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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: Qualification et fabrication

Reference number
ISO 14692-2:2017(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document 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*.

This second edition cancels and replaces the first edition (ISO 14692-2:2002), which has been technically revised. It also incorporates the Technical Corrigendum ISO 14692-2:2002/Cor 1:2005.

A list of all the parts of ISO 14692 can be found on the ISO website.

Introduction

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

The qualification programme and the quality programme are the most significant clauses in this document.

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

Part 2: Qualification and manufacture

1 Scope

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

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 resins — Determination of the residual styrene monomer content, as well as the content of other volatile aromatic hydrocarbons, by gas chromatography*

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

ISO 11359-2, *Plastics — Thermomechanical analysis (TMA) — Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature*

ISO 14130, *Fibre-reinforced plastic composites — Determination of apparent interlaminar shear strength by short-beam method*

ISO 14692-1:2017, *Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping — Part 1: Vocabulary, symbols, applications and materials*

ISO 14692-3:2017, *Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping — Part 3: System design*

ISO 14692-4:2017, *Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping — Part 4: Fabrication, installation, inspection and maintenance*

API 15HR, Specification for high pressure fiberglass line pipe, Fourth Edition

ASME RTP-1-2007, *Reinforced thermoset plastic corrosion-resistant equipment*

ASTM D638, *Standard test method for tensile properties of plastics*

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

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

IMO MSC.61(67), *Adoption of the International Code for application of fire test procedures*

IMO Resolution A.653(16), *Fire test procedures for surface flammability of bulkhead, ceiling and deck finsh materials as amended by Resolution IMO MSC.61(67): Annex 1 Part 5*

3 Terms, definitions, symbols and abbreviated terms

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Manufacturer's declarations

4.1 Procedure

Prior to the start of the qualification programme, the manufacturer shall declare:

a) G_{xx};

b) MPR_{xx};

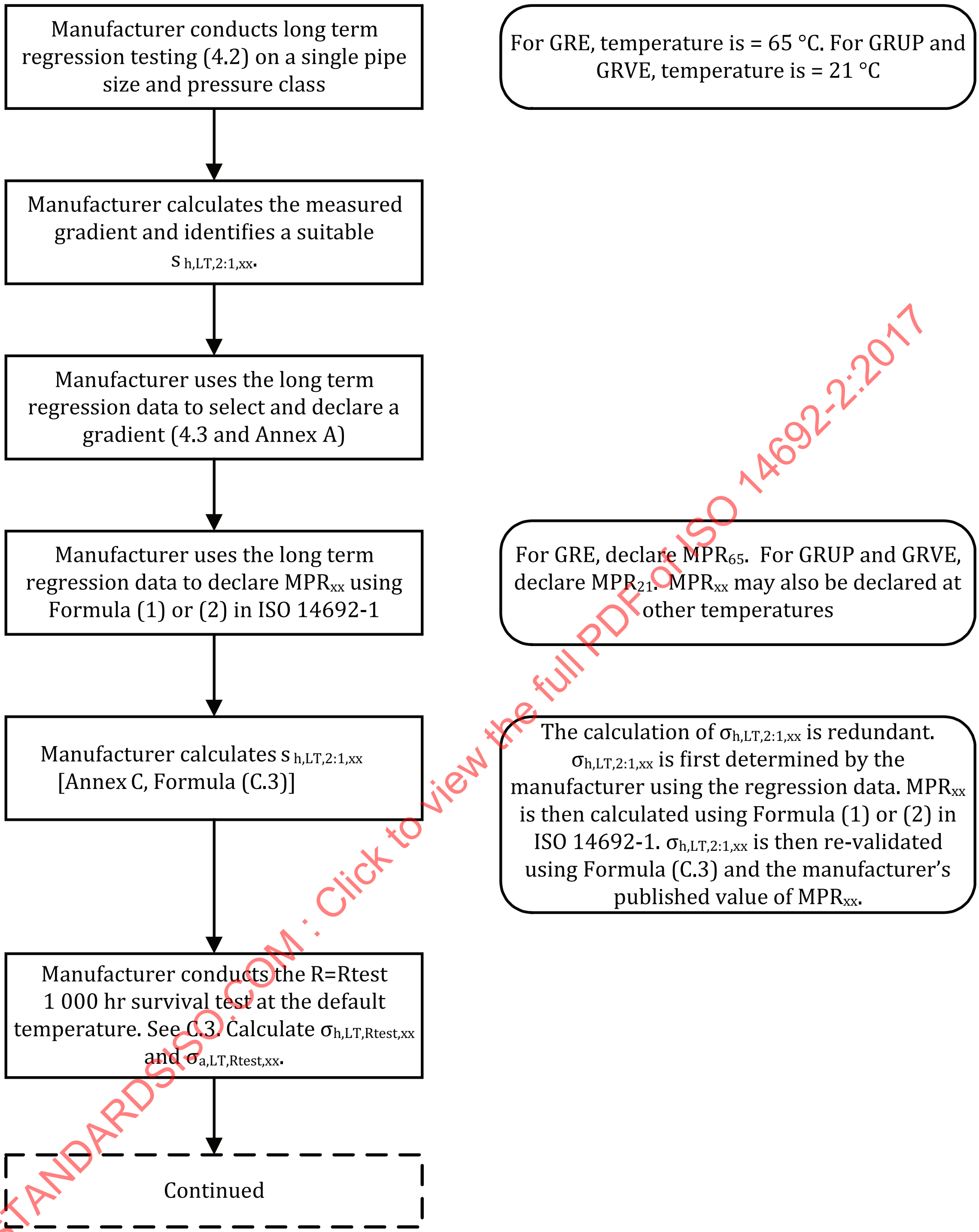
c) the long term envelope data points;

d) the threshold envelope data points;

e) dimensional data;

f) baseline values for degree of cure, barcol hardness (GRUP and GRVE only) and glass content, where applicable.

The data shall be based on a standard design life of 20 years. Figure 1 provides a flowchart of the procedure for declaring the manufacturer's data.


Manufacturer conducts long term regression testing (4.2) on a single pipe size and pressure class
For GRE, temperature is = 65 °C. For GRUP and GRVE, temperature is = 21 °C
Manufacturer calculates the measured gradient and identifies a suitable $s_{h,LT,2:1,xx}$.
Manufacturer uses the long term regression data to select and declare a gradient (4.3 and Annex A)
Manufacturer uses the long term regression data to declare MPR_{xx} using Formula (1) or (2) in ISO 14692-1
For GRE, declare MPR_{65}. For GRUP and GRVE, declare MPR_{21}. MPR_{xx} may also be declared at other temperatures
Manufacturer calculates $s_{h,LT,2:1,xx}$ [Annex C, Formula (C.3)]
The calculation of $\sigma_{h,LT,2:1,xx}$ is redundant. $\sigma_{h,LT,2:1,xx}$ is first determined by the manufacturer using the regression data. MPR_{xx} is then calculated using Formula (1) or (2) in ISO 14692-1. $\sigma_{h,LT,2:1,xx}$ is then re-validated using Formula (C.3) and the manufacturer's published value of MPR_{xx}.
Manufacturer conducts the R=Rtest 1 000 hr survival test at the default temperature. See C.3. Calculate $\sigma_{h,LT,Rtest,xx}$ and $\sigma_{a,LT,Rtest,xx}$.
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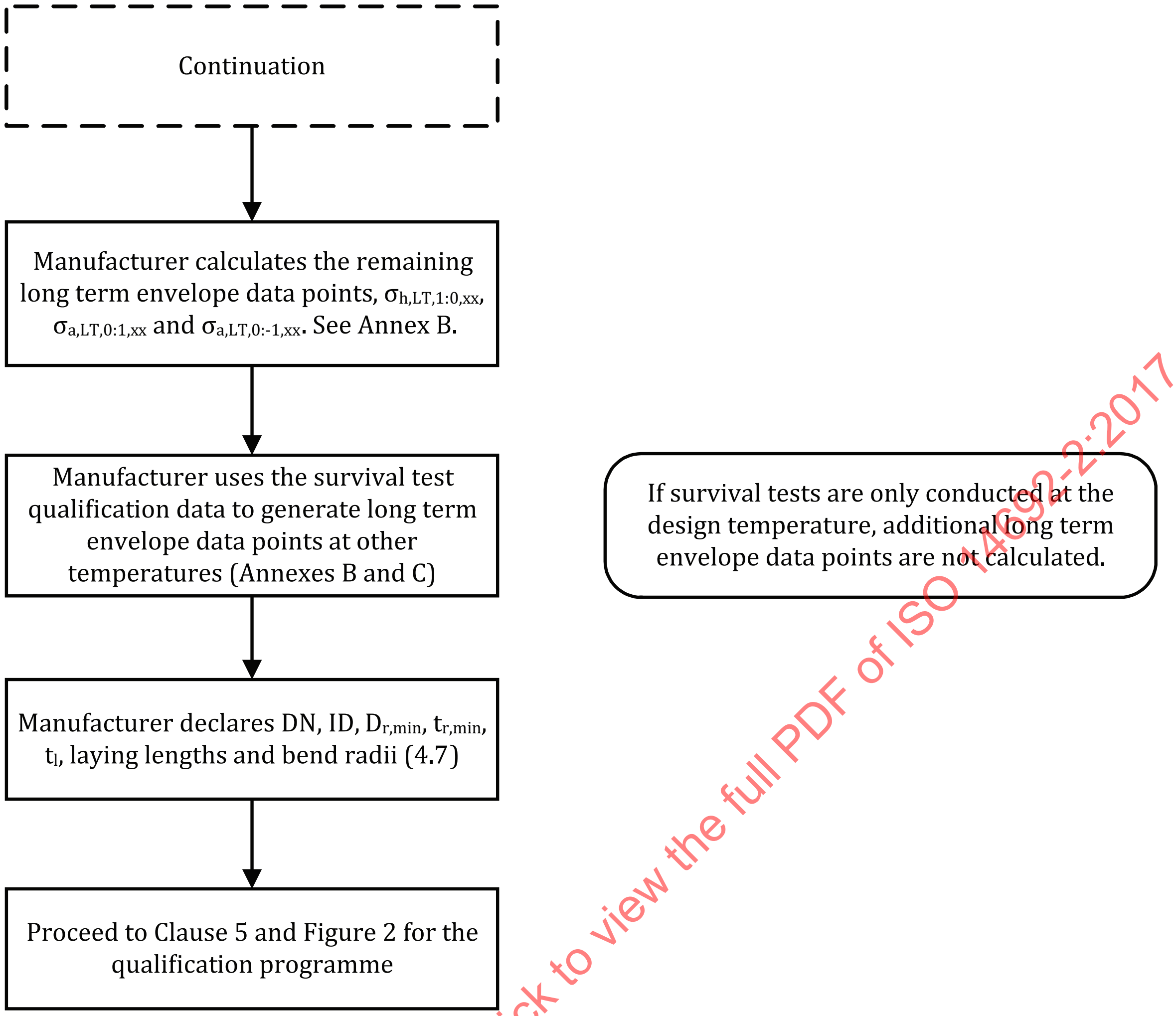


Figure 1 — Procedure for declaring manufacturer's data

4.2 Long term regression testing

The manufacturer shall provide at least one full regression curve as per ASTM D2992 as modified in this subclause and in 5.1. The regression curve shall be at 65 °C or higher for GRE and 21 °C or higher for GRUP or GRVE.

The manufacturer's gradient from the full regression curve shall be compared with the values in Table A.1 and a gradient can be selected per the process in Annex A.

NOTE 1 The one full regression curve does not have to be at or above the design temperature of the project. For example, the enquiry sheet specifies a design temperature of 93 °C and the manufacturer has a full regression curve at 85 °C for GRE-Aliphatic Amine. Since the resin matrix is GRE and the temperature of the full regression curve is above 65 °C, the data are acceptable. On the other hand, validation of the long term envelope via survial tests would have to be performed at the design temperature of the project.

The manufacturer shall conduct the long term regression on either a plain pipe or a pipe+joint, for one pipe diameter only, the diameter to be determined by the manufacturer.

NOTE 2 For economical and practical reasons, long term regression testing is typically conducted on small diameters. The recommended minimum pipe size is DN50. Data seems to be more consistent as the size increases (i.e. DN100 test results seem to be more consistent than DN50 test results).

The $D_{r,min}/t_{r,min}$ ratio of the pipe size shall be within the range of published $D_{r,min}/t_{r,min}$ ratios that are to be qualified. Ideally, the $D_{r,min}/t_{r,min}$ ratio of the pipe size should be close to the average $D_{r,min}/t_{r,min}$ ratio of all of the pipe sizes to be qualified. It is not desirable to have the $D_{r,min}/t_{r,min}$ ratio of the pipe size at either extreme.

The test fluid shall be potable water. For testing completed prior to the publication of this document, the test fluid may be salt water. In this case, the salt content shall be specified and shall not be greater than 35 g/L. The intention of this requirement is to allow validation of existing test data, but to require potable water for future testing. Potable water is a more aggressive test medium than salt water. Test data using mineral oil should be rejected since mineral oil is not a degrading agent to the bond between the glass fibres and the resin matrix.

All tests shall be conducted with unrestrained (i.e. "free") ends.

4.3 Gradient, G_{xx}

The manufacturer shall declare gradient, G_{xx}, in accordance with Annex A.

4.4 MPR_{xx}

MPR_{xx} shall be defined in accordance with ISO 14692-1:2017, 4.1.

For design temperatures in excess of 65 °C for GRE and 21 °C for GRUP and GRVE, the manufacturer shall also publish MPR_{xx} at the design temperature or higher.

The following shall be taken into account:

a) Default temperatures are 65 °C (MPR_{65}) for GRE and 21 °C (MPR_{21}) for GRVE and GRUP. For clarity, MPR shall always be published with a temperature subscript (e.g. MPR_{65} or MPR_{21}, not *MPR*).

b) The default temperature for GRE is established at 65 °C since this temperature is at or above the design temperature for many typical GRE applications and since many manufacturers have conducted qualification testing for pressure at this temperature.

c) The default temperature for GRUP is established at 21 °C since there are many applications for GRUP near ambient temperature and the amount of qualification testing for pressure by manufacturers at 65 °C is less than that at 21 °C to 50 °C.

d) GRVE can be suitable for applications at temperatures above 65 °C. However, the amount of qualification testing for pressure above 65 °C by manufacturers is very small. Like GRUP, there is more qualification data between 21 °C to 50 °C, thus the default temperature for GRVE is established at 21 °C.

e) The manufacturer uses the survival tests to validate MPR_{xx} (see 5.3.1).

4.5 Partial factors

4.5.1 Partial factor for design lifetime, A_0

The partial factor for design lifetime, A_0, is specified in ISO 14692-3:2017, 6.1.1.

4.5.2 Partial factor for chemical degradation, A_2

The partial factor for chemical degradation, A_2, shall be 1,0.

NOTE 1 It is the resin rich liner, not the structural cage, that is designed to prevent chemical degradation. A partial factor applied to the reinforced wall thickness would provide little to no value in preventing chemical degradation.

NOTE 2 Water permeates thermoset resins quite quickly. The silane coupling agent is the key component providing resistance to breakdown from water attack. Without the silane coupling agent, water permeation would occur followed by a breakdown of the bond between the glass and resin followed by etching of the fibers and finally fiber failure.

NOTE 3 While the silane coupling agent provides resistance to breakdown from water attack, other chemicals can attack the bond between the resin and the glass reinforcement. Some of these chemicals include strong acids and bases such as sodium hydroxide. It is these chemicals that require a resin-rich, reinforced liner of sufficient thickness to protect the structural layers from permeation of these chemicals and attack of the bond between the glass and the resin. Most of these chemicals do not permeate quickly, so practical liners are possible. Other standards, such as ASTM D3681 or EN 13121-2, can be suitable as a qualification programme to predict the thickness of the liner based on exposure to various chemicals in a stressed condition.

