

Rating method	T_{TD} ratio		
	G = 0,075 and Z = 2,68	G = 0,1 and Z = 3,35	G = 0,125 and Z = 4,02
Case 3: Short-term	4,00	5,0	6,0
Case 2: Medium-term (1 000 h)	2,19	2,49	2,85
Case 1: Long-term regression	1,50	1,50	1,50
G = slope of regression line Z = ratio of p_{STHP} to p_q			

Table B.2 shows a comparison of the T_{TD} ratios for values of f_2 = 0,67 and f_3 = 0,85 which is more typical for an above-ground application.

Table B.2 — Comparison of the ratio of the test pressure and maximum design pressure if f_3 = 0,85

Rating method	T_{TD} ratio		
	G = 0,075 and Z = 2,68	G = 0,1 and Z = 3,35	G = 0,125 and Z = 4,02
Case 3: Short-term	4,71	5,88	7,06
Case 2: Medium-term (1 000 h)	2,58	2,93	3,35
Case 1: Long-term regression	1,76	1,76	1,76
G = slope of regression line Z = ratio of p_{STHP} to p_q			

In practice, particularly for pipes above-ground, the minimum safety factor will usually be greater than 1,5 because of the need for the design to take account of considerations, such as bending, mechanical handling, impact and fire. In addition, there is an inherent conservatism associated with the value of p_{LCL} due to the method of testing.

Annex C
(normative)

Failure envelope

This annex provides guidance on the measurement of strength data for GRP pipe under different combinations of hoop and axial stress. This procedure is relevant if it is possible to apply additional axial loads over and above the induced axial load from internal pressure to the component.

To generate the regression curve, the test details and measurement should be in accordance with 6.2.3.1.

The long-term envelope, see Figure C.1, is derived from either a fully measured short-term envelope or a 1 000 h survival test envelope, see 6.2.3.2.2. A minimum of three data points is required to define the short-term envelope. These data points shall be collected for a fixed ratio of applied hoop stress to axial stress, and are defined as:

— Point 1: 0:1 hoop to axial stress, i.e. axial tension only ($\sigma_{sa(0:1)}$), in megapascals, measured in accordance with 6.2.6.

— Point 2: 1:1 hoop to axial stress, i.e. internal pressure + axial tension ($\sigma_{sa(1:1)}$ and $\sigma_{sh(1:1)}$), in megapascals.

— Point 3: 2:1 hoop to axial stress, i.e. internal pressure only ($\sigma_{sa(2:1)}$ and $\sigma_{sh(2:1)}$), in megapascals, measured in accordance with 6.2.6.

The manufacturer may carry out additional short-term testing at other stress ratios at his discretion.

The hoop and axial loads shall be applied simultaneously, not sequentially. The manufacturer shall record the load application rate.

The idealized long-term failure envelope is geometrically similar to the short-term envelope with all three data points being scaled according to f_{scale}, where:

$$f_{scale} = \sigma_{qs} / \sigma_{sh(2:1)}$$

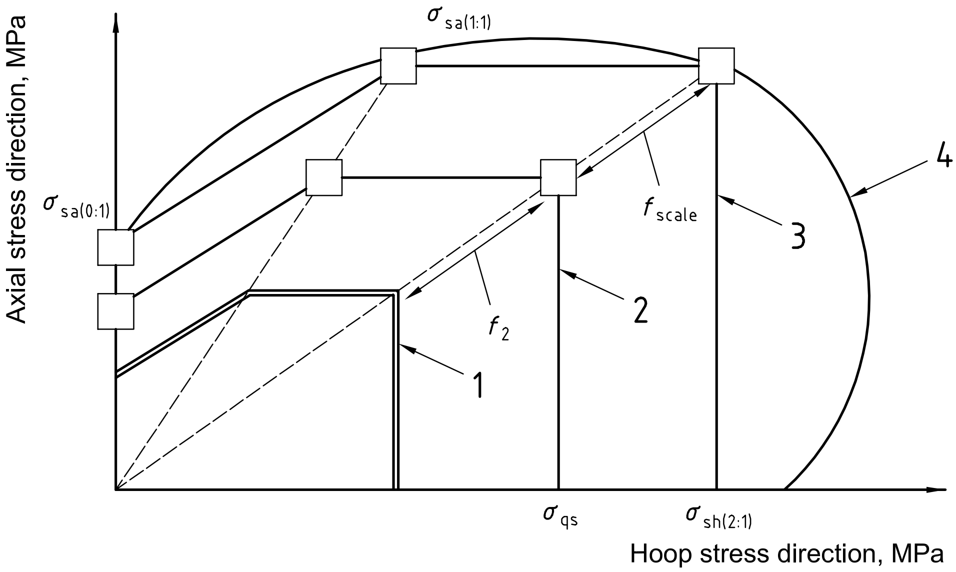
where

σ_{qs} is the qualified stress, in megapascals, as defined in Equation (7);

$\sigma_{sh(2:1)}$ is the short-term hoop strength, in megapascals, as defined in Equation (12).

The long-term design envelope is based on this idealized long-term envelope multiplied by an appropriate factor of safety, f_2, defined in 7.6.2 of ISO 14692-3:2002.

The manufacturer may also at his discretion construct a long-term failure envelope by carrying out regression testing of pipe under combination of internal pressure and bending conditions.



Key

1 long-term design envelope

2 idealized long-term envelope

3 idealized short-term envelope

4 schematic representation of the short-term failure envelope

Figure C.1 — Idealized envelopes for a single-wound-angle ply GRP pipe with winding angles in the range of approximately 45° to 75°

Annex D
(informative)

Guidance on determination of partial factors A_1 and A_2 for temperature and chemical resistance

D.1 Overview

D.1.1 Temperature

The permeability of fluids into reinforced plastics increases rapidly with increasing temperature. The absorption of liquids also accelerates viscoelastic processes such as creep, especially with uncrosslinked or inadequately crosslinked matrix resins. Temperature also accelerates many of the degradation processes caused by the fluids when they have entered the matrix.

D.1.2 Chemical resistance

When an organic resin matrix is placed in contact with a liquid, there is invariably absorption of the liquid by the resin. This can lead to damage depending on the mutual compatibility between the liquid and polymer. Problems of chemical compatibility tend to arise when the specified chemical environment and operating temperature fall outside the supplier's experience.

The chemical resistance of thermoset resins is very much dependent on the type/grade of resin and curing conditions. Nonsaturated polyester resins cured at room temperature tend to be limited to ambient-temperature and water-service applications, as they often have poor solvent resistance at elevated temperature.

Enhanced chemical resistance and temperature performance can be provided by fully cured vinyl ester, epoxy, phenolic and furane resins. With epoxy resins, a key factor influencing chemical resistance is the choice of curing agent (hardener) used, e.g. anhydride, aliphatic amine or aromatic amine.

Chemicals of possible concern, depending on the resin system and exposure conditions, include

a) strong acids and alkalis,

b) organic acids,

c) strong aromatic solvents,

d) strong oxidizing agents, e.g. hypochlorite,

e) methanol.

For most resins, the principal source of physical and chemical attack is from water rather than hydrocarbon, although there are exceptions. Absorption of water results in plasticizing of the resin and lowering of the glass transition temperature, with consequent reduction in mechanical performance at elevated temperature.

If glass is used for the reinforcement fibre, there is a risk of environmental stress-cracking (ESC) when exposed to acidic environments. The problem is avoided by providing an adequate resin-rich or suitable chemically resistant veil to act as a barrier to protect the glass. In addition, a grade of more acid-resistant glass fibre may be used for the construction of the component.

D.2 Quantifying performance

For some chemicals other than water, it is not possible to determine partial factors A_1 and A_2 separately, and testing will result in determination of the product $A_1 \cdot A_2$.

There are many procedures for testing GRP materials at elevated temperature and/or exposed to chemicals, for example ISO 175 [2], ASTM C581 [3], ASTM D543 [4], but few provide acceptance criteria. This is because the acceptance criteria depend on the nature of the failure mode applicable to the application.

If the effects of temperature alone are being considered, it is acceptable to extrapolate a value of A_2 between a value of 1 at 65 °C and 0 at the T_g.

Possible test procedures that can be adapted to provide a means for deriving partial factors A_1 and A_2 include ASTM D3681 [5] and prEN 13121-2 [6].

If there are doubts about the values of A_1 and A_2, a 1 000 h survival test should be carried out on the product sector representative at the appropriate temperature and chemical conditions in accordance with 6.2.3.2.2. Consideration should be given to ensuring that the test media is given sufficient time to permeate into the walls of the GRP pipe in order to achieve representative saturation conditions of the material prior to carrying out the survival test. The test pressure should be 1,15 times the value determined according to Equation (7), to provide a 15 % margin of safety.

Annex E
(normative)

Fire endurance testing

E.1 General

E.1.1 This test method covers the determination of the fire endurance of GRP pipe, fittings and joints to be used in offshore applications. The test pressure shall be the design pressure, p_d. If p_d is not known, the test pressure shall be $p_{d,max}$, which is 0,67 × p_q where p_q is the qualifed pressure of the pipe component.

The number and dimensions of test specimens, as well as requirements for the qualification of a range of pipe diameters, shall be in agreement with the authority having jurisdiction. This will depend on the confidence in the predictive model (see E.7 for further guidance).

NOTE The following combination of procedures is equivalent to testing components in accordance with the levels defined in IMO Resolution A.753(18) [1], where:

Level 1 is equivalent to: **DE.HF.EA/60:** E.2.3, E.3.2.1, E.4.2 and E.5 a) for 1 h;

Level 2 is equivalent to: **DE.HF.EA/30:** E.2.3, E.3.2.1, E.4.2 and E.5 a) for 30 min;

Level 3 is equivalent to: **ST.IF.EB/30:** E.2.3, E.3.3, E.4.4 and E.5 b) for 30 min.

E.1.2 The test configuration is determined by the fire type, which may be any of the following:

- jet fire;
- furnace fire (hydrocarbon pool fire);
- impinging flame.

These are defined in E.3.1, E.3.2, E.3.3.

E.1.3 Preparation of the fire test specimens shall be in accordance with E.2.

E.1.4 The fire type and test configuration shall be in accordance with E.3.1, E.3.2 or E.3.3.