4.5.3 Partial factor for cyclic loading, A_3

The partial factor for cyclic loading, A_3, is specified in ISO 14692-3:2017, 6.1.3.

4.6 Long term envelope data points

The manufacturer shall declare and demonstrate the long term envelope data points ($\sigma_{h,LT,2:1,xx}$, $\sigma_{a,LT,2:1,xx}$, $\sigma_{h,LT,0:1,xx}$, $\sigma_{a,LT,0:1,xx}$, $\sigma_{h,LT,Rtest,xx}$, $\sigma_{a,LT,Rtest,xx}$, $\sigma_{a,LT,0:-1,xx}$ and $\sigma_{h,LT,1:0,xx}$) and the threshold envelope data points ($\sigma_{h,thr,2:1}$, $\sigma_{a,thr,2:1}$, $\sigma_{h,thr,Rtest}$, $\sigma_{a,thr,Rtest}$, $\sigma_{a,thr,0:-1}$ and $\sigma_{h,thr,1:0}$) by testing in accordance with Annex B. The threshold envelope data points do not have a temperature subscript as the threshold is defined, by default, at 65 °C for GRE and 21 °C for GRUP and GRVE.

Long term envelope data points are defined at temperatures. To calculate a long term envelope data point, survival tests on pipe(s), joint(s) and fitting(s) are required at the design temperature (or higher) in accordance with Annex C.

4.7 Dimensions

The manufacturer shall declare the following dimensions:

a) DN;

b) ID;

c) $D_{r,min}$ and $t_{r,min}$;

d) t_l;

e) laying lengths;

f) bend radii (for elbows).

The nominal diameter should be agreed between the manufacturer and principal.

4.8 Baseline values

The manufacturer shall declare basline values for quality control puposes for the following:

a) degree of cure;

b) barcol hardness (GRUP and GRVE only);

c) glass content.

The manufacturer shall select samples from standard production to determine the baseline values.

Samples for baseline testing should be taken from standard production to ensure that results are being obtained across the entire standard deviation of the population. Samples for baseline testing should not be limited to the 1 000 h qualification samples since these samples can be anywhere within the standard deviation of the population.

4.9 Flexibility factors and SIFs

The manufacturer shall declare flexibility factors for bends in accordance with ISO 14692-3:2017, 7.4. The manufacturer shall declare SIFs for bends and tees in accordance with ISO 14692-3:2017, 7.5.

4.10 Production processes and jointing instructions

The manufacturer shall declare general production processes and jointing instructions sufficient to verify that the scaling rules in Annex F have been met. Proprietary processes need not be disclosed.

5 Qualification programme

5.1 General

The qualification programme is a one-time process. If the manufacturer has test data from a previous project, the manufacturer may have the option to use this data on other projects. However, the principal may also have the option to require one or more of the tests in Table 1 to be conducted for their particular project. These tests shall be specified on the enquiry sheet (refer to ISO 14692-1:2017, Annex D). The principal may also have the option, via the enquiry sheet in ISO 14692-1:2017, Annex D, to specify which tests, if any, shall be conducted by a laboratory that meets ISO/IEC 17025.

The qualification programme shall be based on a standard design life of 20 years. A_0 shall be used to scale the design envelope to other design lives. A_0 shall not be greater than 1,0.

The test fluid for the qualification procedure for pressure and temperature shall be potable water. See also 4.2 for a clarification of the test fluid.

All tests involving internal pressure shall be conducted with unrestrained (i.e. "free") ends.

Table 1 provides a summary of the qualification programme. Figure 2 shows a flowchart of the procedure for product qualification. Figure 3 shows a flowchart of the procedure for determining elastic properties.

Permanent repair procedures shall be qualified according to this qualification programme.

NOTE The manufacturer's repair procedures that only involve qualified components may not need any additional qualification.

When joints are qualified, the joint shall be made in accordance with the manufacturer's declared joint instructions. This qualifies both the joint and its joint instructions.

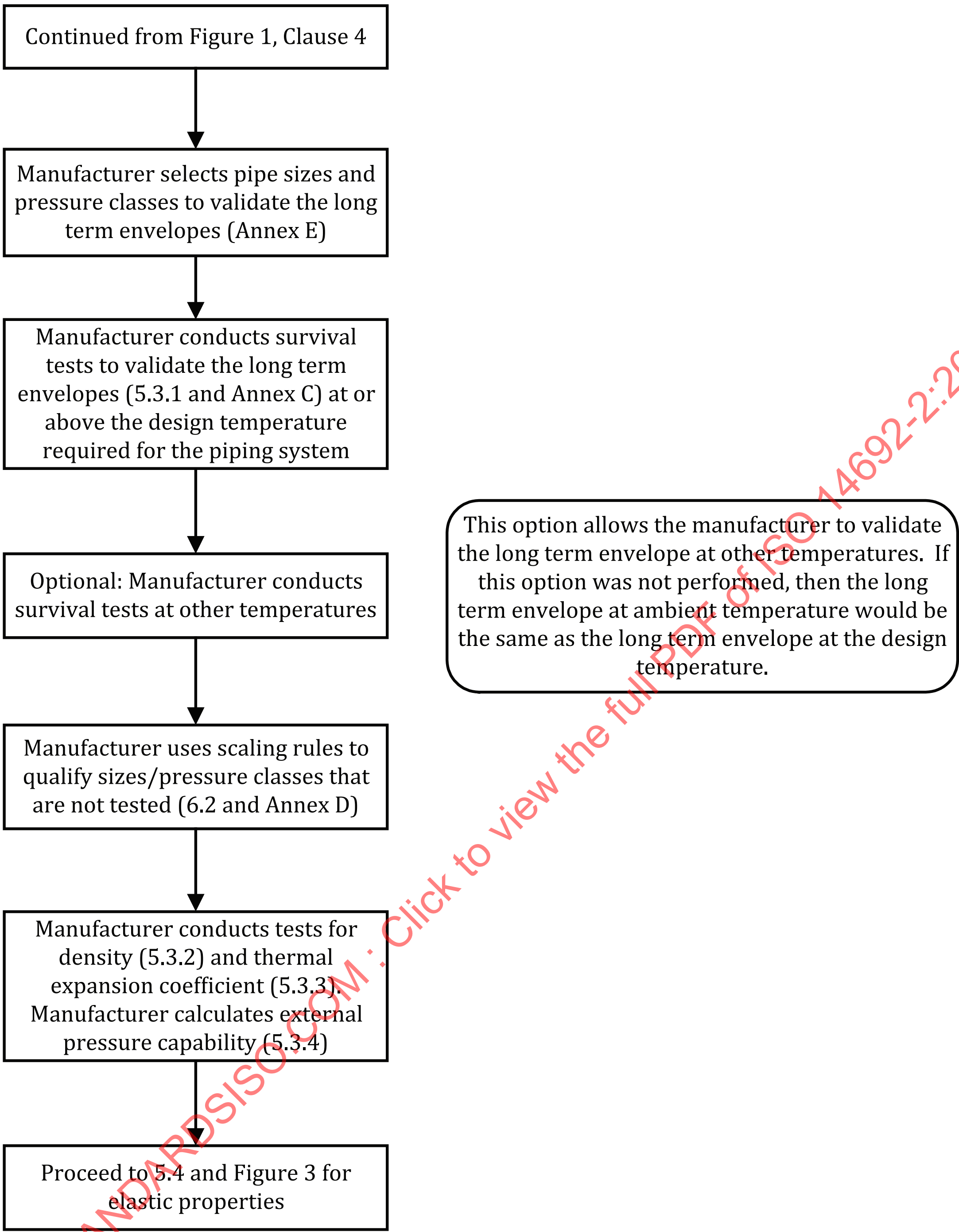


Figure 2 — Procedure for the product qualification portion of the qualification programme

Table 1 — Summary of the qualification programme

No	Ref.	Test procedure	Product(s)	Generated data	Use
Product qualification					
1	4.2	ASTM D2992	Plain pipe or pipe + joint, one size	Measured G_{xx}	To validate $rd_{1\ 000}$
2	C.2.2	ASTM D1598 as modified in 5.3.1	Plain pipe or pipe + joint, one size	$R = R_{test}$ survival test	To validate the $R = R_{test}$ data point on the threshold and long term envelopes
3	5.3.1	ASTM D1598 as modified in 5.3.1	Plain pipe, sizes per 5.2 and Annex E	Survival test	To validate the threshold and long term envelopes
4	5.3.1	ASTM D1598 as modified in 5.3.1	Pipe+joint and fittings, sizes per 5.2 and Annex E	Survival test	To validate the threshold and long term envelopes
5	5.3.1 and Annex F	ASTM D1598 as modified in 5.3.1	Flanges, sizes per 5.2 and Annex E	Survival test	To validate the threshold and long term envelopes
6		10 cycle pressure test			
7		Vacuum test			
8		Combined loading test			
9	5.3.2	Manufacturer's standard	Plain pipe, one pipe size	ρ	Weight
10	5.3.3	Manufacturer's standard or ASTM D696 or ISO 11359-2	Plain pipe, one pipe size	α_a	Axial pipe deflection
11	5.3.4	ISO 14692-3:2017, 7.9 (by calculation)		External collapse pressure	Hoop pipe stability
Elastic properties					
12	5.4.2	ASTM D2105	Plain pipe, one pipe size	E_a	
13	5.4.3	Per API 15HR	Plain pipe, one pipe size	E_h and ν_{ah}	
14	5.4.4	Per Annex G	Plain pipe, one pipe size	ν_{ha}	
15	5.4.5	ASTM D2412 (buried applications only)	Plain pipe, one pipe size	E_{hb}	Hoop pipe stability, stiffness

5.2 Scaling rules

The components to be tested can be any combination of diameter, pressure class and product type. Requirements for the selection of diameter, pressure class and product type can be found in Annex E.

Once the diameters and pressure classes have been selected and the components have been tested, the manufacturer shall then use scaling rules to qualify all other components. Requirements for scaling rules can be found in Annex D.

5.3 Product qualification

5.3.1 Validation of long term envelopes

The manufacturer shall conduct survival test(s) on pipes, pipes + joints, fittings and flanges in accordance with ASTM D1598 with the following modifications:

a) the requirements in 5.1 shall apply;

b) the qualification temperature (i.e. the test temperature) for at least one set of survival tests shall be equal to or greater than the design temperature;

NOTE 1 A set is two samples of each size/component to be tested. The intention is to require the manufacture to conduct the necessary survival tests at the design temperature (or higher) of the project. A set of survival tests may also be conducted at other lower temperatures.

c) two samples of each component/size shall be tested;

d) the size(s) to be tested shall be determined in accordance with Annex E;

e) the survival test time and pressure shall be calculated in accordance with Annex C;

f) the test specimen shall show no signs of weepage or leakage during the test (i.e. the test is a survival test);

g) the calculations in ASTM D1598 are not required;

h) for the $R = R_{\text{test}}$ survival test, modifications to ASTM D1598 are in accordance with Annex C.

NOTE 2 Components can be tested individually or combined as a single test specimen (e.g. a manufacturer who needs to qualify a pipe, joint, bend, tee and flange in one size may elect to conduct five tests; one for the pipe, one for the pipe + joint, one for the bend, one for the tee and one for the flange or the manufacturer can elect to conduct a single test on an assembly with the pipe, joint, bend, tee and flange). However, it is likely that the pipe will have to be tested separately from the fitting/joint since the $P_{\text{T1 000,xx}}$ of the pipe will be higher than the $P_{\text{T1 000,xx}}$ of the fitting/joint.

Additional requirements for flanges are in Annex F.

NOTE 3 Unlike testing for elastic properties, pre-conditioning prior to survival testing is not required, but can be performed by the manufacturer.

Repeated failures of these survival tests should require reduction of the MPR_{xx}.

5.3.2 Density

The density, ρ, shall be calculated in accordance with the manufacturer's standard.

5.3.3 Thermal expansion coefficient

The thermal expansion coefficient, α_{a}, shall be calculated in accordance with ASTM D696 or ISO 11359-2.

5.3.4 Qualification procedure for external pressure

The external pressure capability of pipes shall be calculated by analytical methods in accordance with ISO 14692-3:2017, 7.9.

5.4 Elastic properties

5.4.1 General

Figure 3 shows a flowchart of the procedure for determining elastic properties.

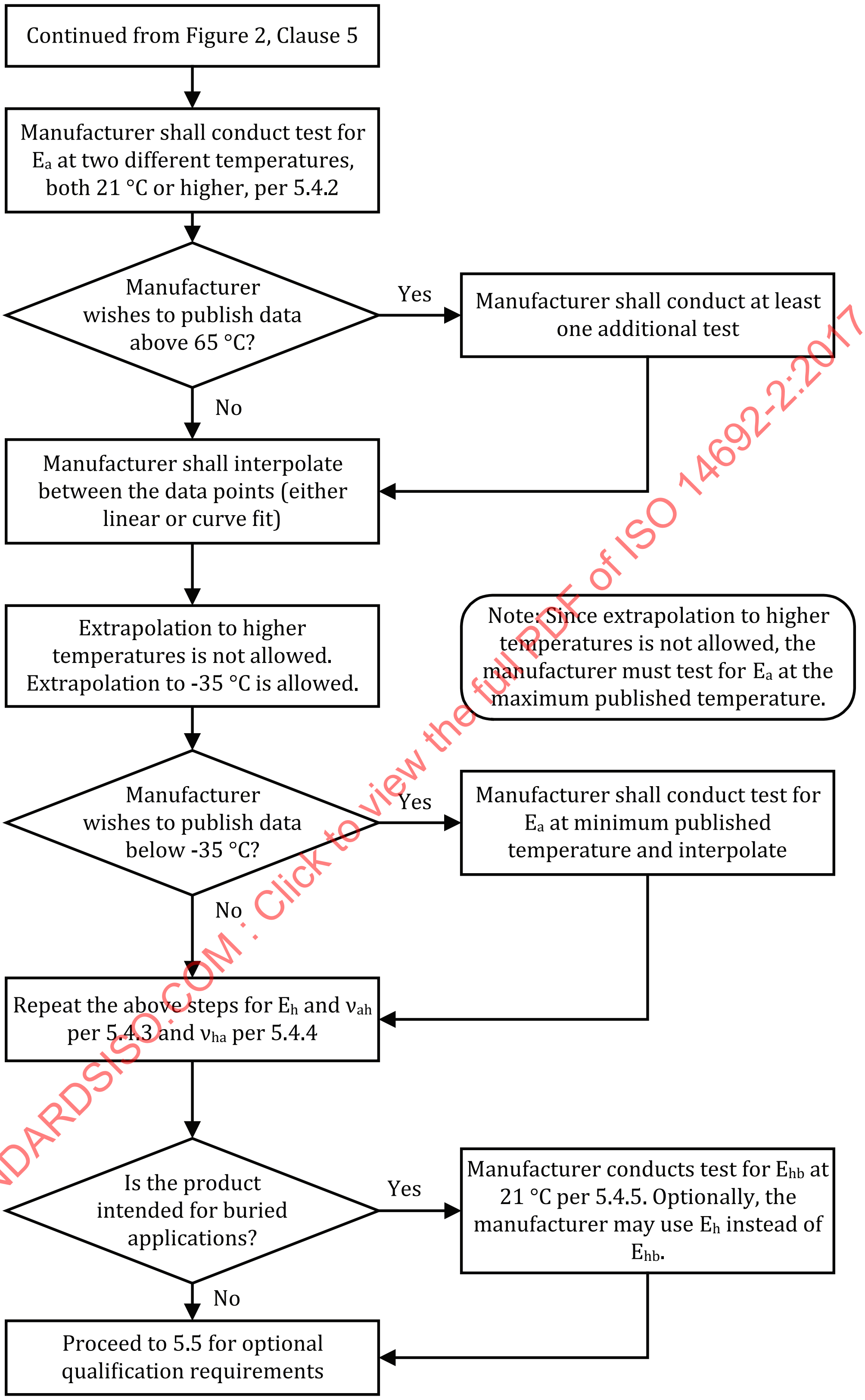


Figure 3 — Procedure to determine elastic properties

NOTE 1 Wind angle and layer thickness appear to be more important to elastic properties than the resin matrix or the curing agent.

Elastic properties, such as E_a and ν_{ah} will vary by temperature. Manufacturers should provide elastic properties as a function of temperature for accurate pipeline analysis.

NOTE 2 For GRE, when the temperature is well below the glass transition temperature (T_g) of the resin, the elastic properties do not appear to deviate from one GRE resin matrix to another GRE resin matrix when the layer thickness of the sample remains the same. It can be feasible to allow elastic properties for one GRE resin matrix to be used for other GRE resin matrices.

NOTE 3 Most manufacturers measure elastic properties separately in the hoop and axial direction. Elastic properties measured this way usually do not meet the compliance equation: $E_h/E_a = \nu_{ha}/\nu_{ah}$.

When testing for elastic properties, the test samples shall be pre-conditioned to an internal pressure test at MPR_{xx} at the test temperature “xx” for 168 h with unrestrained ends.

Some form of “shakedown loading” applied to the samples prior to measuring elastic properties should be beneficial. This would eliminate residual curing shrinkage stresses in the pipe wall. The best shakedown load is to apply the rated pressure to the pipe sample as a closed end pressure vessel for one week (168 h) at the test temperature. This would “stretch out” all residual stress, so the initial non-linear behavior would be largely eliminated.

5.4.2 Axial tensile modulus, E_a

The axial tensile modulus, E_a, shall be determined in accordance with ASTM D2105.

NOTE 1 Secant modulus is the slope of the line between the origin and any point on the stress-strain curve. Tangent modulus is the slope at any point on the stress-strain curve and is a measure of the instantaneous rate of change of stress as a function of strain. The elastic modulus in ASTM D2105 is a tangential modulus, measuring the slope of the initial linear portion of the stress-strain curve. For guidance on the use of the elastic modulus, the user can refer to ASTM D2105-01.

For large diameter products, the manufacturer shall have the option of determining E_a in accordance with ASTM D638.

NOTE 2 Some winding processes are only suitable for large diameters (DN600 and greater). These processes cannot be replicated in a smaller diameter suitable for testing per ASTM D2105. While ASTM D2105 is the preferred test method (since it involves testing a full section of pipe), ASTM D638 is an option for certain processes.

5.4.3 Hoop tensile modulus, E_h, and minor Poisson's ratio, ν_{ah}

The hoop tensile modulus, E_h, and the minor Poisson’s ratio, ν_{ah}, shall be determined in accordance with API 15HR.

5.4.4 Major Poisson's ratio, ν_{ha}

The major Poisson's ratio, ν_{ha}, shall be determined in accordance with Annex G.

5.4.5 Circumferential bending modulus, E_{hb}

The circumferential bending modulus, E_{hb}, shall be set equal to the value of E_h or shall be determined in accordance with ASTM D2412 and Formula (1):

$$E_{hb} = \frac{F_c \times 1\ 000 \times r^3}{\Delta y \times 6{,}7 \times I} \quad (1)$$

where

F_c compressive load per unit pipe length, expressed in N/mm;

Δy pipe deflection, expressed in mm;

r mean pipe radius, equal to 0,5 × $D_{r,act}$, expressed in mm;

I moment of inertia of the pipe = $t_{r,act}^3/12$, expressed in mm^3.

E_{hb} will typically be larger than E_h, thus using E_h for E_{hb} should be conservative.

5.5 Optional qualification requirements

5.5.1 Electrical conductivity

Where conductive components are specified by the principal, resistivity shall be tested in accordance with 7.3.1. For components requiring electrical conductivity due to external charge generating mechanisms, the surface resistivity shall be 10^5 ohms or less. For components requiring electrical conductivity due to internal charge generating mechanisms, the volume resistivity shall be 10^3 ohm-meter or less.

NOTE Internal charge generating mechanisms would typically be due to pipes carrying non-conductive fluids. External charge generating mechanisms would typically be due to pipes in a hazardous area where an incendive dishcharge combined with the generation and accumulation of static electricity can potentially ignite a flammable atmosphere.

5.5.2 Potable water certification

When specified by the principal, piping shall comply with the potable water requirements of the national health or certifying authorities in the country of use.

5.5.3 Impact resistance

When specified by the principal, the product shall be tested for impact resistance. The test procedure and acceptance criteria shall be agreed between the manufacturer and the principal.

5.5.4 Qualification procedure for fire performance

Products shall be assigned a fire classification code in accordance with Annex H.

5.5.5 Low temperature performance

5.5.5.1 Long term envelope data

For temperatures below −35 °C, the manufacturer shall demonstrate that the product is capable of performing satisfactorily.

5.5.5.2 Elastic properties

For temperatures below −35 °C, the manufacturer shall determine the elastic properties in accordance with 5.4 and may then interpolate between the published values.

NOTE 1 GRP materials do not undergo ductile/brittle transition at temperatures as low as −35 °C; hence, there is no significant abrupt change in mechanical properties at low temperatures. However for elastic properties, some test data has shown an increase at lower temperatures, thus the reasoning for extrapolation of elastic properties.

NOTE 2 A possible concern is that at temperatures lower than −35 °C, internal residual stresses could become large enough to reduce the safe operating envelope of the piping system. While there is some recent test data at temperatures as low as −65 °C, this data has not been considered in the writing of this document.

6 Requalification

Changes to a component by an amount beyond that agreed with the principal shall invalidate the component's previous qualification. Examples of changes in component design which require requalification are defined in Table 2.

Components shall be requalified in accordance with Annex I or ASTM D2992, Section 12 (Procedure B).

NOTE The concept of requalification with inter-laminar shear strength (ILSS) and axial tensile strength (ATS) as specified in Annex I is a new concept. For future product development, this method will most likely be the preferred method. However, manufacturers with existing data per ASTM D2992 will not have this option since no baseline data was generated at the time of qualification and since requalification may have already been done per ASTM D2992, Section 12. Therefore, ASTM D2992, Section 12 will remain an option for requalification, even though it is a more onerous requirement than ILSS and ATS.

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

Table 2 — Change in component design that require requalification

Component	Change
Reinforcement	— reinforcement manufacturer — reinforcement type and composition — reinforcement finish (sizing) — tow tex/yield change of 25 % or more (plus or minus)
Resin and adhesive	— resin/adhesive manufacturer — curing system change in chemistry — curing temperature change of 20 % or more (plus or minus) — curing time change of 20 % or more (plus or minus) — resin/adhesive grade[a] — curing system catalyst or hardener[b]
Internal surface[c]	— composition — thickness
Design	— geometry and dimensions outside of the scaling rules — winding angle (> ±5°)[d]

[a] An example of a resin/adhesive grade for GRVE would be a change from a bis-A epoxy vinyl ester to a novolac-based epoxy vinyl ester.

[b] An example of a curing system catalyst change for GRVE would be a change from MEKP (methyl ethyl ketone peroxide) catalyst to BPO (benzoyl peroxide) catalyst.

[c] This is a requalification requirement only for those products that can not be manufactured without a liner. For example, centrifugal casting.

[d] For thick-wall products, it is likely that the wind angle on the outside portion of the wall can change by several degrees from the wind angle on the inside portion of the wall. For thinner wall products, the tolerance on the wind angle will most likely be closer to ±3°.

7 Quality programme for manufacture

7.1 General requirements

The manufacturer shall have a quality management system (QMS).

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

Table 3 provides a summary of the quality programme.

Table 3 — Summary of quality programme

No	Ref.	Test procedure	Product(s)	Generated data	Use
1	7.2.2	Mill hydrostatic test	Pipes	N/A	
	7.2.3		Spoolpieces	N/A	
2	7.2.4	ISO 11357-2 Differential scanning calorimetry (DSC)	Pipes, pipe + joints, fittings and flanges	T_g	Degree of cure
		Manufacturer's standard for modulated DSC (MDSC)			
		Manufacturer's standard for dynamic mechanical thermal analysis (DMTA)			
3	7.2.5	ASTM D2583	Pipes, pipe + joints, fittings and flanges (GRUP and GRVE only)	Barcol hardness	Degree of cure
4	7.2.6	ISO 1172	Pipes, pipe + joints, fittings and flanges	Glass content	Glass content
5	7.2.7		Pipes, pipe + joints, fittings and flanges	N/A	Visual inspection
6	7.2.8	ASTM D3567	Fittings and flanges	ID, mass, thickness, lay length	
		ASTM D3567	Pipes	ID, mass per unit length, $t_{r,min}$	
NOTE Additional sizes are to be tested if the one size is not representative of all of the products.					

7.2 Quality control tests

7.2.1 General

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 or resin.

7.2.2 Mill hydrostatic test for pipes

For pipes with threaded joints, the mill hydrostatic test for pipes shall be conducted at a frequency of 100 % of continuous production. For pipes with other joints, the mill hydrostatic test for pipes shall be conducted at a frequency of 5 % of continuous production.

For pipes, the hydrostatic test pressure shall be maintained for a minimum of 2 min in order to ascertain there is no leakage. For pipes with threaded joints, the test components shall have unrestrained ends. For pipes with other joints, if practical, test components shall have unrestrained ends. Test temperature shall be at ambient conditions.

The test pressure shall be 1,5 × MPR_{65} for GRE and 1,5 × MPR_{21} for GRUP and GRVE.

NOTE 1,5 × MPR and MPR/0,67 produce the same results with less than 1 % error. 1,5 × MPR is used as this is common practice.

7.2.3 Mill hydrostatic test for spoolpieces

For spoolpieces, if practical and agreed between the manufacturer and principal, the manufacturer shall conduct a mill hydrostatic test. The hydrostatic test pressure shall be maintained for a minimum of 30 min in order to ascertain there is no leakage. Test components shall have unrestrained ends. Test temperature shall be at ambient conditions.

NOTE 1 Generally, a spoolpiece is only practical to hydrostatically test if it has flanged ends or ends with a mechanical connection suitable for sealing (such as a threaded joint). In most applications, only a small percentage of spoolpieces can be hydrostatically tested.

The test pressure shall be the lower of

a) 1,5 × MPR_{65} for GRE and 1,5 × MPR_{21} for GRUP and GRVE, and

b) the test pressure that will generate stresses less than or equal to the occasional load design envelope for the factory hydrotest loading case.

NOTE 2 The latter requirement is due to the fact that the axial stresses, including the non-pressure bending stresses, that can occur during the test do not exceed the occasional load design envelope. It is expected that any reduction in the factory hydrotest would be 10 % or less. Typically, a reduction in the factory hydrotest would be expected in larger diameter, thin-wall pipe.

7.2.4 Degree of cure

The degree of cure shall be determined at a frequency of 1 % of continuous production. The preferred method for determining the degree of cure of either the base resin or component is by measurement of the glass transition temperature. For GRUP and GRVE, the degree of cure may be determined in accordance with 7.2.5. The manufacturer may propose an alternative procedure for assessing the state of cure subject to agreement with the principal.

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

a) differential scanning calorimetry (DSC) in accordance with ISO 11357-2,

b) modulated differential scanning calorimetry (MDSC) as agreed between the manufacturer and principal, or

c) dynamic mechanical thermal analysis (DMTA).

The manufacturer shall use the same method throughout the quality programme for manufacture.

NOTE MDSC and DMTA are often considered the better methods and, furthermore, MDSC is less confusing since it does not generate three different values. However, for the scope of this document, the extra benefit from MDSC is not necessary and any of the three methods are acceptable.

The measured T_g shall be equal to or greater than the baseline published by the manufacturer minus 5 °C.

EXAMPLE The baseline value is 115 °C, therefore, the measured T_g is to be at least 110 °C.

7.2.5 Barcol hardness

For GRUP and GRVE, barcol hardness testing shall be determined at a frequency of 1 % of continuous production in accordance with ASTM D2583. It is recommended that a minimum of 10 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 can be obtained if the tester impacts surfacing veil.

If the manufacturer is already testing for the glass transition temperature, there is no requirement to additionally conduct testing for barcol hardness.

The measured barcol hardness shall be equal to or greater than the minimum baseline published by the manufacturer.

7.2.6 Glass content

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 components shall not be limited to plain pipe, but should include all components.

For filament wound components, the measured glass content shall be within ±6 % of the baseline published by the manufacturer. For hand-lay-up components, the measured glass content shall be within ±7,5 % of the baseline published by the manufacturer.

NOTE 1 Testing for glass content is a destructive test.

NOTE 2 The location of the test sample on the part can be agreed between the principle and manufacturer. Or, since this is a destructive test, a special component can be manufactured or taken at random to confirm glass content.

7.2.7 Visual inspection

All pipes, fittings and flanges shall be visually inspected for compliance with Annex J and, if appropriate, be repaired or rejected.

7.2.8 Key component dimensions

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

— internal diameter, *ID*;

— for pipes, mass per unit length;

— for fittings and flanges, mass;

— for fittings and flanges, laying length;

— for pipes, the minimum reinforced wall thickness;

— for fittings and flanges, the wall thickness.

NOTE 1 t_l is a nominal thickness and is to be published by the manufacturer, but does not need to be measured per ASTM D3567 as a key component dimension.

For pipes and fittings, the *ID* shall be within the tolerances specified by the manufacturer.

For fittings, the mass shall be within the tolerances specified by the manufacturer. In addition, the mass shall be at least 90 % of the value published by the manufacturer.

Instead of the mass, the manufacturer shall have the option to use a key component dimension, such as an outside diameter or cross-sectional thickness at a specified point for quality control.

NOTE 2 Since measuring $t_{r,act}$ of a fitting is not always practical, there is no adjustment for actual versus published wall thickness as there is for pipe. The manufacturer and principal should give consideration to the mass of the fitting. If the mass of the actual fitting to be tested is more than 110 % of the published mass, consideration should be given to adjusting $P_{T1\,000,xx}$.

NOTE 3 Fittings that are manufactured from pipe sections, such as mitered elbows, can be manufactured integral with a pipe section. Thus, a mass measurement is not always practical for these types of fittings.

For fittings, the laying length shall be within the tolerances specified by the manufacturer.

The minimum reinforced wall thickness shall be determined from the average of six observations, evenly spaced at 60° apart, taken at any one cross section of the pipe. The cross section shall be remote from any build up for joint reinforcement.

It is acceptable to search for, and select, the smallest observation to begin the procedure, however, the remaining five observations shall be evenly spaced at 60° based on the first observation selected.

These six observations shall produce an average result that meets the following requirements:

— the average of these six observations shall be greater than $t_{r,min}$ (the manufacturers stated minimum reinforced wall thickness). Individual measurements may be below the guaranteed $t_{r,min}$, but the average of the six measurements shall not be;

— no more than two of the six observations shall be less than $t_{r,min}$.

— none of the six observations shall be less than 0,95 × $t_{r,min}$.

— where a single observation is found below $t_{r.min}$, none of the six observations shall exceed 1,306 × $t_{r,min}$.

This procedure may be repeated at any location along the pipe length.