E.1.5 The fire test procedures defined in E.4.1 to E.4.6 allow pipe to be tested under any of the following flow conditions:

- dry pipe;
- pipe initially dry for 5 min, then flowing;
- pipe filled with stagnant water;
- pipe initially stagnant for 5 min, followed by flowing water;
- pipe with flowing water.

E.1.6 The acceptance criteria shall be in accordance with E.5.

E.2 Test specimen and set-up requirements

E.2.1 General

E.2.1.1 The test specimen shall be prepared with the joints, fittings and fire-protective coverings, if any, intended for use in the proposed application. All joint types shall be tested, as they are the primary points of failure. The number of specimens shall be sufficient to test all joints and fittings, including joints between non-metal and metal pipes and fittings to be used.

It is recognized that the joint may be the primary point of failure and therefore a straight joint may be considered representative of all bends, elbows and tees of equal or greater wall thickness, provided the construction and constituent materials are the same.

A flange joint is typically used to connect the GRP piping to metallic valves or fittings, and shall be tested as such. A suitable test arrangement includes a test specimen incorporating GRP pipe with a GRP flange connection to a metallic valve body. Alternatively, a valve body may be simulated by an equivalent hollow metal block of similar mass and surface area.

A test specimen incorporating several components of a piping system may be tested in a single test. A suitable arrangement may comprise an inverted L-shaped specimen with vertical pipe on centreline of box connected to horizontal pipe by an elbow.

E.2.1.2 If the piping material, fire-protective coating or covering contains or is liable to absorb moisture, the test specimen shall not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature of (23 ± 2) °C at 50 % relative humidity. Accelerated conditioning is permissible provided the method does not alter the properties of component materials.

E.2.1.3 Special samples shall be used for moisture-content determination and conditioned with the test specimen. These samples shall be so constructed as to represent the loss of water vapour from the specimen by having similar thickness and exposed faces.

E.2.1.4 If pipe is to be tested dry, the test will require the use of a nitrogen tank with regulator. Means shall be provided to record the pressure inside the pipe and the nitrogen flowrate into and out of the specimen in order to indicate leakage.

E.2.1.5 If applicable, a pressure-relief valve shall be connected to one of the end closures of the system.

E.2.1.6 Instrumentation shall be provided to record fuel flowrate, water pressure, water flowrate and water leakage rate from the pipe assembly or individual components.

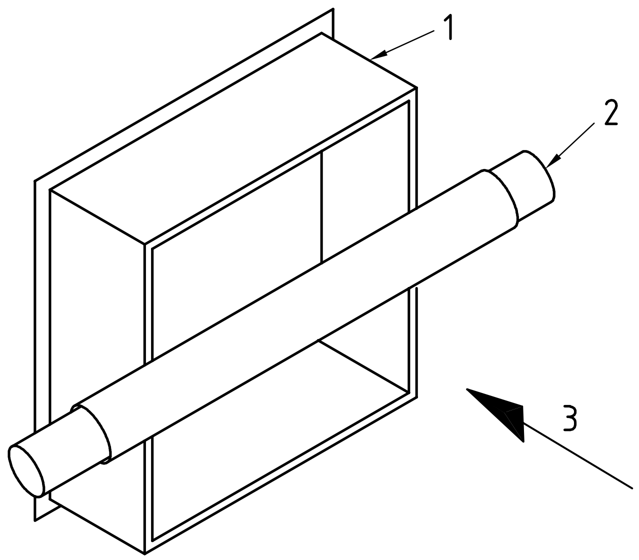
E.2.1.7 The pressure gauge shall be capable of being read with an accuracy of 5 %.

E.2.1.8 Thermocouples may be mounted on the specimen to record temperature conditions during the testing.

E.2.1.9 A minimum of one thermometer or thermocouple shall be used to measure internal water temperature.

E.2.1.10 If the test is carried out indoors, the test building shall be suitably constructed in order to ensure that a hazardous amount of heat or smoke does not accumulate during or after the test.

E.2.2 Jet fire testing



Key

1 Steel box

2 GRP pipe under test

3 Jet fire

Figure E.1 — General view of jet fire testing

E.2.2.1 The test specimen shall be constructed of a single size of piping. The internal diameter shall be 305 mm or less. The external diameter of the piping shall be less than 350 mm.

NOTE The test is not considered fully representative of a system test if the external diameter exceeds 350 mm.

E.2.2.2 The test specimen shall be constructed with a permanent joint and/or fitting showing the most vulnerability (highest leakage rate) when tested according to E.3.2.1 fire conditions (furnace hydrocarbon-pool fire).

E.2.2.3 The test specimen shall be positioned at the front of the opening of an open-ended, non-insulated steel box with a closed back panel, see Figure E.1. The internal dimensions of the box, prior to the application of any fire protection material, are 1,5 m × 1,5 m × 0,5 m. All joints of the box shall be of welded construction and shall be gas-tight. Suitable auxiliary equipment shall be attached to the box to assure its structural stability and to prevent any transient ambient conditions from significantly affecting the testing. The purpose of the box is to provide a “backstop” to the flame and cause swirling of the fire to completely engulf the sample and simulate the erosion effects. The specimen shall extend 0,75 m out to the sides/top/bottom of the test box as applicable.

E.2.2.4 Thermocouples may be mounted within the box or its structure to record temperature conditions during the testing.

E.2.2.5 If metal components such as a flange or deluge nozzle are incorporated in the piping system, the system shall be arranged such that the metal component is put in an area of high heat flux.

E.2.3 Furnace and impinging flame testing

E.2.3.1 The pipe ends and closures may be outside the furnace.

E.2.3.2 If the general orientation of the specimen is horizontal, it shall be supported by one fixed support. Remaining supports shall allow free movement. V-shaped pipe supports shall be considered suitable.

E.2.3.3 If the general orientation of the specimen is horizontal and the pipe is empty, the free length between supports shall not be less than 8 times the pipe diameter.

E.2.3.4 If the general orientation of the specimen is horizontal and the pipe is water-filled, the minimum free length between supports shall be 800 mm ± 50 mm. The test specimen shall be a minimum of 1,5 m long.

NOTE Fire testing of water-filled pipes in closed furnaces carries the risk of possible explosion, although past testing [8] has demonstrated that this test configuration can be carried out safely even if there is a rapid release of water into the hot furnace.

Dimensions in millimetres

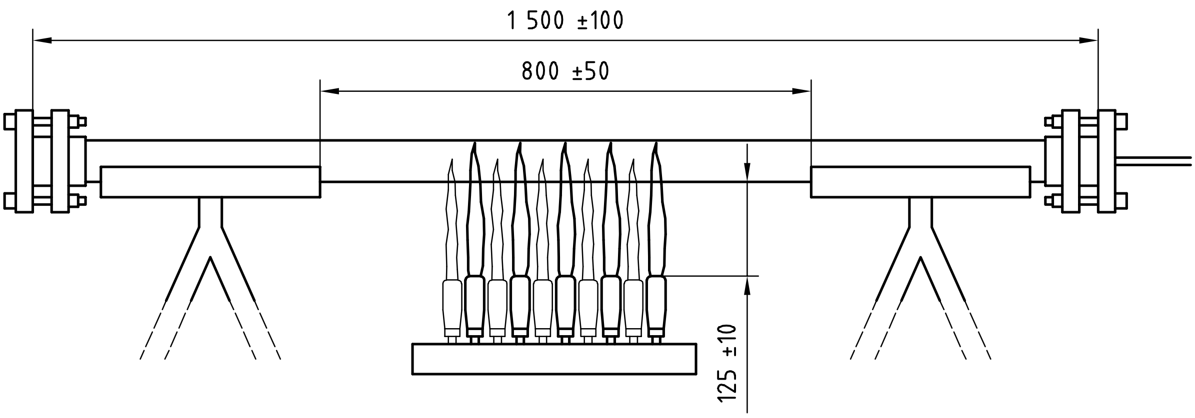


Figure E.2 — General view of impinging flame test arrangement

E.3 Fire specification

E.3.1 Jet fire

E.3.1.1 A propane vaporization and propulsion system shall be used which is capable of delivering 0,3 kg/s ± 0,05 kg/s flowrate under controlled conditions into a “backing box” which has the test specimen mounted at the front opening. The nozzle shall be a tapered, converging type, 200 mm in length with an inlet diameter of 52 mm and an outlet diameter of 17,8 mm. The nozzle shall be located 1,0 m from the front face of the specimen, centred across the box and mounted horizontally between 375 mm and 750 mm from the bottom of the box. The flow shall directly impinge on the test specimen.

E.3.1.2 Fuel used shall be commercial-grade propane delivered to the nozzle as a vapour without a liquid fraction.

E.3.1.3 Prior to conducting the test, calibration runs of the gas flowrate controls shall be conducted.

E.3.1.4 A small “pilot” flame may be started to assure safe ignition of the fuel prior to full flow being established.

E.3.1.5 Fuel flowrate shall be increased to 0,3 kg/s ± 0,05 kg/s. Timing of the test shall begin when the specimen is fully engulfed. Fully controlled flow shall be established within 30 s of the start of the test.

NOTE This medium-scale jet fire test is based upon HSE document OTI 95 634 [9]. The test is considered to simulate the two key conditions of the full-scale jet fire, i.e. heat flux and velocity. The test is able to reproduce the high heat flux measured in the full-scale tests, but with flowrates an order of magnitude lower, by firing the flame into an open-fronted, square, steel test box. The box, of dimensions 1,5 m × 1,5 m × 0,5 m, generates a recirculating flame of 2 m diameter in front of the rear box. The high velocity is obtained by placing the nozzles close to the specimen under test. The test has been shown to reproduce the conditions measured in large-scale jet fires where the heat flux may exceed 250 kW/m^2.

E.3.2 Furnace fire

E.3.2.1 General

The test procedure covers both hydrocarbon and cellulosic fire curves, although the hydrocarbon fire curve is applicable to most offshore situations.

This test method is intended to provide a basis for evaluating the time period during which GRP pipe will continue to perform its intended function when subjected to a controlled standardized fire exposure.

The furnace and thermocouples shall be able to meet the requirements of E.3.2.2 or E.3.2.3, depending on whether the testing is required under hydrocarbon pool fire or cellulosic fire conditions.

E.3.2.2 Hydrocarbon fire curve

The set-up and control of the fire test shall be as specified in clauses 6 through 11 of ASTM E1529 or to an equivalent standard acceptable to the authority having jurisdiction.