NOTE 4 Accurate wall thickness measurements for GRP pipes require destructive testing and cannot be measured on every pipe. Filament winding and other methods have inherent variations in pipe wall thickness. This variation in pipe wall thickness can be found along a single length of pipe, between pipe from the same lot, from the same products produced from different lots and also from a single cross section.

NOTE 5 The 1,306 × $t_{r,min}$ requirement is intended to protect against extreme variations in the pipe reinforced wall thickness at any one cross section 1,306 = $1/0{,}875^2$.

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.

7.2.9 Retest

7.2.9 7.2.9 Retest

NOTE 7.2.7 is not part of the procedure since 100 % of all components are visually inspected.

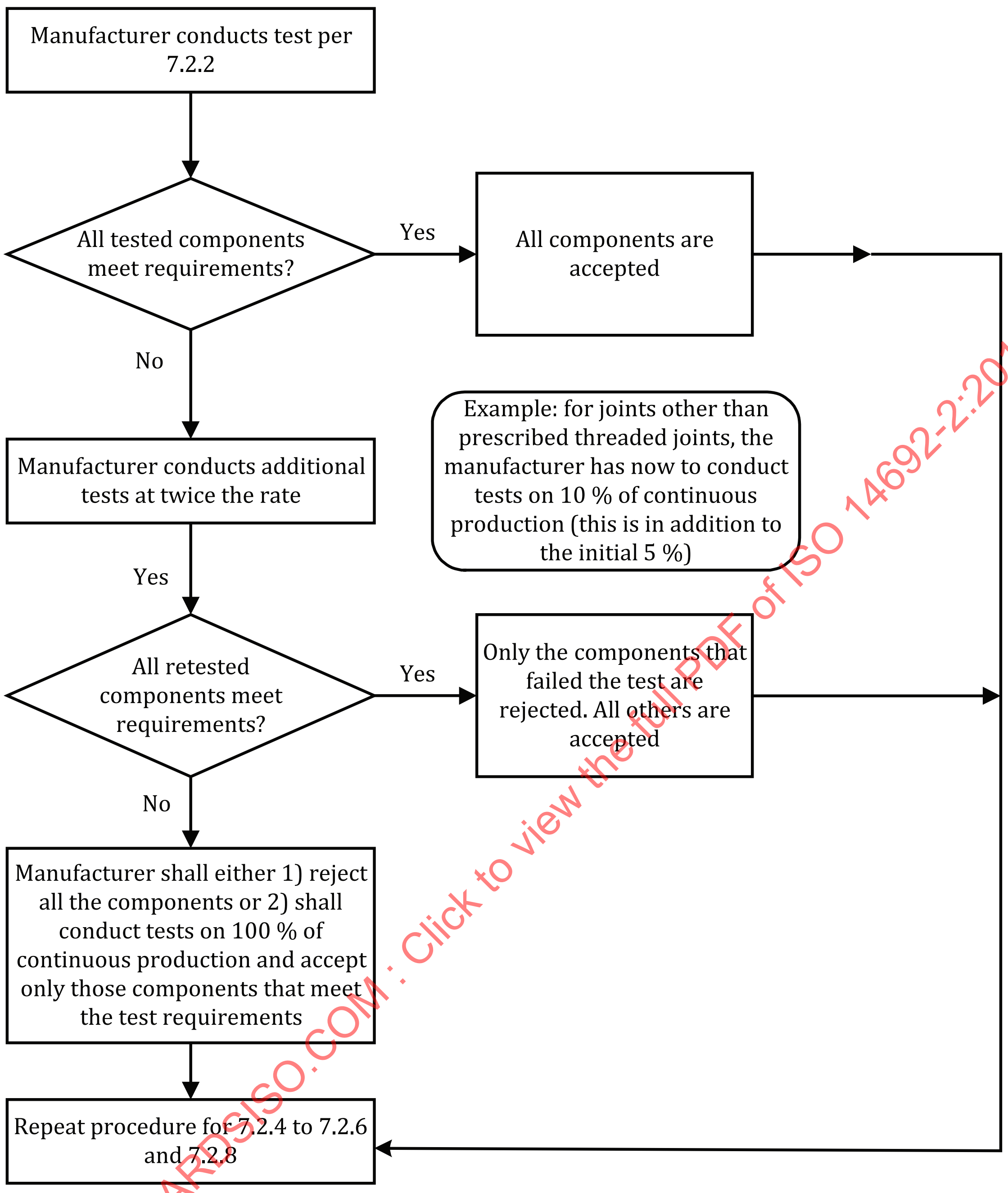


Figure 4 — Retest procedure

7.3 Optional quality control tests

7.3.1 Electrical conductivity per length

Electrical conductivity shall be determined in accordance with Figure 5. The range of components shall not be limited to plain pipe, but should include all component types, including joints, that are being produced by the manufacturer.

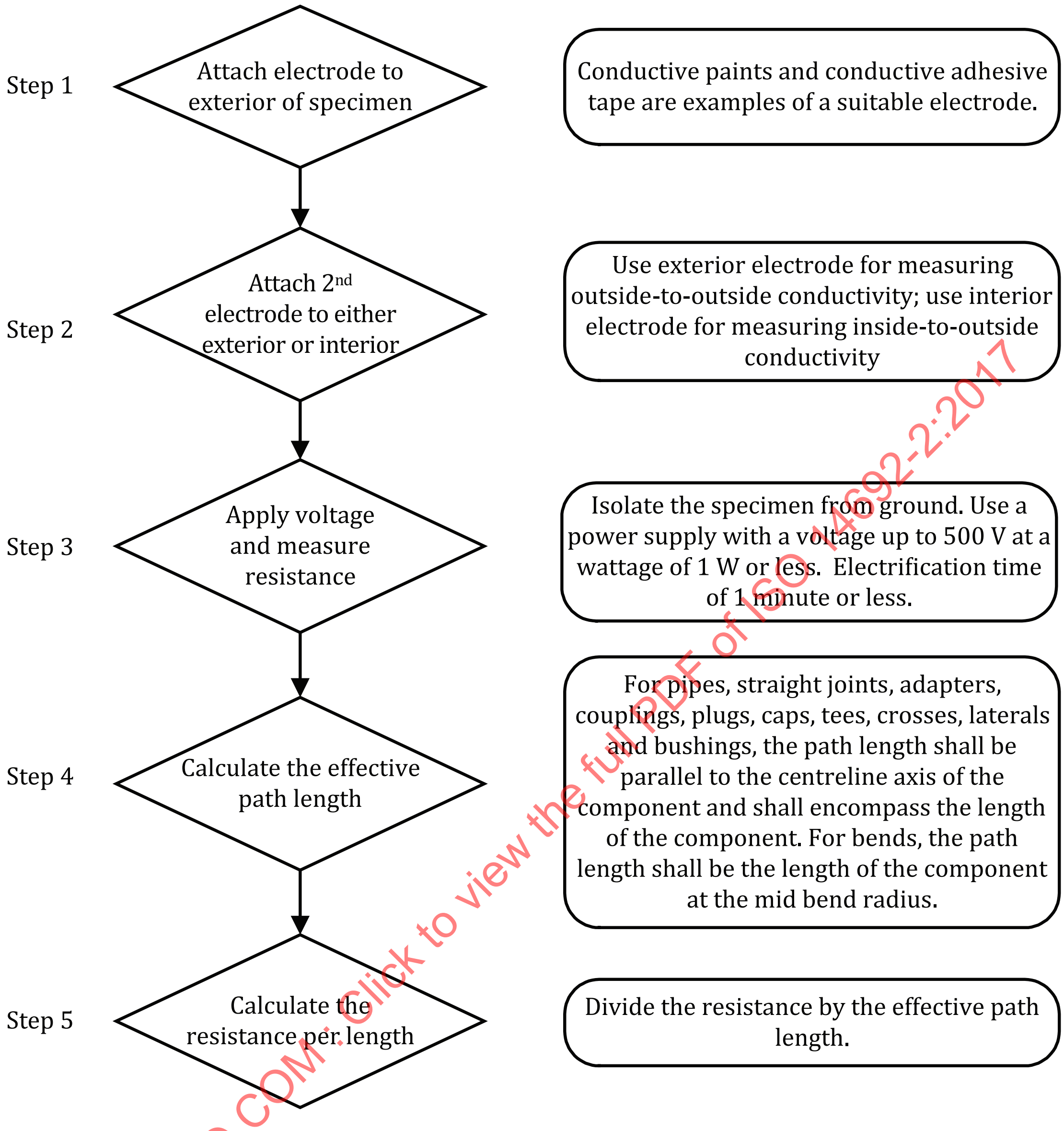


Figure 5 — Electrical conductivity test procedure

7.3.2 Fire performance

Any frequency of fire endurance, surface spread of flame/heat release and smoke obscuration/toxicity tests shall be conducted to the satisfaction of the authority having jurisdiction.

7.3.3 Residual styrene monomer content

For GRUP and GRVE, the residual styrene monomer content for joints in components used in qualification testing may be determined. The measurement shall be performed in accordance with ISO 4901. The residual styrene content shall not be above 2 % (mass fraction) of the resin content.

7.3.4 Additional quality control tests

The principal shall identify any additional quality control tests not specified in this document on the enquiry sheet (see ISO 14692-1:2017, Annex D). Examples include, but are not limited to, axial tensile strength, short term burst pressure and apparent hoop tensile strength. The type, procedure and frequency of any additional quality control tests shall be identified on the enquiry sheet.

Furthermore, the manufacturer may conduct other quality control tests as part of its QMS.

8 Component marking

Pipe and fittings manufactured in accordance with this document shall be marked by the manufacturer. 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 include the following:

a) manufacturer's name or registered trademark;

b) manufacturer's product designation;

c) MPR_{65} (for GRE) or MPR_{21} (for GRUP and GRVE).

9 Handling, storage and transportation

The handling, storage and transportation of GRP components shall be in accordance with ISO 14692-4:2017, 4.2.

10 Documentation

10.1 General

This clause provides a checklist of documentation that is required for the order and supply of components in accordance with this document.

10.2 Enquiry and purchase order documentation

The principal shall provide the manufacturer, in the invitation to tender, an enquiry sheet in accordance with ISO 14692-1:2017, Annex D. The principal shall also provide this information to the manufacturer in the purchase order documentation.

10.3 Qualification documentation

10.3.1 General

The manufacturer shall provide the principal with proof of compliance with the qualification requirements of this document.

10.3.2 Qualification reports

Qualification reports shall be produced and supplied by the manufacturer, if requested by the principal. The qualification report shall at least include:

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 manufacturer's declarations detailed in Clause 4. 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. An example of a qualification report is given in Annex K.

10.3.3 Potable water approval certificates

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

10.4 Production quality control documentation

10.4.1 General

The manufacturer shall provide the principal with proof of compliance with the quality control requirements of Clause 6.

10.4.2 Manufacturing procedure

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

10.4.3 Raw material certificates

Raw material (including ancillaries) certificates 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.

10.4.4 Production quality control reports

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

10.5 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.

Annex A
(normative)

Gradients and temperature limits

A.1 Gradient selection

All pipe wall thickness shall be qualified by 1 000 h survival using the published default gradients. Piping systems (joints and components) that utilize prescribed threaded joints (i.e. threaded joints that meet the requirements of API 15HR) may be qualified by

a) using the default gradients and performing survival testing per 5.3.1, or

b) using measured gradients as per API 15HR.

Piping systems utilizing restrained joints other than the prescribed threaded joints shall be designed using default gradients.

Refer to Figure A.1 and the following steps for selecting the gradient.

Step 1: If the joints are prescribed threaded joints, then the manufacturer has the option of using either measured gradients or default gradients. If the manufacturer opts for measured gradients, then use the measured value as the gradient and the flowchart ends.

Step 2: If the resin matrix is neither GRE, GRUP nor GRVE, then go to A.3.3.

NOTE 1 In the case of a product that uses multiple resin matrices (e.g. GRE-IPD pipe plus GRE-MDA joints), the higher default gradient is selected as the baseline value.

Step 3: If the qualification temperature (i.e. test temperature used in the long term regression testing in 4.2) is within the values of Table A.1, then the default value is read from this table. Interpolate, if necessary.

Step 4: If the qualification temperature is above the values of Table A.1, then the default value is extrapolated using the two data points at the highest temperatures.

Otherwise, the qualification temperature is below −35 °C and the value at −35 °C is the default value.

Step 5: Compare the measured gradient to the default value. The measured gradient is obtained from the long term regression testing conducted in 4.2. If the measured gradient is equal to or less than the default value, then use the default value as the gradient.

Step 6: If the measured gradient is 125 % or less than the default value, then use the default value as the gradient.

NOTE 2 To account for small discrepancies in test reports when converting from Celsius to/from Farhenheit, the temperature from the full regression curve can deviate from the values in Table A.1 by ±2,5 °C. Example, a manufacturer has a full regression curve at 66 °C. Since extrapolation of values is not allowed, the default value at 65 °C can be used as the equivalent of the value at 66 °C when performing step 6.

Otherwise, the measured gradient is larger than 125 % of the default value. In this instance, the measured gradient shall be used as the gradient. Furthermore, since the measured gradient is much steeper than the default values, these default values shall be adjusted by the ratio of the measured gradient to the default gradient for all qualifications at all temperatures.

The process is repeated for any other qualification temperatures.

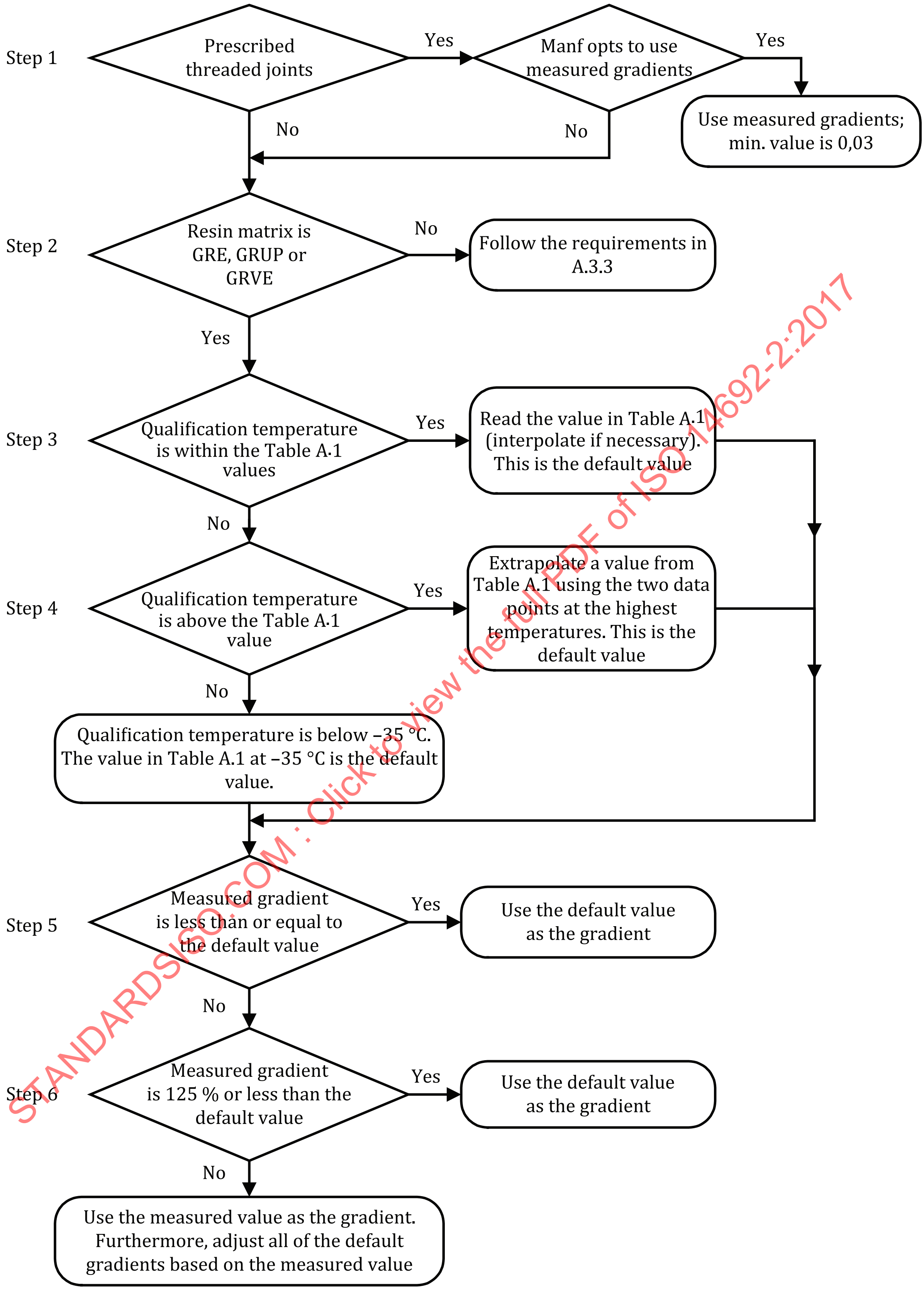


Figure A.1 — Gradient selection process

A.2 Measured gradients

The manufacturer shall determine the measured gradient in accordance with ASTM D2992.