NOTE The ASTM E1529 standard exposure conditions simulate the condition of total continuous engulfment of a pipe or piping system in the luminous flame (fire plume) area of a large free-burning hydrocarbon pool fire. The test is required to provide an average total cold-wall heat flux on all exposed surfaces of the test specimens of 158 kW/m^2. This heat flux is attained within the first 5 min of test exposure and maintained for the duration of the test. The temperature of the environment that generates the heat flux is required to be at least 815 °C after the first 3 min of the test and to be between 1 010 °C and 1 080 °C at all times after the first 5 min.

E.3.2.3 Cellulosic fire curve

The set-up and control of the fire test shall be as specified in ISO 834-1, or to an equivalent standard acceptable to the authority having jurisdiction.

E.3.3 Impinging flame

E.3.3.1 The apparatus shall comprise a burner which produces an air-mixed flame. The inner diameter of the burner heads shall be 29 mm. The burner heads shall be mounted in the same plane and supplied with gas from a manifold (see Figure E.2). Each burner shall be equipped with a valve, if necessary, in order to adjust the flame height. The height of the burner stand shall also be adjustable.

E.3.3.2 The distance between the burner heads and the pipe shall be maintained at 125 mm ± 10 mm during the test. If the test specimen includes a fitting or joint, consideration shall be given to increasing the distance between the top of the burner heads and bottom of the pipe in order to prevent the distance between the fitting or joint and the top of the burner heads becoming too small. If necessary, the pipe and joint or fitting may have to be qualified in two tests, in which the distance between the top of the burner heads and pipe component is set for either the pipe or for the fitting or joint. The configuration of the test shall be agreed with the authority having jurisdiction.

E.3.3.3 For piping 150 mm or less in diameter, the fire source shall consist of two rows of 5 burners. For piping greater than 150 mm in diameter, one additional row of burners shall be included for each 50 mm increase in diameter while maintaining the heat flux.

E.3.3.4 During the test, a constant heat flux averaging (113,6 ± 11,4) kW/m^2 shall be maintained 125 mm ±10 mm above the centreline of the array.

a) This flux corresponds to a pre-mix flame of propane of minimum purity 95 % with a fuel flowrate of 5 kg/h for a total heat release of 65 kW.

b) The gas consumption shall be measured with an accuracy of ± 3 % in order to maintain a constant heat flux.

E.3.3.5 The exterior flame temperature shall be measured by means of two thermocouples mounted not more than 25 mm from the pipe near the centre span of the assembly.

a) The thermocouples shall be capable of measuring temperatures up to 1 100 °C, e.g. Type K.

b) The thermocouples shall be mounted in a horizontal plane at the level of the pipe.

c) The test temperature shall be taken as the average of the two thermocouple readings.

E.4 Procedure

E.4.1 General

E.4.1.1 Measure the dimensions of the specimen in accordance with ASTM D3567. Take the measurements of liner thickness and external coatings if applicable.

E.4.1.2 The water temperature at the start of the test shall not be less than 15 °C.

E.4.1.3 Carry out the test in such an environment that the effects of the weather, e.g. wind and rain, do not influence the test. The ambient air temperature prior to testing shall be between −10 °C and +40 °C.

E.4.1.4 Pressure-test each test specimen to 1,5 × test pressure prior to mounting in the test rig. No leakage is allowed during this test.

E.4.1.5 If applicable and prior to conducting the test, conduct calibration runs of the water flow system.

E.4.1.6 No alterations to couplings, fittings, joints, fasteners, insulation or other components shall be made after the commencement of the fire-endurance testing (e.g. flange bolts shall not be re-torqued after completion of the fire-exposure testing and prior to hydrostatic testing; conduct post-fire hydrostatic testing without altering the component in any way).

E.4.1.7 If pipe is to be tested when filled with water, take precautions to ensure the pipe is completely filled with water with no air pockets.

E.4.1.8 Record the test temperature, pressure and water temperature continuously during the test.

E.4.1.9 Test the pipes according to E.4.2, E.4.3, E.4.4, E.4.5 and E.4.6 as applicable.

E.4.1.10 Upon completion of the fire exposure period, allow the sample, together with any fire-protective coating, to cool (with flowing water, if desired).

E.4.1.11 After cooling, pressurize the specimen at the test pressure for a minimum of 15 min with stagnant water (make-up water is allowed). Measure and record overall leakage and leakage of each component after this period.

E.4.1.12 If fire-protective coverings are used, conduct the pressure test without the covering, if practical.

E.4.2 Dry pipe

E.4.2.1 If the pipe is required to be dry at the start of the test, completely drain the specimen of water after the initial test and secure it into position. Make all thermocouple and plumbing connections at this time. Close the ends of the specimen, allowing pressurized nitrogen to be connected with one end.

E.4.2.2 Pressurize the specimen with nitrogen. Maintain the nitrogen pressure inside the test specimen automatically at (0,07 ± 0,01) MPa [(0,7 ± 0,1) bar] during the test.

E.4.2.3 Start the test according to the fire specification procedures given in the relevant subclause of E.3 and continue for the required duration, which shall be a minimum of 15 min.

E.4.3 Dry then flowing fluid

E.4.3.1 If the pipe is required to be dry at the start of the test, completely drain the specimen of water after the initial test and secure it into position. Make all thermocouple and plumbing connections at this time.

E.4.3.2 Start the test according to the fire specification procedures given in the relevant subclause of E.3 and continue in the dry condition for 5 min.

E.4.3.3 After the 5-min dry period, introduce water at a linear velocity not to exceed 1 m/s. Maintain pressure in the system at a minimum of 0,9 × test pressure for the system. Establish these conditions within 1 min after the flow of water begins.

E.4.3.4 Continue the test under flowing water conditions for the required duration, which shall be a minimum of 15 min.

E.4.4 Stagnant fluid

E.4.4.1 Completely fill each pipe specimen with water and vent to exclude air bubbles.

E.4.4.2 Start the test according to the fire specification procedures given in the relevant subclause of E.3.

E.4.4.3 Maintain water pressure during stagnant water tests at (0,3 ± 0,05) MPa [(3 ± 0,5) bar] during the test.

E.4.4.4 Continue the test in the stagnant condition for a minimum of 30 min.

E.4.5 Stagnant then flowing fluid

E.4.5.1 Completely fill each pipe specimen with water and vent to exclude air bubbles.

E.4.5.2 Start the test according to the fire specification procedures given in the relevant subclause of E.3.

E.4.5.3 Maintain the test pressure in the system at a minimum of 0,9 × test pressure for the system.

E.4.5.4 Continue the test in the stagnant condition for 5 min.

E.4.5.5 After the 5-min stagnant period, introduce water at a linear velocity not to exceed 1 m/s. Pressure in the system shall be maintained at a minimum of 0,9 × test pressure for the system.

E.4.5.6 Continue the test for the required duration, which shall be a minimum of 15 min.

E.4.6 Flowing fluid

E.4.6.1 Prior to conducting the test, conduct calibration runs of the water flow system.

E.4.6.2 Completely fill each pipe specimen with flowing water.

E.4.6.3 Start the test according to the fire specification procedures given in the relevant subclause of E.3.

E.4.6.4 The linear velocity of fluid shall not exceed 1 m/s.

E.4.6.5 Maintain pressure in the system at a minimum of 0,9 × test pressure for the system.

E.4.6.6 Continue the test for the required duration, which shall be a minimum of 15 min.

E.5 Acceptance criteria

Depending on the acceptance criteria met during the test, the following integrity codes are applicable:

a) Integrity EA: Capable of maintaining the test pressure without leakage during or after the test.

b) Integrity EB: No leakage during fire test, although a slight weeping may be accepted. Capable of maintaining the test pressure after cooling without significant leakage, i.e. not exceeding 0,2 l/min for a minimum of 15 min. The definition of slight weeping shall be determined by the authority having jurisdiction.

NOTE One method that may be considered is to locate a pressure gauge on both sides of the test specimen to measure pressure throughout the test. Any leakage from the test specimen may be considered slight weeping if the pressure on the outlet side is at least 95 % of the pressure on the inlet side.

c) Integrity EC: Minimal or no leakage ($\leqslant$ 0,5 l/min) during fire test. Capable of maintaining the test pressure after cooling with known leakage (leakage rate per metre length of pipe to be quantified in each case).

d) Integrity ED: Leakage permitted ($\geqslant$ 0,5 l/min) during fire test. Capable of maintaining the test pressure after cooling with known leakage (leakage rate per metre length of pipe to be quantified in each case).

e) Integrity EE: Leakage permitted ($\geqslant$ 0,5 l/min) during fire test. Pressure that can be maintained after cooling with known leakage to be quantified.

E.6 Test report

Report the following information:

a) complete identification of the pipe or fitting tested, including manufacturer’s name and code;

b) description of fire-protective coating, if applicable;

c) diameter of pipe, fitting(s), and/or joint(s);

d) orientation of pipe, fitting(s), and/or joint(s);

e) free length between supports, if applicable;

f) endurance time;

g) leakage rate;

h) appearance of test specimen(s) before, during and after the fire test;

i) date of test.

E.7 Size of pipe to be fire-tested

Qualification of piping systems of different diameters than those tested depends on the confidence in the predictive model. The reasons for testing more than one pipe diameter are

a) to ascertain the effect of pipe diameter on the endurance of the parent material,

b) to ascertain the sensitivity to pipe diameter of the fire performance of the joint,

c) to verify that design for fire endurance can be extrapolated to other pipe diameters.

The design for fire endurance shall take into account the following requirements.

— Sufficient wall thickness shall be provided to withstand normal loads experienced during operations, i.e. self-weight, pressure, thermal expansion, etc.

— A sacrificial layer shall be provided to account for material degradation in a fire. In most pipe designs, the wall thickness is a function of diameter, but the loads and rate of degradation from heat flux may not be a simple function of diameter.

For example, the effect of self-weight has a proportionally greater effect on the strength capability of a large-diameter pipe at the supports than a small-diameter pipe. Therefore proportionally more wall thickness is required to support the loading of a large-diameter pipe at the supports compared to a smaller diameter pipe. In addition, the utilization of the strength capability of the adhesive or laminated joint also increases with diameter, particularly for diameters larger than 400 mm, i.e. the joint is proportionally more highly stressed with increasing diameter.