NOTE 1 There is a difference in ASTM D2992, Formula A1.21 and σ^2 in ISO 14692-2:2002, Formula K.10. ASTM D2992, Formula A1.21 is missing a factor of 2. The formula should read $\sigma_e{}^2 = 2\lambda\sigma_\delta{}^2$. There is also a difference in ASTM D2992, Formula A1.21 and $V_{ar}(Y_L)$ in ISO 14692-2:2002, Formula K.15. ISO 14692-2:2002 will calculate the variance of the line, $V_{ar}(Y_L)$, smaller than the method in ASTM D2992. Consequently, ISO 14692-2:2002, Annex K will calculate an LCL value that is larger than the method in ASTM D2992.

NOTE 2 The measured gradient is the slope of the line. Even though the slope is negative, the measured gradient is defined as a positive number.

Measured gradients that are less than 0,030 shall be set to 0,030.

EXAMPLE A manufacturer has a full regression curve with a measured gradient of 0,026. The data can be considered acceptable, however, the value of 0,030 is to be used for the measured gradient.

A.3 Default gradients

A.3.1 General

Default gradients as a function of temperature and resin system are provided in Table A.1 and Figure A.2.

Table A.1 — Default gradients, G_{xx}

Resin system	Temperature						
	–35 °C	21 °C	50 °C	65 °C	80 °C	93 °C	121 °C
GRE, anhydride	0,045	0,045		0,065	0,105		
GRE, aliphatic amine	0,045	0,045		0,065		0,100	
GRE, cyclo-aliphatic amine (IPD)	0,045	0,045		0,065		0,090	
GRE, aromatic amine (MDA)	0,045	0,045		0,065		0,090	0,115
GRUP, polyester	0,055	0,055	0,070				
GRVE, vinyl ester	0,055	0,055	0,065	0,075			

NOTE 1 Interpolation of values is allowed.

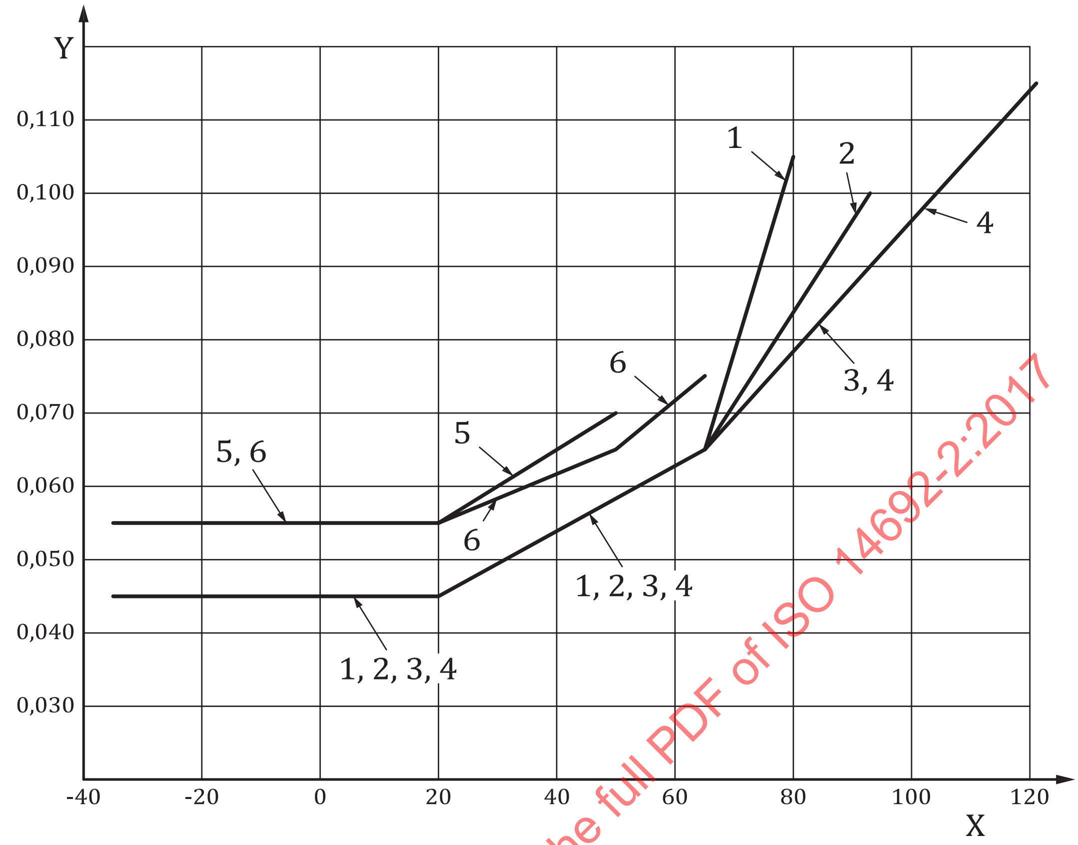
NOTE 2 The omission of default gradients at higher temperatures may not automatically preclude the use of a particular resin system at that temperature. For example, most of the long term testing on GRVE resin systems is between 21 °C and 65 °C, thus default gradient are only established up to 65 °C. However, some GRVE resin systems have T_g values of 140 °C or higher. To use the resin system at these higher temperatures, the requirements in A.3.2 may have to be met.

EXAMPLE 1 G_{80} for an anhydride epoxy is 0,105.

EXAMPLE 2 G_{60} for GRVE is 0,072 (found by interpolation).

EXAMPLE 3 G_{-55} for GRUP is 0,055.

EXAMPLE 4 G_{105} for IPD epoxy is not available in this table since 105 °C is above the highest published temperature of 93 °C for IPD epoxy.



Key

1 GRE, anyhydride
2 GRE, aliphatic amine
3 GRE, cyclo-aliphatic amine (IPD)
4 GRE, aromatic amine (MDA)
5 GRUP
6 GRVE
X temperature, T
Y gradient, *G*

Figure A.2 — Graphical description of default gradients

A.3.2 Higher design temperatures

If a manufacturer qualifies a product using one of these resin systems at a design temperature above the temperatures in this annex, the following requirements shall apply.

a) The manufacturer shall provide a measured gradient for one pipe (or pipe + joint) size at the design temperature.

b) The manufacturer shall extrapolate a value from the default gradients, using the two data points at the highest temperatures. This extrapolated value shall be the default value and shall be used in steps 5 and 6 of Figure A.1 to determine the gradient.

c) The manufacturer shall qualify the components with 1 000 h qualification testing. $rd_{1\,000,xx}$ shall be calculated in accordance with Annex C. Scaling rules in accordance with Annexes D and E apply.

EXAMPLE A manufacturer wishes to qualify GRVE at 120 °C. This is above the highest value in Table A.1: 65 °C. The two highest data points are 0,065 at 50 °C and 0,075 at 65 °C. Extrapolating these two values to 120 °C is 0,075 + (0,075 − 0,065) × (120 − 65)/(65 − 50) = 0,112. The manufacturer's measured gradient has to be greater than or equal to 0,112 and has to be used as G_{xx} in Annex C.

A.3.3 Other resin systems

If a manufacturer qualifies a product using a resin system not shown in Figure A.2, the following requirements shall apply.

a) The manufacturer shall provide a measured gradient for one pipe (or pipe + joint) size at the design temperature.

b) The measured gradient shall not be lower than the default gradients for GRE, aromatic amine (MDA) in this annex. If the design temperature is above the highest temperature, the manufacturer shall extrapolate a value from the default gradients, using the two data points at the highest temperatures. The measured gradient shall be greater than or equal to this value;

c) The manufacturer shall qualify the components with 1 000 h qualification testing. $rd_{1\,000,xx}$ shall be calculated in accordance with Annex C. Scaling rules in accordance with Annexes D and E apply.

EXAMPLE A manufacturer wishes to qualify GRP with a phenolic resin at 115 °C. The values for GRE, aromatic amine are 0,090 at 93 °C and 0,115 at 121 °C. Interpolating these two values to 115 °C is 0,090 + (0,115 − 0,090) × (115 − 93)/(121 − 93) = 0,110. The manufacturer's measured gradient has to be greater than or equal to 0,110 and has to be used as G_{xx} in Annex C.

A.3.4 Lower design temperatures

Refer to 5.5.5.

Annex B
(normative)

Long term envelope data points

B.1 General

The long term envelopes are key inputs to ISO 14692-3, as they are scaled to the design envelopes with the f_2 part factor and the A_0, A_2 and A_3 partial factors. Refer to Figure B.1 for a graphical representation of the long term envelope.

The dimensions of the long term envelope are based on the following pieces of data:

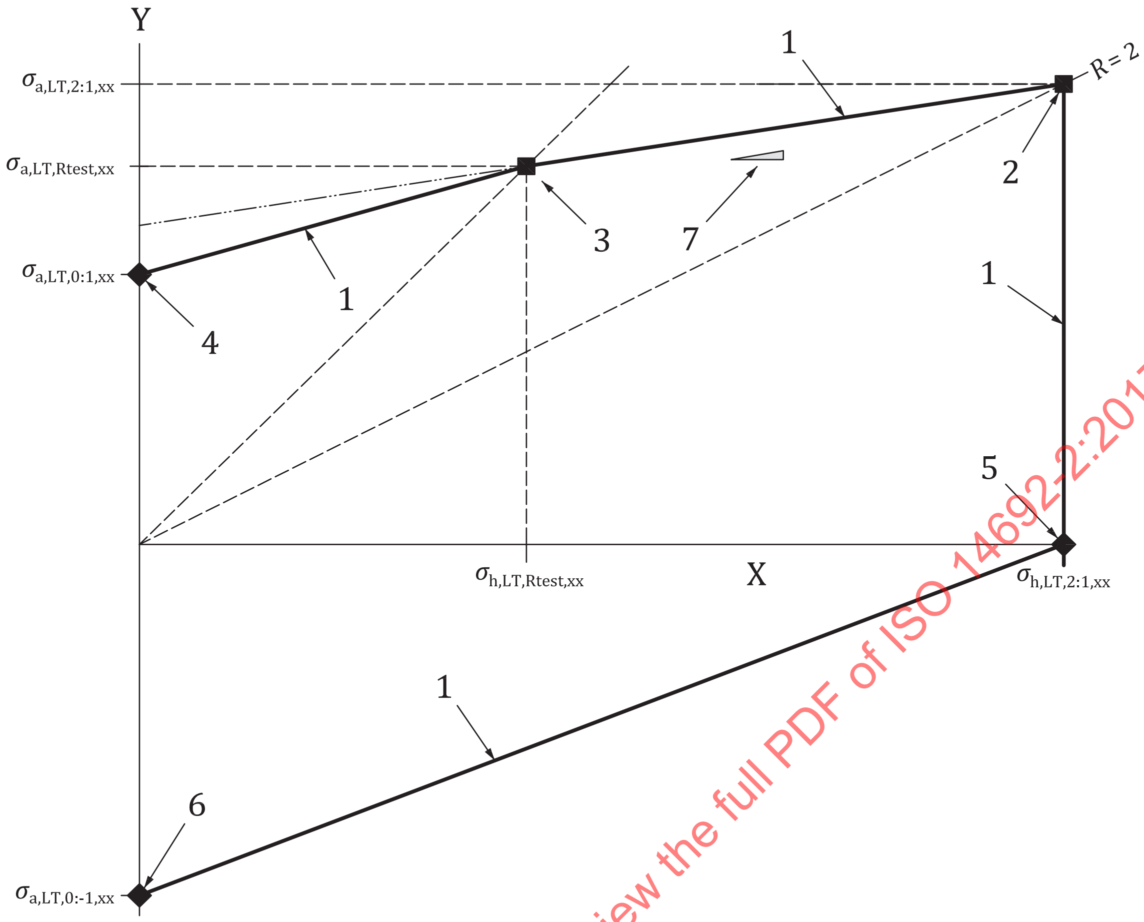
$\sigma_{h,LT,2:1,xx}$	hoop stress component of the R = 2 data point as per B.2.2;
$\sigma_{a,LT,2:1,xx}$	axial stress component of the R = 2 data point as per B.2.2;
$\sigma_{h,LT,Rtest,xx}$	hoop stress component of the $R = R_{test}$ data point as per B.2.3;
$\sigma_{a,LT,Rtest,xx}$	axial stress component of the $R = R_{test}$ data point as per B.2.3;
$\sigma_{a,LT,0:1,xx}$	axial stress component of the R = 0 data point as per B.2.4;
$\sigma_{a,LT,0:-1,xx}$	axial compressive stress component of the R = 0:-1 data point as per B.2.5;
$\sigma_{h,LT,1:0,xx}$	hoop stress component of the R = 1:0 data point as per B.2.6.

NOTE 1 $\sigma_{h,LT,0:1,xx}$ and $\sigma_{h,LT,0:-1,xx}$, the hoop stress component of the R = 0:1 and R = 0:-1 data points (axial and compressive), are zero.

NOTE 2 $\sigma_{a,LT,1:0,xx}$, the axial stress component of the R = 1:0 data point, is zero.

NOTE 3 The long term envelope is temperature dependent.

NOTE 4 The hoop and axial stress data points on the long term envelope for the default temperature "xx" (65 °C for GRE and 21 °C for GRUP and GRVE) are to be validated at the R = 2:1 and $R = R_{test}$:1 loading conditions by survival testing according to Annex C. All other points on the long term envelope are determined directly from these two validated data points.



Key

1 long term envelope

2 R = 2:1 (R = 2) data point

3 $R = R_{test}$ data point

4 R = 0:1 (R = 0) data point (tensile)

5 R = 1:0 data point

6 R = 0:-1 data point (compressive)

7 slope m of the line from the R = 2 data point to the R_{test} data point

X hoop stress, σ_h

Y longitudinal stress, σ_a

Figure B.1 — Data points on the long term envelope

NOTE 5 The long term envelope has a relationship to the long term gradient from regression testing and the 1 000 h survival strength from 1 000 h survival tests. The threshold envelope is set equal to the long term envelope at 65 °C (for GRE) or 21 °C (for GRUP and GRVE). As the threshold envelopes are set at fixed temperatures, there is no temperature subscript for the threshold envelope. These definitions of threshold envelope are to the best of present knowledge. However, the manufacturer remains responsible and may declare a more conservative threshold envelope.

NOTE 6 An example of incremental damage to the pipe laminate is surface micro-cracks that, if overstressed, could propagate and eventually reduce the design life of the product. While micro-cracking occurs even at operating pressure, these cracks will not propagate when σ_{thr} is appropriately selected.

B.2 Long term envelope data points at the default temperatures

B.2.1 Default temperature

The default temperatures are 65 °C for GRE and 21 °C for GRUP and GRVE.

B.2.2 R = 2:1 data point

The R = 2:1 data point shall be calculated using Formulae (B.3) and (B.4).

B.2.3 $R = R_{test}$ data point

The $R = R_{test}$ data point shall be calculated using the values for $\sigma_{h,LT,Rtest,xx}$ and $\sigma_{a,LT,Rtest,xx}$ validated in C.3.

B.2.4 R = 0:1 data point

The R = 0:1 data point shall be calculated according to Formulae (B.1) and (B.2):

$$\sigma_{h,LT,0:1,xx} = 0 \quad \text{(B.1)}$$

$$\sigma_{a,LT,0:1,xx} = 0,8 \times \left(\sigma_{a,LT,Rtest,xx} - \frac{\sigma_{a,LT,2:1,xx} - \sigma_{a,LT,Rtest,xx}}{\sigma_{h,LT,2:1,xx} - \sigma_{h,LT,Rtest,xx}} \times \sigma_{h,LT,Rtest,xx} \right) \quad \text{(B.2)}$$

where

$\sigma_{a,LT,2:1,xx}$ long term envelope axial stress for an unrestrained, hydraulic (2:1) condition at xx °C, expressed in MPa;

$\sigma_{h,LT,2:1,xx}$ long term envelope hoop stress for an unrestrained, hydraulic (2:1) condition at xx °C, expressed in MPa;

$\sigma_{a,LT,Rtest,xx}$ long term envelope axial stress for a partially restrained, hydraulic (R_{test}) condition at xx °C, expressed in MPa;

$\sigma_{h,LT,Rtest,xx}$ long term envelope hoop stress for a partially restrained, hydraulic (R_{test}) condition at xx °C, expressed in MPa.

NOTE The value of 0,8 is meant to conservatively cacluate the R = 0 data point from the R = 2 and R_{test} data points.

B.2.5 R = 0:-1 data point

The R = 0:-1 data point shall be calculated using Formulae (B.3) and (B.4):

$$\sigma_{h,LT,0:-1,xx} = 0 \quad \text{(B.3)}$$

$$\sigma_{a,LT,0:-1,xx} = -1,25 \times \sigma_{a,LT,0:1,xx} \quad \text{(B.4)}$$

where

$\sigma_{a,LT,0:1,xx}$ long term envelope axial stress for a pure axial loading condition at xx °C, expressed in MPa.

B.2.6 *R* = 1:0 envelope data point

The *R* =1:0 data point shall be calculated using Formulae (B.5) and (B.6):

$$\sigma_{h,LT,1:0,xx} = \sigma_{h,LT,2:1,xx} \quad (B.5)$$

$$\sigma_{a,LT,1:0,xx} = 0 \quad (B.6)$$

where

$\sigma_{h,LT,2:1,xx}$ long term envelope hoop stress for an unrestrained, hydraulic (2:1) condition at xx °C, expressed in MPa.

B.3 Long term envelope data points at other temperatures

The dimensions of the long term envelope at other temperatures can be related directly to the published MPR_{xx} values that have been verified with the survival tests with Formulae (B.7) to (B.11):

$$\sigma_{h,LT,R_{test,yy}} = \frac{MPR_{yy}}{MPR_{xx}} \times \sigma_{h,LT,R_{test,xx}} \quad (B.7)$$

$$\sigma_{a,LT,R_{test,yy}} = \frac{MPR_{yy}}{MPR_{xx}} \times \sigma_{a,LT,R_{test,xx}} \quad (B.8)$$

$$\sigma_{a,LT,0:1,yy} = \frac{MPR_{yy}}{MPR_{xx}} \times \sigma_{a,LT,0:1,xx} \quad (B.9)$$

$$\sigma_{a,LT,0:-1,yy} = \frac{MPR_{yy}}{MPR_{xx}} \times \sigma_{a,LT,0:-1,xx} \quad (B.10)$$

$$\sigma_{h,LT,1:0,yy} = \frac{MPR_{yy}}{MPR_{xx}} \times \sigma_{h,LT,1:0,xx} \quad (B.11)$$

$$\sigma_{h,LT,2:1,yy} = \frac{MPR_{yy}}{MPR_{xx}} \times \sigma_{h,LT,2:1,xx} \quad (B.12)$$

$$\sigma_{a,LT,2:1,yy} = \frac{MPR_{yy}}{MPR_{xx}} \times \sigma_{a,LT,2:1,xx} \quad (B.13)$$

NOTE xx is 65 °C for GRE and 21 °C for GRUP and GRVE.

where

$\sigma_{h,LT,2:1,yy}$ hoop stress component of the *R* = 2 long term envelope data point at yy °C;

$\sigma_{a,LT,2:1,yy}$ axial stress component of the *R* = 2 long term envelopedata point at yy °C;

$\sigma_{h,LT,Rtest,yy}$ hoop stress component of the *R* = R_{test} long term envelope data point at yy °C;

$\sigma_{a,LT,Rtest,yy}$ axial stress component of the *R* = R_{test} long term envelope data point at yy °C;

$\sigma_{a,LT,0:1,yy}$ axial stress component of the *R* = 0 long term envelope data point at yy °C;

$\sigma_{a,LT,0:-1,yy}$ axial compressive stress component of the R = 0:-1 long term envelope data point at yy °C;

$\sigma_{h,LT,1:0,yy}$ hoop stress component of the R = 1:0 long term envelope data point at yy °C;

MPR_{xx} maximum pressure rating at sustained conditions for a 20 year design life at the temperature of xx °C;

MPR_{yy} maximum pressure rating at sustained conditions for a 20 year design life at the temperature of yy °C.

The "yy" temperature shall be higher than the "xx" temperature.

The ratio of MPR_{yy} over MPR_{xx} shall be ≤1,0.

Annex C
(normative)

Survival tests

C.1 General

Survival test pressures are based on MPR_{xx}, design life time and $rd_{1\,000,xx}$. $rd_{1\,000,xx}$ is a function of the gradient, G_{xx}.

The manufacturer shall have the option to conduct the survival test(s) at either 2 000 h, 3 000 h, 4 000 h, 5 000 h or 6 000 h (i.e. in increments of 1 000 h) instead of 1 000 h. $rd_{Time,xx}$ and the testing time ($P_{TTime,xx}$) shall be recalculated accordingly, where time is the predetermined test time in h and xx is the temperature in °C.

C.2 *R* = 2:1 Survival test pressure

C.2.1 Pipes

For pipes, use Formula (C.1) or (C.2):

$$P_{T\,1\,000,xx} = rd_{1\,000,xx} \times \frac{MPR_{xx}}{f_2} \times \frac{t_{r,act} \times D_{r,min}}{t_{r,min} \times D_{r,act}} \tag{C.1}$$

$$P_{T\,M,xx} = \left[10^{(\log 175\,200 - \log M) \times G_{xx}} \right] \times \frac{MPR_{xx}}{f_2} \times \frac{t_{r,act} \times D_{r,min}}{t_{r,min} \times D_{r,act}} \tag{C.2}$$

where

$t_{r,min}$	minimum reinforced pipe wall thickness, expressed in mm;
$t_{r,act}$	actual reinforced pipe wall thickness, expressed in mm;
$D_{r,min}$	mean diameter of the minimum reinforced pipe wall, expressed in mm;
$D_{r,act}$	actual mean diameter of the reinforced pipe wall, expressed in mm;
$rd_{1\,000,xx}$	1 000 h to 20 years scaling ratio at xx °C;
MPR_{xx}	maximum pressure rating at xx °C, expressed in MPa;
f_2	part factor for loading in the sustained condition, default value is equal to 0,67;
M	test time, either 1 000, 2 000, 3 000, 4 000, 5 000 or 6 000, expressed in h;
$P_{T\,M,xx}$	pressure of survival test carried out at xx °C , expressed in MPa;
G_{xx}	gradient at xx °C.

NOTE Formula (C.1) is only valid at 1 000 h. When M = 1 000 h, Formula (C.2) equals Formula (C.1).

When using Formula (C.1), replace $rd_{1\,000,xx}$ with the appropriate *rd* value (e.g. $rd_{2\,000,xx}$) to test at times other than 1 000 h.

Since measuring $t_{r,act}$ is a destructive process (it involves cutting the pipe at a cross-section), $t_{r,act}$ can not be measured until after the test is complete. The manufacturer shall make an estimate of $t_{r,act}$ prior to the survival test being conducted. After the test is successfully completed, $t_{r,act}$ shall be measured. If the measured value of $t_{r,act}$ is less than or equal to the greater of 105 % of the original estimated value used in Formula (C.1) and the original estimated value used in Formula (B.1) plus 0,50 mm, the sample should be accepted.

Once completed satisfactorily, MPR_{xx} shall be considered validated and $\sigma_{h,LT,2:1,xx}$ and $\sigma_{a,LT,2:1,xx}$ can then be calculated using Formulae (C.3) and (C.4):

$$\sigma_{h,LT,2:1,xx} = \frac{MPR_{xx}}{f_2} \times \frac{D_{r,min}}{2 \times t_{r,min}} \quad \text{(C.3)}$$

$$\sigma_{a,LT,2:1,xx} = \frac{MPR_{xx}}{f_2} \times \frac{D_{r,min}}{4 \times t_{r,min}} \quad \text{(C.4)}$$

where

$t_{r,min}$ minimum reinforced pipe wall thickness, expressed in mm;

$D_{r,min}$ mean diameter of the minimum reinforced pipe wall, expressed in mm;

MPR_{xx} maximum pressure rating at xx °C, expressed in MPa;

f_2 part factor for loading in the sustained condition, default value is equal to 0,67.

C.2.2 Pipe + joints, flanges, bends, tees, reducers and other fittings

For pipe + joints, flanges, bends, tees, reducers and other fittings, use Formula (C.5) or (C.6):

$$P_{T\ 1\ 000,xx} = rd_{1\ 000,xx} \times \frac{MPR_{xx}}{f_2} \quad \text{(C.5)}$$

$$P_{T\ M,xx} = \left[10^{(\log 175\ 200 - \log M) \times G_{xx}} \right] \times \frac{MPR_{xx}}{f_2} \quad \text{(C.6)}$$

where

$rd_{1\ 000,xx}$ 1 000 h to 20 years scaling ratio at xx °C;

MPR_{xx} maximum pressure rating at xx °C, expressed in MPa;

f_2 part factor for loading in the sustained condition, default value is equal to 0,67;

M test time, either 1 000, 2 000, 3 000, 4 000, 5 000 or 6 000, expressed in h;

$P_{T\ M,xx}$ pressure of survival test carried out at xx °C , expressed in MPa;

G_{xx} gradient at xx °C.

NOTE 1 Formula (C.5) is only valid at 1 000 h. When M = 1 000 h, Formula (C.6) equals Formula (C.5).

NOTE 2 Since measuring $t_{r,act}$ of a fitting is not always practical, there is no adjustment for actual versus published wall thickness as there is for pipe. However, the manufacturer and principal should give consideration to either the mass or a key component dimension (such as an outside diameter or cross-sectional thickness at a specified point) of the fitting. Ideally, the actual fitting to be tested should be at the lower end of the tolerance for that fitting. For example, if a fitting has a published mass of 22 kg with a tolerance of 19,8 kg to 27 kg, the fitting selected for the survival test should ideally have a mass of 23,4 kg (the average of the tolerance range) or less. If the mass of the actual fitting to be tested is more than 110 % of the published mass, consideration should be given to increasing $P_{T1\ 000,xx}$ based on the ratio of the actual mass to the published mass.

NOTE 3 Fittings that are manufactured from pipe sections, such as mitered elbows, can be manufactured integral with a pipe section. Thus, a mass measurement is not always practical for these types of fittings.

C.3 $R = R_{test}$ survival test pressure

C.3.1 Derivation of R_{test}

The manufacturer shall conduct a 1 000 h survival test in accordance with 5.3.1 at a ratio R_{test} on a pipe at 65 °C for GRE and 21 °C for GRUP and GRVE. For guidance on test equipment, refer to C.3.2.

Identify the target $\sigma_{h,LT,Rtest,xx}$ and $\sigma_{a,LT,Rtest,xx}$ to be validated by the test:

$$\sigma_{h,LT,Rtest,xx} = \frac{\sigma_{h,LT,2:1,xx}}{2} \tag{C.7}$$

$$2 \times \sigma_{h,LT,Rtest,xx} \geq \sigma_{a,LT,Rtest,xx} \geq \sigma_{h,LT,Rtest,xx} \tag{C.8}$$

For pipes, use Formulae (C.9) and (C.10) and Figure C.1 to calculate the 1 000 h survival test pressures:

$$P_{T1\ 1000,Rtest,xx} = rd_{1\ 000,xx} \times \sigma_{h,LT,Rtest,xx} \times \frac{2 \times t_{r,act}}{D_{r,act}} \tag{C.9}$$

$$P_{T2\ 1000,Rtest,xx} = rd_{1\ 000,xx} \times \sigma_{a,LT,Rtest,xx} \times \frac{A_{r,act}}{A_{i,act}} \tag{C.10}$$

where

$P_{T1\ 1\ 000,xx}$ P1 pressure of survival test carried out at xx °C , expressed in MPa, refer to Figure B.1;

$P_{T2\ 1\ 000,xx}$ P2 pressure of survival test carried out at xx °C , expressed in MPa, refer to Figure B.1.

Once completed satisfactorily, $\sigma_{h,LT,Rtest,xx}$ and $\sigma_{a,LT,Rtest,xx}$ shall be considered validated.

In Formulae (C.9) and (C.10), since a pipe is being tested, the actual dimensions of the test sample are required. Since measuring $t_{r,act}$ is a destructive process (it involves cutting the pipe at a cross-section), $t_{r,act}$ can not be measured until after the test is complete. The manufacturer shall make an estimate of $t_{r,act}$ prior to the survival test being conducted. After the test is successfully completed, $t_{r,act}$ shall be measured. If the measured value of $t_{r,act}$ is less than or equal to the greater of 105 % of the original estimated value used in Formula (C.1) and the original estimated value used in Formula (B.1) plus 0,50 mm, the sample should be accepted.

The slope, m, of the line from the R = 2 data point to the R_{test} data point shall be calculated according to Formula (C.11):

$$m = \frac{\sigma_{a,LT,2:1,xx} - \sigma_{a,LT.Rtest,xx}}{\sigma_{h,LT,2:1,xx} - \sigma_{h,LT,Rtest,xx}} \quad (C.11)$$

If $\sigma_{a,LT,Rtest,xx}$ is larger than $\sigma_{a,LT,2:1,xx}$ (i.e. if m, the slope, is less than zero), then the default SIFs in ISO 14692-3:2017, 7.5 shall not be used and the manufacturer shall be required to determine the SIFs according to ISO 14692-3:2017, 7.5 and A.3.

NOTE 1 The default SIFs are based on the fact that t $\sigma_{a,LT,Rtest,xx}$ is equal to or smaller than $\sigma_{a,LT,2:1,xx}$.