Conversely there will be a proportionally greater thermal mass of water with increasing pipe diameter, which will retard the rate of material degradation from fire and proportionally less sacrificial material will be needed with increasing pipe diameter.

To reduce the number of pipe diameters needing to be qualified, it is necessary to demonstrate that the design can be extrapolated to other diameters. The predictive model is concerned with two mechanisms:

— the rate at which material is being degraded by the fire;

— the ability of the unburnt material to withstand the loads applied to the pipe.

The first mechanism depends on the fire type, but the second is likely to be independent of fire type once the temperature of the material exceeds a minimum value. This being the case, it will be possible to develop the structural aspects of the predictive fire model by carrying out a series of tests using a less expensive testing arrangement, such as the impinging flame test. The tests shall be sufficiently well instrumented to enable the manufacturer to collect the evidence necessary to validate his model.

The extension of the predictive model to cover more severe fire tests, such as the hydrocarbon furnace test, will require less testing as confidence in the predictive model grows. In the first instance, this will require testing the smallest and largest diameters of piping to be qualified to validate the predictive model under different fire conditions. Further extrapolation of the model to cover jet fire conditions may require just one additional test. Note that the largest outside diameter of pipe that may be jet-fire tested in accordance with the arrangement given in E.2.2 is about 350 mm.

A key factor determining the fire performance of a pipe component variant is the thickness-to-diameter (t/D) ratio and whether it is larger or smaller than that of the variant which has been fire-tested. If fire-protective coatings or layers are included in the variant used in the fire test, only variants with the same or greater thickness of protection, regardless of the (t/D) ratio, shall be qualified by the fire test.

Annex F
(normative)

Modifications to fire reaction test procedures

F.1 Samples for flame spread test

The pipe samples for testing flame spread shall be prepared in the following manner.

a) Tests shall be made for each pipe material and size.

b) The test sample shall be fabricated by cutting pipe lengthwise into individual sections and then assembling the sections into a test sample as representative as possible of a flat surface. A test sample shall consist of at least two sections. The test sample shall be 800 mm ± 5 mm long. All cuts shall be made normal to the pipe wall.

c) The number of sections to be assembled together to form a test sample shall be that which corresponds to the nearest integral number of sections which will result in a test sample with an equivalent linearized surface width between 155 mm and 180 mm. The surface width is defined as the measured sum of the outer circumferences of the assembled pipe sections that are exposed to the flux from the radiant panel.

d) The assembled test sample shall exhibit no gaps between individual sections.

e) The assembled test sample shall be constructed in such a way that the edges of two adjacent sections shall coincide with the centreline of the test holder.

f) The individual test sections shall be attached to the calcium silicate backing board using a suitable wire inserted at 50 mm intervals through the board and tightened by twisting at the back.

g) The individual pipe sections shall be mounted so that the highest point of the exposed surface is at the same distance as a conventional flat sample.

h) The space between the concave unexposed surface of the test sample and the surface of the calcium silicate backing board shall be left void.

i) The void space between the top of the exposed test surface and the bottom edge of the sample holder frame shall be filled with a high-temperature-insulating wool if the width of the pipe segments extend under the side edges of the sample holding frame.

F.2 Samples for smoke and toxicity test

The test samples shall be prepared in the following manner.

a) The test samples shall be taken from piping sizes having the maximum and minimum wall thicknesses intended to be used. This will qualify all piping sizes for a specific piping material, provided that the wall thickness falls within the tested range.

b) The test sample shall be fabricated by cutting pipes lengthwise into individual sections and then assembling the sections into a test sample as representative as possible of a flat surface. All cuts shall be made normal to the pipe wall.

c) The number of sections that shall be assembled together to form a square test sample with sides measuring 75 mm shall be that which corresponds to the nearest integral number of sections which will result in a test sample with an equivalent linearized surface width between 75 mm and 90 mm. The surface width is defined as the sum of the outer circumferences of the assembled pipe sections measured normal to the lengthwise sections.

d) The assembled test sample shall exhibit no gaps between individual sections.

e) The assembled test sample shall be constructed in such a way that the edges of two adjacent sections coincide with the centreline of the test holder.

f) The test samples shall be mounted on calcium silicate board and held in place by the edges of the test frame and, if necessary, by wire.

g) The individual pipe sections shall be mounted so that the plane of the highest point of the exposed surface shall be in the same position as an exposed flat plate.

h) The space between the concave unexposed surface of the test sample and the surface of the calcium silicate backing board shall be left void.

i) The void space between the top of the exposed test surface and the bottom edge of the sample holder frame shall be filled with a high-temperature-insulating wool if the pipe extends under the frame.

j) If the pipes include fireproofing or coatings, the composite structure consisting of the segmented pipe wall and fireproofing shall be tested and the thickness of the fireproofing shall be the minimum thickness specified for the intended usage.

k) The test sample shall be oriented in the apparatus such that the pilot burner flame is perpendicular to the lengthwise piping sections.

Annex G
(normative)

Determination of electrostatic properties of GRP pipe system components

G.1 General

This annex provides procedures to quantify the electrical conductivity and charge dissipation properties of both GRP pipe and fitting components.

The test method includes provision (see G.5) for determining the electrostatic properties before and after exposure to either tap water or brine and other chemicals, to evaluate their effect on the material properties if required.

If required, the components shall include fire-protective insulation and/or conductive coating, if applicable.

If a protective coating is applied to the outside of the pipe, the coating shall not be removed for the purpose of achieving a better electrical contact unless required as part of normal installation practice.

The electrical properties shall be evaluated according to one or more of the following test methods:

a) determination of electrical resistance per length of the component in accordance with G.2;

b) determination of charge-shielding properties of the component in accordance with G.3;

c) determination of charge-decay time of the component in accordance with G.4;

d) determination of electrical continuity across the joint in accordance with G.6.

G.2 Determination of electrical resistance per length

G.2.1 Summary of test procedure

In this test method, the length of the potential current path is measured and then the resistance is determined using a suitable megohmmeter. The results are expressed in terms of resistance per length. The current paths of interest are:

— the inside surface of the pipe at one end of test assembly to the outside surface of the pipe or earth-bonding clamp at the other end of test assembly;

— outside surface of the pipe or earth-bonding clamp at one end of test assembly to the outside surface or earth-bonding clamp of the pipe at the other end of test assembly.

The test method may be also used to determine the effect of typical chemical exposures on the conductive properties of the pipe.

G.2.2 Test apparatus

G.2.2.1 **Voltage supply**, capable of delivering up to 1 000 V and able to provide a voltage of 100 V or less.

G.2.2.2 **Megohmmeter**, capable of measuring resistance between $2 \times 10^3\ \Omega$ and $1 \times 10^{10}\ \Omega$ with a resolution of 5 %.

G.2.3 Test specimen

G.2.3.1 Pipe

The minimum nominal diameter of the pipe tested shall be 50 mm. The length of the specimen shall be 1 m or six times the nominal diameter of the pipe plus two times the width of the grounding clamps if applicable, whichever is greater.

G.2.3.2 Pipe with fitting/joint

The minimum nominal diameter of the pipe, fitting or joint tested shall be 50 mm. The electrical construction of the pipe shall be compatible with that of the fitting/joint. The joint or fitting shall be attached to two lengths of pipe. This may require some fittings, for example flanges, to be assembled in pairs. The length of each pipe shall be six times the nominal diameter of the pipe plus one times the width of the grounding clamps if applicable. To achieve this length, additional sections of conductive pipe shall be added using the manufacturer's normally recommended assembly methods.

G.2.3.3 Fitting and spoolpiece with no pipe attachment

If it is known that the electrical conductive properties are not continuous at the connection, i.e. each component is required to be independently earth-bonded with a grounding clamp, it shall be acceptable to test the component without the pipe attachment. In the following procedures, the earth-bonding clamps shall be attached to each end of the component rather than to the attached pipes.

G.2.4 Procedure

G.2.4.1 General

G.2.4.1.1 Precondition the samples in accordance with G.5.2.

G.2.4.1.2 If the effect of the environment on the electrical properties is to be evaluated, first carry out the procedure given in G.5.3.

G.2.4.1.3 If the electrical conductivity properties of the pipe and joint/fitting combination are to be evaluated, first determine the electrical properties of the pipe on its own.

G.2.4.1.4 Attach a suitable electrode (see G.2.4.1.5) or grounding clamp to the outside surface of the pipe on one end of the pipe or assembly, to provide the necessary conductivity, without causing damage to the surface.

EXAMPLE Conductive paints, conductive adhesive tape or brine-soaked sponges held in place with clamps.

If a grounding clamp is applied, the surface preparation shall not exceed that used when piping systems are installed according to the manufacturer's recommendations.

G.2.4.1.5 Apply two additional electrodes, one around the interior circumference of the specimen and one around the exterior circumference on the other end of the pipe or assembly. If the test is being carried out to confirm continuity of the embedded conducting elements within the component body, the exterior electrode may be a grounding clamp that is applied in a similar manner to the first.

G.2.4.1.6 The distance of the electrodes from the end of the specimen wall shall be greater than or equal to twice the specimen thickness. The width of the electrodes shall be between four and six times the specimen wall thickness. A thinner electrode width is permissible provided the width is stated in the test report.

G.2.4.1.7 Testing shall be carried out at two voltages. The first set of tests shall be carried out at 100 V or less. The second set of tests shall be carried out between 100 V and 1 000 V. The test at the higher voltage shall be carried out after the test performed at the lower voltage.

NOTE Voltage breakdown is more likely to occur at voltages above 100 V, which will affect the results.

G.2.4.1.8 On completion of the tests, all conductive materials that have been applied to the pipe shall be removed, e.g. conductive paints, since these could provide an unwanted isolated electrical conductor during service.

G.2.4.2 Outside to outside surface electrical measurement

G.2.4.2.1 Isolate the test specimen from ground and attach suitable wires to the two external electrodes.

G.2.4.2.2 Determine the resistance using the megohmmeter. The power applied should not exceed 1 W and the electrification time should not exceed 1 min unless otherwise specified. Record the readings from the megohmmeter and the accuracy at that range. Record the appearance of the test specimen and the condition of the clamps.

G.2.4.3 Inside to outside surface electrical measurement

G.2.4.3.1 Isolate the test specimen from ground and attach suitable wires to the internal and external electrodes at the other end of the pipe section.