The actual R-ratio of the R_{test} data point shall be calculated using Formula (C.12):

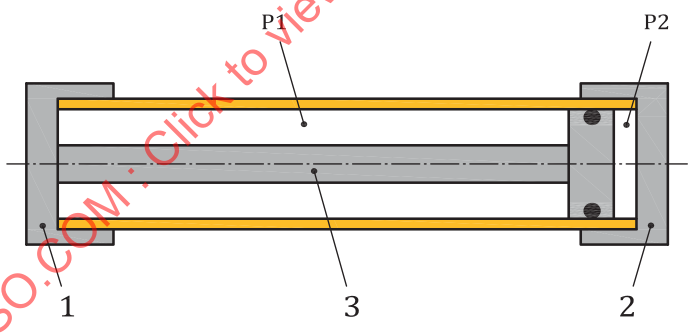
$$R_{test} = \frac{\sigma_{h,LT,Rtest,xx}}{\sigma_{a,LT,Rtest,xx}} \quad (C.12)$$

The actual ratio of the R = R_{test} data point shall be determined by the manufacturer and shall be between 0,5 and 1,0.

NOTE 2 Selecting $\sigma_{a,LT,Rtest,xx}$ using Formula (C.8) will generate a ratio between 0,5 and 1,0.

C.3.2 Test equipment for R_{test}

An example of test equipment that may be used for determination of the R = R_{test} data point of the long term envelope is shown in Figure C.1. Controlling pressures P1 and P2 can generate the aimed combinations of hoop and axial stress. Friction between inner diameter of pipe and plunger is to be minimized.



Key

1 test head #1

2 test head #2

3 plunger + rod

P1 pressure creating hoop stress on the test sample

P2 pressure creating axial stress on the test sample

Figure C.1 — Example test equipment for R = R_{test} datapoint

C.4 $rd_{1\,000,xx}$

$rd_{1\,000,xx}$ is the ratio between the survival test pressure, $P_{T1\,000,xx}$ and MPR_{xx}/f_2 and is defined by Formula (C.13):

$$rd_{1\,000,xx} = 10^{(\log 175\,200 - \log 1\,000) \times G_{xx}} \qquad \text{(C.13)}$$

where

G_{xx} gradient at xx °C;

f_2 part factor for loading in the sustained condition, default value is equal to 0,67.

See Table C.1 for values of $rd_{1\,000,xx}$ based on the default gradients, a 20 year design life and 1 000 h test time.

Table C.1 — Default 1 000 h test ratios

Resin system	Temperature						
	-35 °C	21 °C	50 °C	65 °C	80 °C	93 °C	121 °C
Anhydride	1,26	1,26		1,40	1,72		
Aliphatic amine	1,26	1,26		1,40		1,68	
Cyclo-aliphatic amine (IPD)	1,26	1,26		1,40		1,59	
Aromatic amine (MDA)	1,26	1,26		1,40		1,59	1,81
Polyester	1,33	1,33	1,44				
Vinyl ester	1,33	1,33	1,40	1,47			

Values are based on a 20 year design life and 1 000 h test time.

Interpolation of values is allowed.

EXAMPLE 1 $rd_{1\,000,65}$ for GRE is 1,40.

EXAMPLE 2 $rd_{1\,000,21}$ for GRVE and GRUP is 1,33.

EXAMPLE 3 $rd_{1\,000,80}$ for an Anhydride Epoxy is 1,72.

EXAMPLE 4 $rd_{1\,000,60}$ for GRVE is 1,45 (found by interpolation).

EXAMPLE 5 $rd_{1\,000,-55}$ for GRUP is 1,33.

EXAMPLE 6 $rd_{1000,105}$ for IPD epoxy is not available in this table since 105 °C is above the highest published temperature of 93 °C for IPD epoxy. If a manufacturer intended to use an IPD epoxy at 105 °C, follow the requirements in A.3.2. Use the gradient, G_{xx}, calculated in A.3.2, in the applicable Formulae (C.1) to (C.13) to calculate the survival test pressure.

Annex D
(normative)

Scaling rules

D.1 Scaling rules

Once the components have been tested, the manufacturer can then use scaling rules to qualify all other components using the following guidelines:

a) All scaling shall start from a qualified part.

b) The process for manufacture shall remain constant (for example, it is not possible to scale from filament wound parts to compression-molded or laminated parts and vice-versa).

c) Within a process, the following shall be maintained in order to scale the results:

1) T_g from cure should be similar;

2) all raw materials shall be identical or qualified as identical using the alternate qualification method;

3) glass content shall be within the tolerances specified in 7.2.6;

4) ratio of reinforcing materials shall be identical (roving to weft tape to woven cloth, etc.);

5) winding process for manufacture shall be identical;

6) order of material placement shall be very similar;

d) For fittings and flanges, the joint type shall remain the same (for example, a fitting with the joint type taper-by-taper adhesive shall not be used to scale to a fitting with the joint type taper-by-straight adhesive).

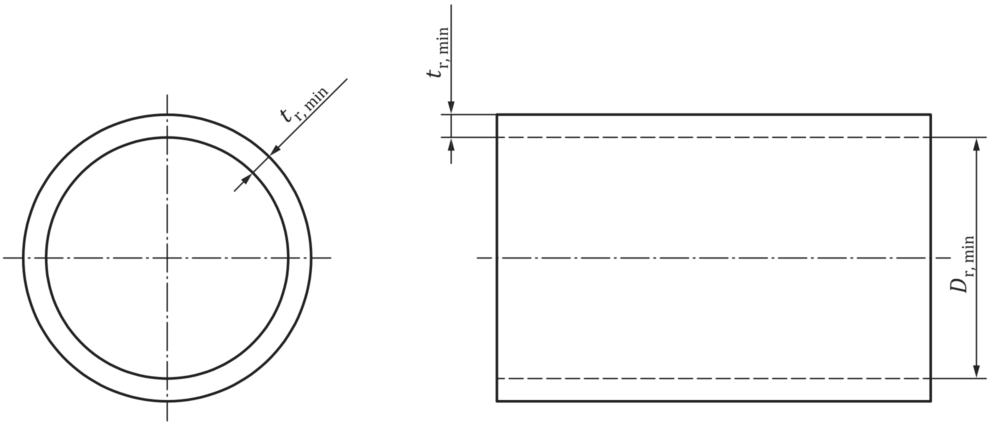
e) Formulae for scaling shall be developed by part configuration. The manufacturer shall provide drawings to show the new part meets all the scaling configurations from the qualified part.

The rules in this annex are not to be considered an exhaustive list of the potential requirements for scaling. It is the best available practice at the time of writing. Future work will be required to develop improved scaling rules.

D.2 Pipe body

Pipe 1 is a pipe that has been qualified through testing. Pipe 2 is a pipe that meets the requirements of Annex E. Pipe 2 shall be considered qualified without testing if the following scaling rule is met (see Figure D.1 for definitions):

$$\frac{t_{\mathrm{r,min,2}}}{\mathrm{MPR}_2 \times D_{\mathrm{r,min,2}}} \geq \frac{t_{\mathrm{r,min,1}}}{\mathrm{MPR}_1 \times D_{\mathrm{r,min,1}}} \qquad \text{(D.1)}$$



Key

$t_{r.min}$ pipe wall thickness

$D_{r,min}$ pipe nominal diameter

Figure D.1 — Critical dimensions for pipes

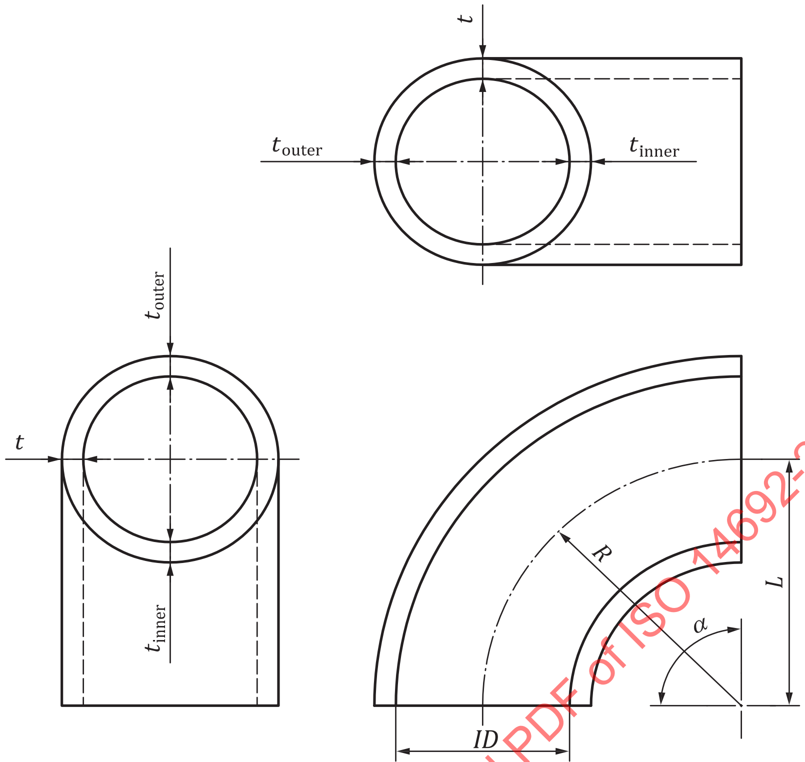
D.3 Bends

Bend 1 is a bend that has been qualified through testing. Bend 2 is a bend that meets the requirements of Annex E. Bend 2 shall be considered qualified without testing if the following scaling rules are met (see Figure D.2 for definitions):

$$\frac{t_2}{\text{MPR}_2 \times ID_2} \geq \frac{t_1}{\text{MPR}_1 \times ID_1} \tag{D.2}$$

$$\frac{R_2}{ID_2} \geq 0{,}95 \times \frac{R_1}{ID_1} \tag{D.3}$$

$$\alpha_2 \leq 1{,}05 \times \alpha_1 \tag{D.4}$$



Key

t	average bend wall thickness
t_{inner}	inner bend wall thickness
t_{outer}	outer bend wall thickness
ID	bend internal diameter
L	length from start of bend to bend centreline
R	bend radius
α	bend angle

Figure D.2 — Critical dimensions for bends

NOTE $t_{r,min}$ and $D_{r,min}$ are not used for bends and other fittings as these dimensions would not be easily determined.

t refers to the total wall thickness of the bend. Depending on the type of construction, t can vary significantly from t_{inner} and t_{outer}. The manufacturer should specify which wall thickness is to be used in the scaling rules.

These scaling rules can be applied to both full-sweep bends and mitered bends. A full-sweep bend shall only be used to scale to other full-sweep bends. A mitered bend shall only be used to scale to other mitered bends.

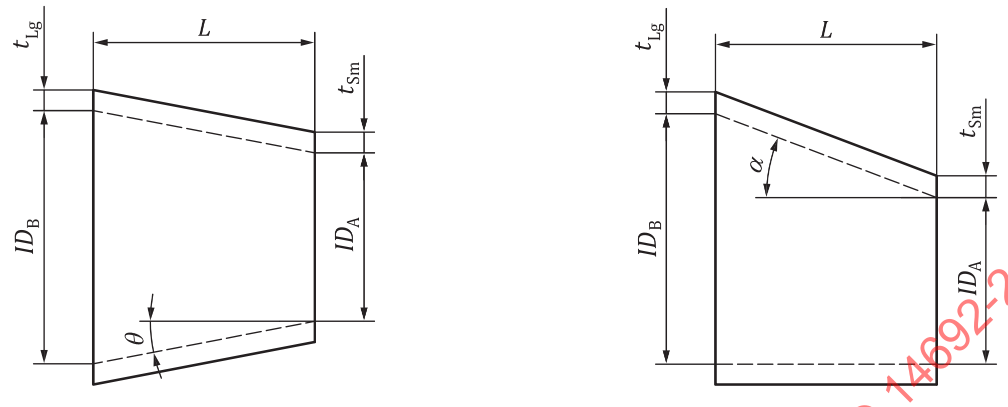
D.4 Reducers

Reducer 1 is a reducer that has been qualified through testing. Reducer 2 is a reducer that meets the requirements of Annex E. Reducer 2 shall be considered qualified without testing if the following scaling rules are met (see Figure D.3 for definitions):

$$\frac{t_{\mathrm{Lg}2}}{\mathrm{MPR}_2 \times ID_{\mathrm{B}2}} \geq \frac{t_{\mathrm{Lg}1}}{\mathrm{MPR}_1 \times ID_{\mathrm{B}1}} \tag{D.5}$$

$$\alpha_2 \leq 1{,}05 \times \alpha_1 \text{ (eccentric reducers)} \tag{D.6}$$

$$\theta_2 \leq 1{,}05 \times \theta_1 \text{ (concentric reducers)} \tag{D.7}$$



Key

t_{Lg} wall thickness of adjoining pipe (diameter ID_B)

t_{Sm} wall thickness of adjoining pipe (diameter ID_A)

ID_A pipe inner diameter (smaller diameter pipe)

ID_B pipe inner diameter (larger diameter pipe)

α angle of eccentric reducer

θ half-angle of concentric reducer

Figure D.3 — Critical dimensions for concentric and eccentric reducers

T_{Sm} shall be ≥ than T_{Lg}.

NOTE 1 The set of scaling rules for reducers implies that qualified concentric reducers can only be used to scale to other concentric reducers. And, qualified eccentric reducers can only be used to scale to other eccentric reducers. There might be a suitable method for scaling from one type of reducer to another, however, this has not been developed in this document.

NOTE 2 Only the large size of the reducer is used for scaling. This implies that if an 8" × 4" concentric reducer is qualified with testing, then other 8" concentric reducers (for example 8" × 2", 8" × 3" and 8" × 6") do not require testing nor scaling.

D.5 Socket flanges

Socket flange 1 is a socket flange that has been qualified through testing. Socket flange 2 is a socket flange that meets the requirements of Annex E. Socket flange 2 shall be considered qualified without testing if the following scaling rules are met (see Figure D.4 for definitions):

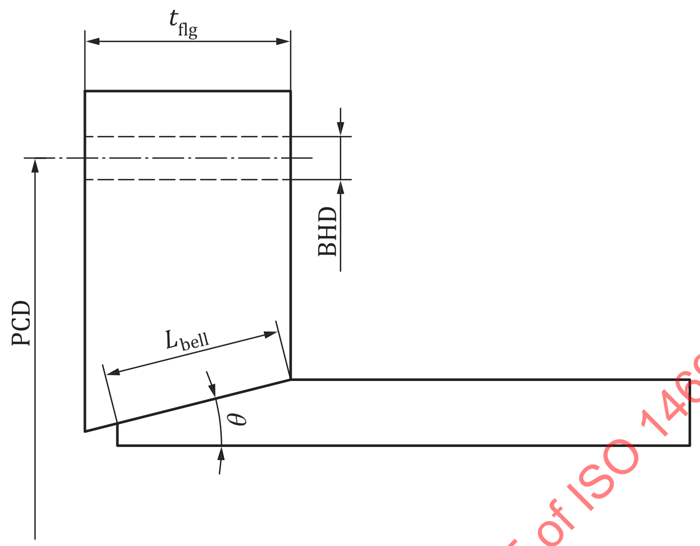
$$\frac{L_{\text{bell},2}}{\text{MPR}_2 \times ID_2} \geq \frac{L_{\text{bell},1}}{\text{MPR}_1 \times ID_1} \tag{D.8}$$

$$\theta_2 \leq 1{,}05 \times \theta_1 \tag{D.9}$$

$$\frac{(\pi \times \text{PCD}_2 - N \times \text{BHD}_2) \times t_{\text{flg},2}}{(\pi \times \text{PCD}_1 - N \times \text{BHD}_1) \times t_{\text{flg},1}} \geq \frac{ID_2 \times \text{MPR}_2}{ID_1 \times \text{MPR}_1} \tag{D.10}$$

$$J_2 \geq J_1 \tag{D.11}$$

where J is the flange rigidity calculated per ASME VIII Division 1, Appendix 2.