G.2.4.3.2 Determine the resistance using the megohmmeter. The power applied should not exceed 1 W and the electrification time should not exceed 1 min, unless otherwise specified. Record the readings from the megohmmeter and the accuracy at that range. Record the appearance of the test specimen and the condition of the clamps.

G.2.5 Calculation of pipe and joint/fitting electrical resistance

G.2.5.1 The electrical resistance shall be calculated for the two cases:

— external to external surface of component;

— external to internal surface of component.

Care shall be taken to ensure that these two situations are treated separately.

G.2.5.2 For the pipe, the resistance per length of pipe shall be calculated by dividing the resistance of the pipe by the distance between electrodes.

G.2.5.3 The resistance of the fitting or joint shall be calculated as follows:

a) calculate the resistance of each length of pipe attached to the joint or fitting by multiplying the resistance per length by the distance from the electrode to the fitting/joint. This should be the same for both lengths of pipe;

b) subtract two times the pipe resistance from the overall resistance measured across the assembly, to give the resistance across the fitting/joint.

The resistance per length shall be determined by dividing the resistance by the effective path length. The effective path length depends on the type of fitting and mode tested.

G.2.5.4 For pipes, straight joints, adapters, couplings, plugs, caps, and bushings, the path length shall be parallel to the centreline axis of the component and shall encompass the length of the component.

G.2.5.5 For elbows, the path length shall be the length of the component at the mid bend radius.

G.2.5.6 For crosses and tees, one path length shall be parallel to the centreline axis of the component and shall encompass the length of the component. The other path length shall be along the shortest path from adjacent openings through each 90° bend.

G.2.5.7 For laterals, one path length shall be parallel to the centreline axis of the component and shall encompass the length of the component. The second path length shall be along the shortest distance between adjacent openings through the oblique angle. The third path length shall be along the shortest distance between adjacent openings through the obtuse angle.

G.2.6 Test report

The test report shall include the following information:

a) complete identification of the pipe and fitting/joint fire-protective coating tested, including manufacturer's name and code;

b) diameter of pipe, fitting or joint;

c) details of megohmmeter, name and model number, resolution capability and magnitudes of the two voltage applied;

d) mode of testing, i.e. external to external or external to internal, and whether pipe attachments and earth-bonding clamps were used;

e) results of testing;

f) resistance per length of pipe for each voltage applied;

g) resistance per length of fitting/joint for each voltage applied;

h) environmental exposure time, if applicable;

i) appearance of test specimen;

j) date of test.

G.3 Determination of charge-shielding properties of reinforced thermosetting-resin pipe, fittings and joints

G.3.1 General

This test method determines whether a hazardous potential will be produced on the exterior surface of a grounded GRP pipe, fitting or joint when a step-function electric field is applied to the interior surface.

This test method is generally only applicable to pipes and fitting components of inside diameter greater than 100 mm.

G.3.2 Summary of test

In this test, a high voltage is applied to the interior surface of a grounded reinforced thermosetting-resin pipe, fitting or joint, and the resulting voltage on the exterior surface, if any, is measured.

The shielding test aims to show that the embedded layer prevents the generation of high potentials on the pipe surface due to charging inside the pipe. The criterion is that potentials should be too low to lead to incendive discharges from patches of contamination on the pipe wall. The threshold for such discharges is taken as 1 kV, which is on the low side. The test aims to simulate the hazard process by measuring the potential attained by a standard conductive patch applied to the outside of the pipe. The patch size required to store incendive amounts of energy at a potential of 1 kV is quite large, but a smaller patch size is specified, partly for test convenience and partly because it builds a bit of caution into the measurement (a smaller patch averages less and therefore responds more to the peaks in potential).

The general procedure is to raise the internal potential inside the pipe using a conductive liquid, mount a conductive patch at several points around the pipe and use a field meter to measure the potential on the patch (non-contacting measurement is important).

The test method may be also used to determine the effect of typical chemical exposures on the electrostatic dissipative properties of the pipe.

G.3.3 Test apparatus

G.3.3.1 **DC supply**, capable of producing a minimum voltage of 1 000 V.

G.3.3.2 **Fieldmeter**, able to measure and display values of electric field of 100 $V \cdot m^{-1}$ with zero stable within 50 $V \cdot m^{-1}$ over at least 1 000 s.

A reading of 100 $V \cdot m^{-1}$ shall be at least 10 % of an analog scale reading or at least the second digit of a digital display. The instrument display shall give a linear response to electric field, symmetric with polarity and with no hysteresis. These properties shall be within 5 % of full-scale reading of the operating range. The output time constant at the display shall be less than 1 s.

NOTE Operation of the fieldmeter is based on procedures given in BS 7506: Part 2:1996 [10].

G.3.3.3 **Conductive patch**, comprising aluminium foil and adhesion medium (e.g. conductive grease, aerosol spray).

G.3.4 Sample preparation

G.3.4.1 The preferred minimum diameter of pipe, fitting or joint tested is 100 mm, to reduce the effect of the curved surface on the test set-up and readings. Smaller diameters are acceptable but additional measures may need to be taken to ensure that the electric field conditions between the pipe surface and instrument are as intended.

G.3.4.2 For pipe components, the minimum length of sample should be six times the diameter.

G.3.4.3 If appropriate, for example to provide a fixture for the grounding clamp, additional sections of conductive pipe shall be added as necessary to the component, using the manufacturer's normally recommended assembly methods for an electrically conductive joint. If the additional sections are needed, resistance measurements shall be taken across the joints in accordance with G.2.4.

G.3.4.4 Prepare a patch by cutting from a roll of aluminium foil a patch of dimensions either 150 mm × 150 mm, or 150 mm long by half the component circumference across.

G.3.4.5 Identify five locations on the outside of the component for positioning the patch and detector (fewer locations may be acceptable if a complicated shape makes this difficult). The locations should generally extend around the periphery and be equidistant over the length of the component, taking into account the requirements of G.3.5.6 and G.3.5.8. Additional locations may be needed to take into account regions where there is a change in component geometry.

G.3.5 Test procedure

G.3.5.1 Precondition the components in accordance with G.5.2.

G.3.5.2 If the effect of the environment on the electrical properties is to be evaluated, first carry out the procedure given in G.5.3.

G.3.5.3 Install a grounding clamp of the earthing system on the exterior of the component at each end of the component in accordance with the manufacturer's instructions. Any surface preparation shall not exceed that normally required when installing a piping system.

G.3.5.4 Blank off only those terminations of the component assembly that are necessary to contain the fluid with a suitable removable plug made from an insulating material which is in contact with just the inside surface of the component. If it is not possible to insert a wire into a free end of the pipe or fitting, one of the plugs shall be provided with an electrode that passes through the thickness of the material. For fittings, this electrode shall be at least 300 mm away from the main body of the fitting. Add an additional section of conductive pipe to the component (see G.3.4.3) if necessary to enable this to be achieved.

G.3.5.5 Completely fill the inside of the specimen with a suitable conductive fluid. Suitable vents may be required to be fitted to one or more of the plugs to enable air to be expelled. Ensure the outside of the component is dry.

G.3.5.6 Position the component vertically on a nonconducting surface, or else suspend it with non-electrically conducting materials so that the outside of the component under test is accessible on all sides. The plug with the electrode shall be positioned such that the inside will be in contact with the conducting fluid.

G.3.5.7 Connect the electrode in the plug to the DC supply.

G.3.5.8 Apply the patch, using the adhesion medium to stick it down. Position the fieldmeter 25 mm from the exterior surface of the component and over the centre of the patch. The fieldmeter shall be at least 305 mm away from the wire connecting the DC supply to the electrode in the plug.

It is recommended that a cylinder of 25 mm diameter be used as a shim to space the meter at the correct distance from the pipe, so that the blades of the field mill cannot inadvertently be damaged.

G.3.5.9 With the specimen connected to earth using the grounding clamp, turn on the DC voltage supply. At the same time, monitor the output of the fieldmeter for 10 min. If it is not possible to maintain the voltage inside the pipe, because of high conduction of current through the pipe wall to earth, discontinue the test and record a pass result. Turn off the DC supply. Calculate the maximum potential, in kilovolts, by multiplying the highest recorded electric field reading, in kilovolts per metre, by the meter stand-off distance of 25 mm.

The curvature of the pipe leads to a lower-than-actual indication of potential on the patch, if the measurement of nearest distance of the meter from patch is used in surface potential calculations. After the charge-shielding measurement is completed, it is recommended that the electric field be applied directly to each patch to determine the magnitude of the saturation potential. This enables a clear understanding of what proportion of the internal potential is induced on the exterior of the pipe.

G.3.5.10 Repeat G.3.5.8 to G.3.5.9 for the remaining test positions.

G.3.5.11 Record the appearance of the test specimen and the condition of the grounding clamp.

G.3.6 Test report

Report the following information:

a) manufacturer of pipe, fitting or joint;

b) designation of product being tested;

c) description of the test sample, including diameter of pipe, fitting or joint and lengths of pipe extenders (when needed);

d) description of earth grounding details;

e) test media if exposure testing is done;

f) conductive fluid utilized;

g) DC supply voltage;

h) record of voltage output from fieldmeter for 10 min after start of test for each test position and after exposure for 1, 3, 6 and 12 months when exposure testing is performed;

i) the calculated highest potential;

j) appearance of test specimen;

k) date of test.

G.4 Determination of charge-decay time of the component

G.4.1 Summary of tests

This test method determines the rate of decay of electrostatic charge present on the exterior surface of a grounded GRP pipe, fitting or joint when a charge is briefly applied to the exterior surface. The short-duration corona charging means that the position of the outer earth boundary of the aperture is not important, and measurements can be made on curved surfaces and surfaces that are smaller than the test aperture area.

NOTE 1 The test method is new for this application and based on procedures given in BS 7506: Part 2 [10].

NOTE 2 This test determines the ability of the pipe to spread charge or convey it to a dissipative layer. It does not test the adequacy of the conductivity provided by the dissipative layer.

The test may also be used to determine the effect of typical chemical exposures on the charge-decay properties of the pipe.

G.4.2 Test apparatus

G.4.2.1 Instrument, capable of determining the self-dissipation of electrostatic charge by the component by depositing a small area of charge on the surface by means of a corona discharge and observing the surface potential by means of a fieldmeter. It shall have the following characteristics.

a) The test aperture for corona should be (50 ± 5) mm diameter or rectangular with equivalent area. The corona points are mounted in a 10 mm diameter circle on a movable insulating plate, backed by a screening layer and are 10 mm above the centre of the test aperture. The fieldmeter sensing aperture shall be 25 mm above the centre of the test area. When the plate with the corona points is moved fully away, the test area shall be clear up to the plane of the fieldmeter sensing aperture.

b) The instrument shall be capable of providing a high-voltage discharge as a brief pulse before the instrument changes mode, to enable the fieldmeter to observe the potential generated by the deposited charge. The instrument shall be designed such that contact with the test surface around the test aperture provides a return route for outwardly migrating charge and high capacitance to trap such charge. The initial voltage developed by the deposited corona charge shall be a minimum of 1 000 V. If this cannot be achieved, then this shall be reported and the highest value attainable used. The corona charge-deposition time should be less than 25 ms.

c) The equipment for charge dissipation shall move fully away from the region of the fieldmeter observation in less than 50 % of the minimum decay time to be measured or 20 ms, whichever is greater.

d) The fieldmeter shall be a field-mill instrument able to measure the surface voltage with an accuracy of ± 5 V to below 40 V with a response time (10 % to 90 %) below 0,01 s. The stability of the zero shall allow measurement of surface voltage with this accuracy over the longest decay times to be measured.

e) During charge deposition and decay-time measurements, the fieldmeter sensing aperture shall be well shielded from any connections or surfaces at high voltage and any insulating surfaces in the apparatus.

f) The influence of residual surface charging shall contribute less than 10 V to the measurement of surface voltage. This shall be tested by making decay-time observations of a fully conductive surface.

g) The instrumentation shall be capable of displaying observations of surface voltage as a function of time and providing a permanent record. The method of time measurement shall provide a resolution and accuracy of measurement within 5 % of the reading or 5 % of the limit, whichever is greater.

G.4.3 Sample preparation

G.4.3.1 The preferred minimum diameter of pipe, fitting or joint tested is 100 mm, to reduce the effect of the curved surface on the test set-up and readings. Smaller diameters are acceptable but additional measures may need to be taken to ensure that the electric field conditions between the pipe surface and instrument are as intended.

G.4.3.2 For pipe specimens, the minimum length of sample should be six times the diameter or 1 m, whichever is shorter.

G.4.3.3 If appropriate, for example to provide a fixture for applying the grounding clamp, add additional sections of conductive pipe, if necessary, to the component, using the manufacturer’s normally recommended assembly methods for an electrically conductive joint. If the additional sections are needed, take resistance measurements across the joints in accordance with G.2.4.

G.4.3.4 Identify a minimum of five locations on the outside of the component for positioning the instrument. The locations should generally extend around the periphery and be equidistant over the length of the component. Additional locations may be needed to take account of regions where there is a change in component geometry.

G.4.4 Test procedure

G.4.4.1 Precondition the samples in accordance with G.5.2.

G.4.4.2 If the effect of the environment on the electrical properties is to be evaluated, first carry out the procedure given in G.5.3.

G.4.4.3 Install a grounding clamp of the earthing system on the exterior of the component at each end of the component, in accordance with the manufacturer’s instructions. Any surface preparation shall not exceed that normally required when installing a piping system.

G.4.4.4 Check that the component surface is clean and free from dust. Remove any loose dust by gentle brushing or blowing with clean dry air. If the surface is obviously contaminated, make measurements with the contamination present and report the condition.

G.4.4.5 Position the component vertically on a nonconducting surface, or else suspend it with non-electrically conducting materials in a manner to ensure that the outside of the component under test is accessible on all sides.

G.4.4.6 Place the charge-decay instrument on the component and operate in accordance with the manufacturer's instructions. Ensure that the test equipment remains steady and undisturbed on the surface for the duration of each measurement. Carry out testing at the polarity that generates the higher corona current for a given voltage. Record observations of surface voltage, corona voltage and current as a function of time.

An instantaneous fall in surface potential can be recorded at the start of the decay waveform, which is associated, not with a real decay of charge, but with a step change in the capacitance of the system when (for example) the charging source is disconnected or removed. The charge-decay waveform should be recorded during test to ensure that any such behaviour is detected.

NOTE 1 Since the test piece is not flat, the instrument may be prone to rock when the shutter opens. This can be avoided by strapping a piece of aluminium plate to either side of the unit with nylon cable fasteners.

NOTE 2 Movement of the test apparatus relative to the surface of the specimen can cause tribocharging, which will affect observations.

G.4.4.7 Repeat G.4.4.4 to G.4.4.6 with the component ungrounded.

G.4.4.8 Record the appearance of the test specimen and the condition of the grounding clamp.

G.4.5 Test report

Report the following information:

a) manufacturer of pipe, fitting, or joint;

b) designation of product being tested;

c) description of the test sample, including diameter of pipe, fitting or joint and lengths of pipe extenders (when needed);

d) description of earth grounding details;

e) test media, if exposure testing is done;

f) records of observations of surface voltage, corona voltage and current as a function of time for earth-grounded and ungrounded specimen and after exposure for 1, 3, 6 and 12 months when exposure testing is done;

g) appearance of test specimen;

h) date of test.

G.5 Conditioning procedure

G.5.1 Test apparatus

G.5.1.1 **Oven,** capable of maintaining a temperature of 65 °C ± 5 °C.

G.5.1.2 **Exposure tank** (optional), of non-metallic construction and resistant to the test environment.

G.5.2 Preconditioning

The test specimen should not be tested until the material has reached an air-dry state. This is defined as the state achieved after preconditioning for 16 h to 24 h at an ambient temperature of (23 ± 2) °C and (50 ± 5) % relative humidity.

G.5.3 Conditioning

G.5.3.1 If the effect of the environment on the electrical properties is to be evaluated, place the components in the exposure tank so that they are completely immersed in the test fluid. Maintain the temperature of the fluid at 15 °C to 27 °C throughout the exposure period.

G.5.3.2 At the end of 1, 3, 6 and/or 12 months, remove the test component from the bath and rinse thoroughly, with tap water if the specimen has been exposed to a water-soluble product or with a hydrocarbon solvent if the specimen has been exposed to a petroleum product.

G.5.3.3 Wipe dry and place the test specimen in the oven at 65 °C ± 5 °C for a period of 2 h.

NOTE The purpose of drying the specimen is to ensure that the results of subsequent testing are indicative of permanent changes in resistivity properties brought about by the conditioning process.

G.5.3.4 Remove the component from the oven and allow it to cool to between 21 °C and 27 °C in a (50 ± 5) % relative humidity environment for 16 h to 24 h.

G.6 Continuity

G.6.1 Test apparatus

G.6.1.1 Megohmmeter, with a minimum scale reading of less than $1 \times 10^6\ \Omega$ with a resolution of 5 %.

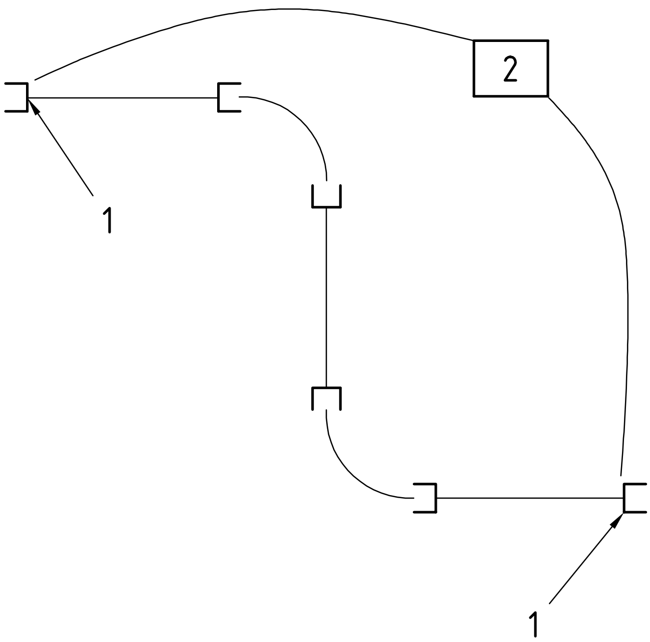
The voltage between the electrodes shall be at least 500 V.

G.6.2 Pipe components

An example of an experimental test set-up is shown in Figure G.1.The assembly shall comprise at least one joint. The total length of assembly, number and type of joints to be included in the test shall be at the discretion of the manufacturer. Both ends of the assembly shall be terminated with an earth-bonding clamp attached in accordance with the manufacturer's instructions. The bonding arrangement used should be as close as possible to actual practice. If an earth clamp is not fitted, an external electrode shall be applied to each end, to provide the necessary conductivity to the surface of the pipe, without causing damage to the surface.

EXAMPLE Conductive paints, conductive adhesive tape or brine-soaked sponges held with clamps.

The earth-bonding clamps or electrodes shall not be connected to earth during the test. The current path length of the assembly shall be calculated according to G.2.5.



Key

1 spool ends

2 megohmmeter attached to ends of spool

Figure G.1 — Example of experimental test set-up

G.6.3 Procedure

Ensure that the test assembly is dry. Connect the megohmmeter between the two earth-bonding clamps or external electrodes at each end of the test assembly. Measure the resistance.

G.6.4 Calculation

Divide the measured resistance by the total path length.

G.6.5 Test report

The test report shall include the following information:

a) complete identification of the pipes/fittings and joints tested including manufacturer's name and code;

b) total length and diameter of pipe/fitting and joint assembly tested;

c) details of megohmmeter, name and model number, resolution capability and voltage applied;

d) results of testing and resistance per length of piping assembly;

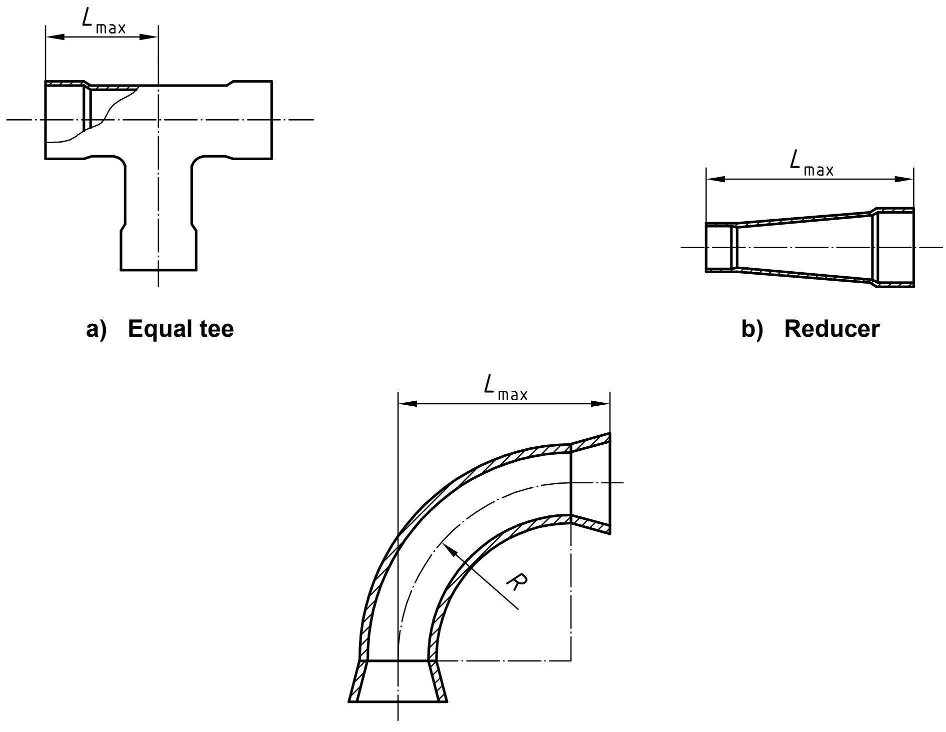
e) date of test.

Annex H
(normative)

Preferred dimensions

The preferred maximum overall length of fittings (bends, tees and reducers), denoted as L_{max} in Figure H.1, should be in accordance with Table H.1 and Table H.2, which are based on components for 2 MPa (20 bar) pressure. Fitting lengths may be longer at higher pressures.

Fitting lengths can in practice be reduced if prefabricated spools (spools fabricated from straight pipe lengths and laminated to form segmental elbows, tees, reducers, etc.) are used instead. For further details of this, reference should be made to the manufacturer.



a) Equal tee

b) Reducer

c) Bend

Figure H.1 — Fittings lengths

Table H.1 — Preferred maximum overall length of bends and tees

Dimensions in millimetres

Nominal pipe diameter	Preferred length L_{max}	
	Bends	Tees
25	100	127
40	120	140
50	167	154
80	235	221
100	330	290
150	420	333
200	540	413
250	540	413
300	753	554
350	700	557
400	780	610
450	827	694
500	928	775
600	1 076	784
700	1 050	784
800	1 200	849
900	1 350	974
1 000	1 500	981
1 100	1 650	942
1 200	1 800	1 143

Table H.2 — Preferred maximum overall length of concentric reducers

Reduced diameter mm	**Maximum diameter** mm																
	40	**50**	**80**	**100**	**150**	**200**	**250**	**300**	**350**	**400**	**500**	**600**	**700**	**800**	**900**	**1 000**	**1 100**
25	200	220															
40		225	300														
50			280	355													
80				395	480												
100					380	600											
150						535	650										
200							645	700									
250								745	750								
300									780	800							
350										785	900						
400											970	1 070					
500												925	1 185				
600													975	1 150			
700														975	1 200		
800															1 000	1 300	
900																1 025	1 350
1 000																	1 050
1 100																	

Annex I
(informative)

Example of enquiry sheet

1. Principal/Agent		
	Principal	**Agent**
Company		
Contact		
Telephone		
Telefax		

2. Project	
Project name	
Location	
Type of system	
Fluid composition	
Special operations	

3. Service conditions	
Design pressure (MPa)	
Service cyclicity and transient loads	
Above-ground or buried system?	
Design external pressure (MPa)	
Maximum fluid temperature (°C)	
Minimum fluid temperature (°C)	
Maximum ambient temperature (°C)	
Minimum ambient temperature (°C)	
Flow velocity and particulate content	

4. Additional items	
Is manufacturer's supervision of installation required?	
Is potable water health certification required?	
If "Yes" above, specify applicable health authorities	
Restrictions on resin/curing agent	
Are resin-rich internal liners required?	
Electrical conductivity requirements	
Fire performance requirements?	
Chemical resistance requirements	

5. Authority		**Signature**		**Date**	
Name					

Annex J
(informative)

Example of qualification summary form

Qualification summary form

1. Manufacturer				
Name		Tel. No.		
Location		Fax. No.		
2. General description				
Component type		Manufacturer designation		
Nominal diameter (mm)		Joint type		
Product sector		Manufacturer designation		
3. Qualified pressure				
p_q or p_{LCL} =		(MPa) at rated temperature of		(°C)
4. Process of manufacture of qualified component				
Manufacturing process procedure	Title			
	Version No.		Issue date:	
Product drawing number				
	Version No.		Issue date:	
5. Materials				
	Reinforced wall		Liner (if applicable)	
Fibre identification				
Resin identification				
Resin type/curing agent				
Additives (specify)				
6. General properties and dimensions				
Nominal unit mass (kg)				
Min. reinforced wall thickness (mm)				
Mean T_g of qualified prototypes (°C)				
Mean glass content of qualified prototypes (% mass fraction)				
Property	**Temperature (°C)**			
	0	23	Rated	
Hoop tensile modulus (MPa)				
Axial tensile modulus (MPa)				
Coefficient of axial thermal expansion (1/°C)				
Axial tensile strength (MPa)				
7. Potable water health certification				
Is health authority certification required?		If "yes", attach copies		

Qualification test details form

1. Qualified component

Component type		Manufacturer pressure rating (MPa)	
Nominal diameter (mm)		Rated temperature (°C)	
Joint type		Manufacturer	
Product sector		Manufacturer designation	

2. 1 000-h test pressure calculation

2.1. Calculation based on representative product regression curve data

Family representative	Type		f_1	
	Nominal diameter (mm)		Gradient, G	
Qualified component (psr or cv)	Proposed p_{LCL} of qualified component (MPa)			
	Min. test pressure (MPa) (=$p_{LCL} \times 10^{2,24 \times G}$)			

2.2 Calculation based on default gradient

Qualified component (psr or cv)	Proposed p_{LCL} (MPa)		Default gradient G	
	Min. test pressure (MPa) (=$p_{LCL} \times 10^{2,24 \times G}$)			

3. 1 000 hour test results

Test sample data			T_g (°C)	Glass content (% mass fraction)	Test conditions		Survival time (h)
No.	Date of manufacture	Production number			Temp (°C)	Pressure (MPa)	
1							
2							
Mean							

4. p_{STHP} results (if applicable)

Test sample data			T_g (°C)	Glass content (% mass fraction)	Test conditions		p_{STHP} MPa
No.	Date of manufacture	Production number			Temp (°C)	Pressure (MPa)	
1							
2							
3							
3							
5							
Quoted p_{STHP}							

4. Qualification report

Title							
Date				Ref. No.			

5. Authority

Name		**Signature**		**Date**	

Annex K
(normative)

Least-square method for calculating the long-term hydrostatic pressure from regression data

K.1 General

The analysis is concerned with fitting the best straight line fit through a fixed number, n, of data points, (x_i, y_i). The analysis is based on the following relationship;

$$y = a + bx \quad \text{(K.1)}$$

where

y is the dependent variable;

x is the independent variable;

b is the slope or gradient of the line;

a is the intercept of line with the y axis.

A linear functional relationship analysis is used, subject to tests for sign of the slope and appropriateness of data. The relevant equations are given together with example data and results, on the basis of which any other statistical package may be used subject to validation by agreement with the example results to within indicated limits.

For the purposes of this annex, a standard service life of 20 years is assumed.

K.2 Procedure for analysis of data

A linear functional analysis is used to calculate the following information based on n pairs of data values, y and x:

— the slope of the line, b;

— the intercept of the line with the y axis, a;

— the correlation coefficient, r;

— the predicted mean and 95 % lower confidence limit (p_{LCL}) at the design life.

K.3 Assignment of variables

Let x be lg(t), where t is the time, in hours.

Let y be lg(p), where p is the pressure, or stress, in megapascals.

K.4 Functional relations and basic statistics

K.4.1 Basic statistics — Definitions

The following basic symbols and definitions are used:

n = the number of observed data points (t_i, p_i);

y_i = $\lg(p_i)$, where p_i is the pressure or stress at failure of observation i, where i = 1, n;

x_i = $\lg(t_i)$, where t_i is the time at failure of observation i, where i = 1, n.

$\bar{y}$ = arithmetic mean of y_i, $\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$ (K.2)

$\bar{x}$ = arithmetic mean of x_i, $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ (K.3)

K.4.2 Sums of squares — Definitions

The sum of squares cross-product, S_{xy}, is:

$$S_{xy} = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y}) \quad \text{(K.4)}$$

If $S_{xy} > 0$, then the data are unsuitable for analysis.

The sum of squares of x_i, S_{xx} is:

$$S_{xx} = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2 \quad \text{(K.5)}$$

The sum of squares of y_i, S_{yy} is:

$$S_{yy} = \frac{1}{n}\sum_{i=1}^{n}(y_i - \bar{y})^2 \quad \text{(K.6)}$$

K.4.3 Correlation of data

The correlation coefficient, r, is defined as;

$$r^2 = \frac{\left(S_{xy}\right)^2}{S_{xx}S_{yy}} \quad \text{where} \quad r = \sqrt{r^2} \quad \text{(K.7)}$$

If the value of r is less than:

$$r < \frac{\text{Student's } t(f)}{\sqrt{n - 2 + \left[\text{Student's } t(f)\right]^2}}$$

then the data are unsuitable for analysis.

Table K.1 lists the minimum acceptable values of the correlation coefficient, r, as a function of number of variables, n. The Student's t value is based on a two-sided 0,01 level of significance.

Table K.1 — Minimum values of the correlation coefficient, r, for acceptable data from n pairs of data

Number of variables n	Degrees of freedom n–2	Student's t(0,01)	Minimum r	Number of variables n	Degrees of freedom n–2	Student's t(0,01)	Minimum r
13	11	3,106	0,6835	26	24	2,797	0,4958
14	12	3,055	0,6614	27	25	2,787	0,4869
15	13	3,012	0,6411	32	30	2,750	0,4487
16	14	2,977	0,6226	37	35	2,724	0,4182
17	15	2,947	0,6055	42	40	2,704	0,3932
18	16	2,921	0,5897	47	45	2,690	0,3721
19	17	2,898	0,5751	52	50	2,678	0,3542
20	18	2,878	0,5614	62	60	2,660	0,3248
21	19	2,861	0,5487	72	70	2,648	0,3017
22	20	2,845	0,5368	82	80	2,639	0,2830
23	21	2,831	0,5256	92	90	2,632	0,2673
24	22	2,819	0,5151	102	100	2,626	0,2540
25	23	2,807	0,5052				

K.5 Calculation of the mean regression line coefficients, a and b

The gradient of the regression line, b is:

$$b = -\sqrt{\lambda} \tag{K.8}$$

where

$$\lambda = \frac{S_{yy}}{S_{xx}}$$

The intercept of the regression line, a, is:

$$a = \overline{y} - b\overline{x} \tag{K.9}$$

NOTE 1 The gradient, b, takes the sign of S_{xy}

NOTE 2 Since $y = \lg(p)$ and $x = \lg(t)$ implies that $p = 10^y$ and $t = 10^x$. The relationship for p in terms of t is: $p = 10^{\left[a + b\lg(t)\right]}$.

K.6 Calculation of error and variance

K.6.1 Definitions — Error

If t_L is the applicable time to failure, then $x_L = \lg(t_L)$.

The error variance is based on the error in y, i.e. difference in predicted Y and measured y for a given x. It is defined as:

$$\sigma^2 = \frac{\sum_{i=1}^{n}(y_i - Y_i)^2}{(n-2)} = \frac{\sum_{i=1}^{n}(y_i - a - bx_i)^2}{(n-2)} \tag{K.10}$$

K.6.2 Total variance

The predicted value of y, Y_L, for a given x, x_L, is given by:

$$Y_\mathrm{L} = a + bx_\mathrm{L} \tag{K.11}$$

The total variance of an individual observation $Y_{\mathrm{L},i}$, Var($Y_{\mathrm{L},i}$), about the predicted mean value, Y_L, is given by:

$$\mathrm{Var}(Y_{\mathrm{L},i}) = \sigma^2 + \mathrm{Var}(Y_\mathrm{L}) = \sigma^2 + \mathrm{Var}(\bar{y}) + (x_\mathrm{L} - \bar{x})^2\,\mathrm{Var}(b) \tag{K.12}$$

The variance for the mean value of $\bar{y}$, Var(y), is given by:

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i \quad \Rightarrow \quad \mathrm{Var}(\bar{y}) = \frac{1}{n^2}\sum_{i=1}^{n}\mathrm{Var}(y_i) = \frac{1}{n^2} n\sigma^2 = \frac{\sigma^2}{n} \tag{K.13}$$

The variance of the gradient of the mean regression line, Var(b), is given by:

$$\mathrm{Var}(b) = \frac{\sigma^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}\left[(n-1) - 2\left\{\frac{\Gamma(n/2)}{\Gamma\left[(n-1)/2\right]}\right\}^2\right] \tag{K.14}$$

The total variance, Var($Y_{\mathrm{L},i}$), for future values of Y_L, for y at x_L is therefore given by [substituting Equations (K.13) and (K.14) into Equation (K.12)]:

$$\mathrm{Var}(Y_{\mathrm{L},i}) = \sigma^2\left(1 + \frac{1}{n} + \frac{(x_\mathrm{L} - \bar{x})^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}\left[(n-1) - 2\left\{\frac{\Gamma(n/2)}{\Gamma\left[(n-1)/2\right]}\right\}^2\right]\right) \tag{K.15}$$

where $\Gamma(n)$ is the gamma function of order n.

K.7 Calculation of the lower confidence limits

The lower confidence limit, p_LCL, is calculated as follows:

$$Y_{\mathrm{LCL}(95\,\%)} = Y_\mathrm{L} - t_v\sqrt{\mathrm{Var}(Y_\mathrm{L})}$$

$$= Y_\mathrm{L} - t_v\sigma\sqrt{\left(\frac{1}{n} + \frac{(x_\mathrm{L} - \bar{x})^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}\left[(n-1) - 2\left\{\frac{\Gamma(n/2)}{\Gamma\left[(n-1)/2\right]}\right\}^2\right]\right)} \tag{K.16}$$

The lower prediction limit, p_{LPL}, is calculated as follows;

$$Y_{LCL(95\,\%)} = Y_L - t_v \sqrt{\mathrm{Var}(Y_{L,i})}$$

$$= Y_L - t_v \sigma \sqrt{\left(1 + \frac{1}{n} + \frac{(x_L - \bar{x})^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2} \left[(n-1) - 2\left\{ \frac{\Gamma(n/2)}{\Gamma\left[(n-1)/2\right]} \right\}^2 \right] \right)} \tag{K.17}$$

where

Y_L is given by $Y_L = a + bx_L$;

t_v is the Student's t value and is based on a two-sided 0,05 level of significance, i.e. 95 % lower confidence limit. Values of t_v are given as a function of number of variables, n, in Table K.2.

Table K.2 — Student's t value for double-sided 0,05 level of significance

Number of variables n	Degrees of freedom n–2	Student's t(0,025) t_v	Number of variables n	Degrees of freedom n–2	Student's t(0,025) t_v
13	11	2,201	26	24	2,064
14	12	2,179	27	25	2,060
15	13	2,160	32	30	2,042
16	14	2,145	37	35	2,030
17	15	2,131	42	40	2,021
18	16	2,120	47	45	2,014
19	17	2,110	52	50	2,009
20	18	2,101	62	60	2,000
21	19	2,093	72	70	1,994
22	20	2,086	82	80	1,990
23	21	2,080	92	90	1,987
24	22	2,074	102	100	1,984
25	23	2,069			

K.8 Worked example

K.8.1 Data set

A worked example is presented summarizing the calculations outlined in K.1 to K.7. Table K.3 presents the sample data set given for illustration purposes.

Table K.3 — Data set

Data point	Time h	lg(time)	Stress psi	Stress MPa	lg(stress)
1	9	0,954 2	5 500	37,917	1,578 8
2	13	1,113 9	5 500	37,917	1,578 8
3	17	1,230 4	5 500	37,917	1,578 8
4	17	1,230 4	5 500	37,917	1,578 8
5	104	2,017 0	5 200	35,849	1,554 5
6	142	2,152 2	5 200	35,849	1,554 5
7	204	2,309 6	5 200	35,849	1,554 5
8	209	2,320 1	5 200	35,849	1,554 5
9	272	2,434 6	5 000	34,470	1,537 4
10	446	2,649 3	5 000	34,470	1,537 4
11	466	2,668 4	5 000	34,470	1,537 4
12	589	2,770 1	4 800	33,091	1,519 7
13	669	2,825 4	4 700	32,402	1,510 6
14	684	2,835 1	5 000	34,470	1,537 4
15	878	2,943 5	4 600	31,712	1,501 2
16	1 299	3,113 6	4 800	33,091	1,519 7
17	1 301	3,114 3	4 700	32,402	1,510 6
18	1 430	3,155 3	4 800	33,091	1,519 7
19	1 710	3,233 0	4 800	33,091	1,519 7
20	2 103	3,322 8	4 800	33,091	1,519 7
21	2 220	3,346 4	4 500	31,023	1,491 7
22	2 230	3,348 3	4 400	30,334	1,482 0
23	3 816	3,581 6	4 700	32,402	1,510 6
24	4 110	3,613 8	4 700	32,402	1,510 6
25	4 173	3,620 4	4 600	31,712	1,501 2
26	5 184	3,714 7	4 400	30,334	1,481 9
27	8 900	3,949 4	4 600	31,712	1,501 2
28	8 900	3,949 4	4 600	31,712	1,501 2
29	10 900	4,037 4	4 500	31,023	1,491 7
30	10 920	4,038 2	4 500	31,023	1,491 7
31	12 340	4,091 3	4 500	31,023	1,491 7
32	12 340	4,091 3	4 500	31,023	1,491 7

K.8.2 Basic statistics (K.4.1)

Mean y, $\overline{y}$	1,523	Equation (K.2)
Mean x, $\overline{y}$	2,930	Equation (K.3)

K.8.3 Sums of squares (K.4.2)

S_{xy}	− 0,0248	Equation (K.4)
S_{xy} **< 0, therefore data suitable**		
S_{xx}	0,798 1	Equation (K.5)
S_{yy}	0,000 88	Equation (K.6)

K.8.4 Correlation of data (K.4.3)

Correlation coefficient, r	0,938 1	Equation (K.7)
Minimum acceptable, r_{min}	0,448 7	Table K.1
$r > r_{min}$, **therefore data suitable**		

K.8.5 Mean regression line coefficients (K.5)

a	1,620 7	Equation (K.9)
λ	0,001 1	Equation (K.8)
b	− 0,033 2	Equation (K.8)

K.8.6 Error (K.6.1)

Error variance, σ^2	0,00011601	Equation (K.10)

K.8.7 Total variance (K.6.2)

Variance, $\overline{y}$	3,6254E-06	Equation (K.13)
Variance, b	2,2526E-06	Equation (K.14)
Student's t, t_v (95 %)	2,042	Table K.2

K.8.8 Calculation of the mean and 95 % lower confidence limit (K.7)

Time h	**lg(time)**	**lg(press.)**	**Pressure** MPa	lg(p_{LCL})	p_{LCL} MPa	lg(p_{LPL})	p_{LPL} MPa
10	1	1,588	38,682	1,580	38,057	1,564	36,677
100	2	1,554	35,837	1,550	35,442	1,532	34,026
1000	3	1,521	33,202	1,517	32,906	1,499	31,537
10000	4	1,488	30,760	1,483	30,402	1,465	29,202
100000	5	1,455	28,498	1,447	28,014	1,431	27,014
175 400 (20 years)	5,244	1,447	27,973	1,439	27,457	1,423	26,503
437 520 (50 years)	5,641	1,434	27,135	1,424	26,568	1,410	25,686
1 000 000	6	1,422	26,402	1,411	25,791	1,397	24,969
		Equation (K.11)		Equation (K.16)		Equation (K.17)	

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