Key

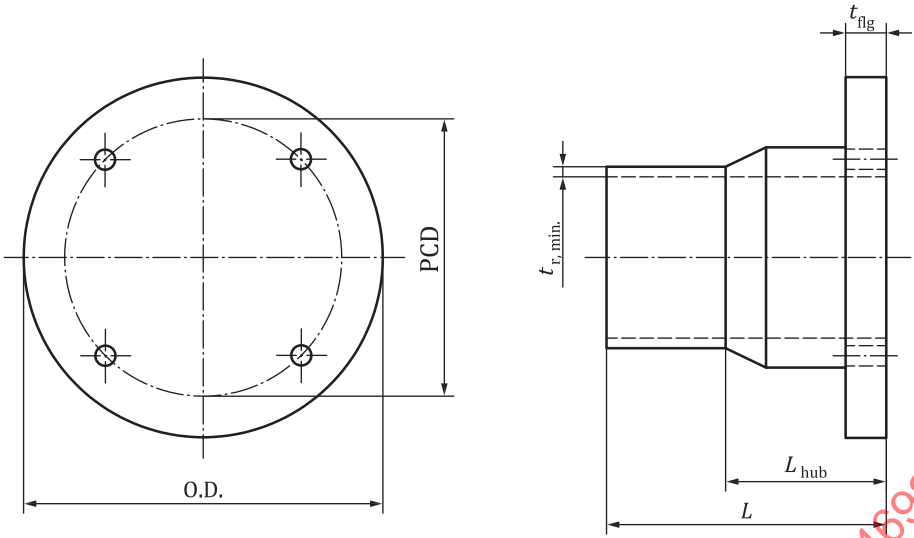
t_{flg} thickness of flange face
BHD bolt hole diameter
L_{bell} length of connection between pipe and flange
PCD pitch circle diameter
θ angle of connection length

Figure D.4 — Critical dimensions for socket flanges

NOTE The diameter of the bolt, is typically slightly smaller than BHD, the diameter of the bolt hole in the flange. A typical difference is about 3 mm.

D.6 Welding neck type flanges

Flange 1 is a flange that has been qualified through testing. Flange 2 is a flange that meets the requirements of Annex E. Flange 2 shall be considered qualified without testing if both flange 1 and flange 2 are designed in accordance with ASME RTP-1-2015, nonmandatory appendix NM-2 or NM-12 (see Figure D.5 for definitions).



Key

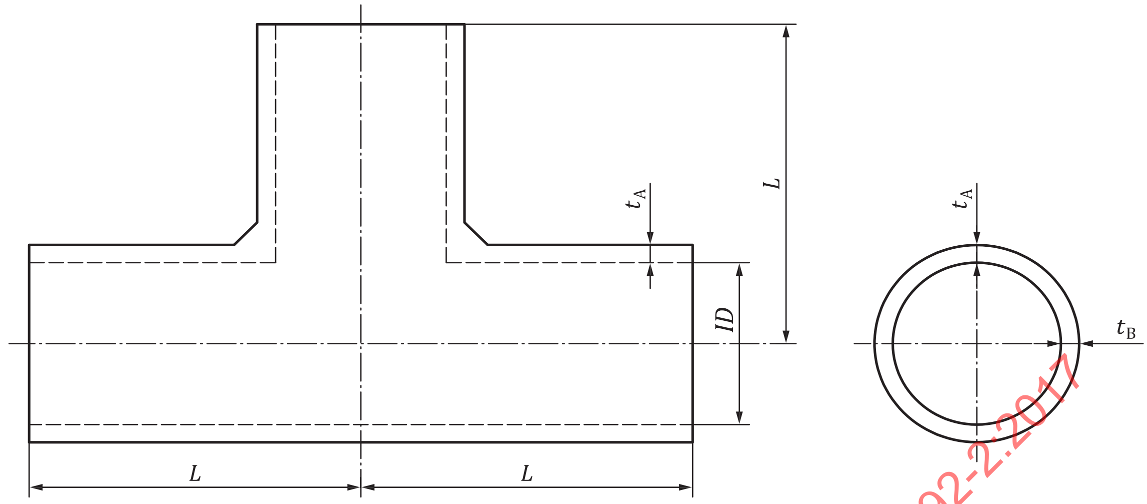
t_{flg}	thickness of flange face
t_{min}	thickness of adjoining pipe wall thickness
L	length of flange
L_{hub}	length of hub section of flange
PCD	pitch circle diameter
O.D.	outer diameter of hub

Figure D.5 — Critical dimensions for weld neck type flanges

D.7 Tees

Tee 1 is a tee that has been qualified through testing. Tee 2 is a tee that meets the requirements of Annex E. Tee 2 shall be considered qualified without testing if the following scaling rule is met (see Figure D.6 for definitions):

$$\frac{t_2}{\mathrm{MPR}_2 \times ID_2} \geq \frac{t_1}{\mathrm{MPR}_1 \times ID_1} \quad \text{(D.12)}$$



Key

t_A thickness of tee at 12 o'clock posotion of main pipe

t_B thickness of tee at 3 o'clock and 9 o'clock position of main pipe

L length of branch connection, end to main pipe centreline and length of main pipe, end the branch centreline

ID main pipe internal diameter

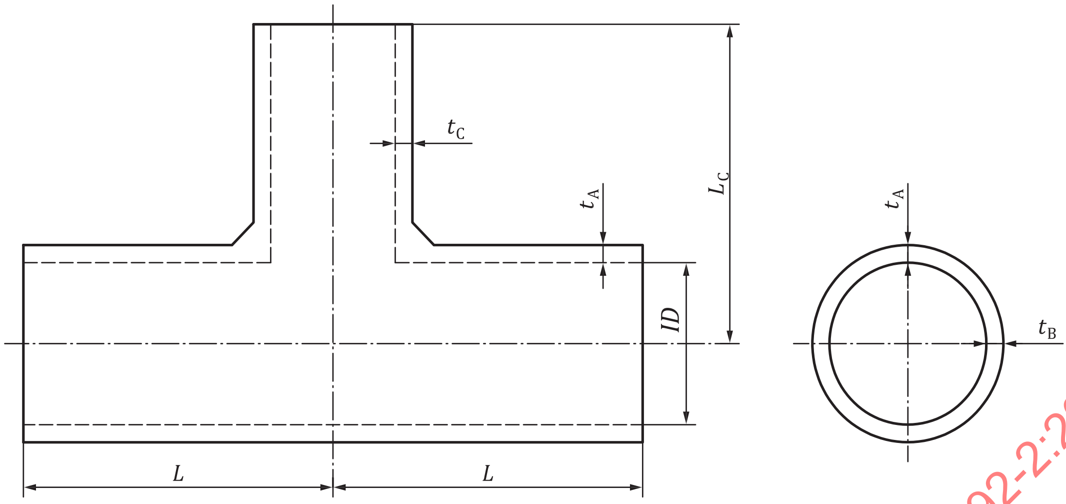
Figure D.6 — Critical dimensions for tees

t_A and t_B refer to the total wall thickness of the tee. Depending on the type of construction, t_A can vary significantly from t_B. The manufacturer should specify which wall thickness is to be used in the scaling rules.

D.8 Unequal tees

Unequal tee 1 is an unequal tee that has been qualified through testing. Unequal tee 2 is an unequal tee that meets the requirements of Annex E. Unequal tee 2 shall be considered qualified without testing if the following scaling rule is met (see Figure D.7 for definitions):

$$\frac{t_2}{\text{MPR}_2 \times ID_2} \geq \frac{t_1}{\text{MPR}_1 \times ID_1} \tag{D.13}$$



Key

t_A thickness of tee at 12 o'clock posotion of main pipe

t_B thickness of tee at 3 o'clock and 9 o'clock position of main pipe

t_C thickness of branch connection

L length of main pipe, end to branch centreline

L_C length of branch connection, end to main pipe centreline

ID main pipe internal diameter

Figure D.7 — Critical dimensions for unequal tees

NOTE 1 t_A and t_B refer to the total wall thickness of the unequal tee. Depending on the type of construction, t_A can vary significantly from t_B. The manufacturer should specify which wall thickness is to be used in the scaling rules.

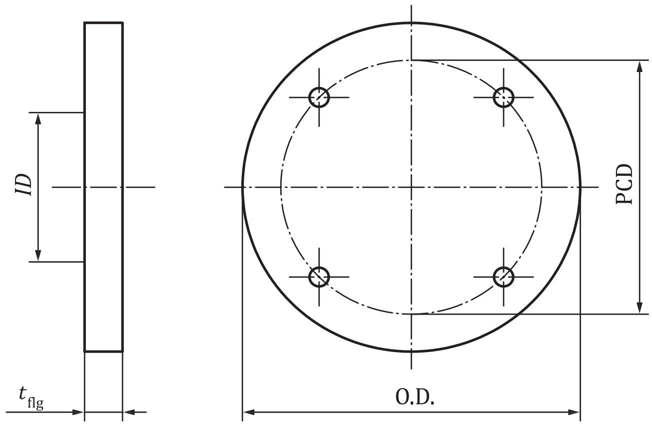
NOTE 2 The crotch thickness of the tee is an important dimension, but is impractical to measure non-destructively.

NOTE 3 Tees are complicated components to analyze. Different scaling rules might need to be considered for tees and unequal tees.

D.9 Blinds

Blind 1 is a blind that has been qualified through testing. Blind 2 is a flange that meets the requirements of Annex E. Blind 2 shall be considered qualified without testing either if both blind 1 and blind 2 are designed in accordance with ASME RTP-1-2015, non-mandatory appendix NM-2 or NM-12, or if the following scaling rule is met (see Figure D.8 for definitions):

$$\mathrm{MPR}_1 \times \left(\frac{\mathrm{PCD}_1}{t_{\mathrm{flg},1}}\right)^2 \geq \mathrm{MPR}_2 \times \left(\frac{\mathrm{PCD}_2}{t_{\mathrm{flg},2}}\right)^2 \quad \text{(D.14)}$$



Key

t_{flg} thickness of blind flange

ID internal diameter of pipe

PCD pitch circle diameter

O.D. outer diameter of blind flange

Figure D.8 — Critical dimensions for blinds

NOTE An additional scaling rule can be needed to address the rigidity/stiffness of the blind. This consideration has not been developed in this document.

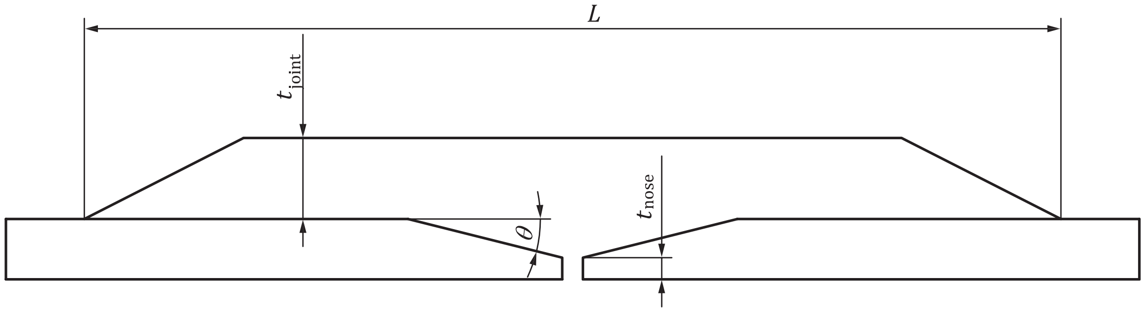
D.10 Laminated joints

Joint 1 is a laminated joint that has been qualified through testing. Joint 2 is a laminated joint that meets the requirements of Annex E. Joint 2 shall be considered qualified without testing if the following scaling rules are met (see Figure D.9 for definitions):

$$\frac{t_{\text{joint},2}}{\text{MPR}_2 \times ID_2} \geq \frac{t_{\text{joint},1}}{\text{MPR}_1 \times ID_1} \quad \text{(D.15)}$$

$$\frac{L_2}{\text{MPR}_2 \times ID_2} \geq \frac{L_1}{\text{MPR}_1 \times ID_1} \quad \text{(D.16)}$$

$$\theta_2 \leq 1{,}05 \times \theta_1 \quad \text{(D.17)}$$



Key

t_{joint} thickness of laminated joint

t_{nose} thickness of pipe at end of taper

L total length of laminated joint

θ angle of pipe taper

Figure D.9 — Critical dimensions for laminated joints

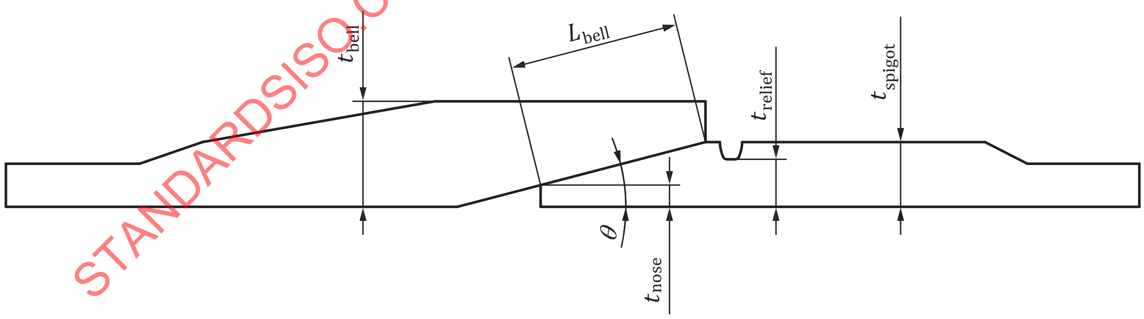
D.11 Taper-by-taper adhesive joints and threaded joints

Joint 1 is a taper-by-taper joint that has been qualified through testing. Joint 2 is a taper-by-taper joint that meets the requirements of Annex E. Joint 2 shall be considered qualified without testing if the following scaling rules are met (See Figure D.10 for definitions):

$$\frac{t_{bell,2}}{MPR_2 \times ID_2} \geq \frac{t_{bell,1}}{MPR_1 \times ID_1} \tag{D.18}$$

$$\frac{L_{bell,2}}{MPR_2 \times ID_2} \geq \frac{L_{bell,1}}{MPR_1 \times ID_1} \tag{D.19}$$

$$\theta_2 \leq 1{,}05 \times \theta_1 \tag{D.20}$$



Key

t_{bell} thickness of bell section of joint

t_{spigot} thickness of spigot section of joint

t_{nose} thickness of pipe at end of spigot section

t_{relief} minimum thickness of pipe at relief in spigot section

L_{bell} length of contact between bell and spigot ends

θ angle of pipe taper

Figure D.10 — Critical dimensions for taper-by-taper and threaded joints

Joint 1 is a threaded joint that has been qualified through testing. Joint 2 is a threaded joint that meets the requirements of Annex E. Joint 2 shall be considered qualified without testing if the scaling rules for taper-by-taper adhesive joints is met and the following scaling rule is met.

$$\frac{t_{\text{relief},2}}{\text{MPR}_2 \times ID_2} \geq \frac{t_{\text{relief},1}}{\text{MPR}_1 \times ID_1} \tag{D.21}$$

NOTE 1 Shear stress presents a unique problem for taper-by-taper adhesive bonded joints. Because the wall thickness is less at the lower pressure rating, the shear stress of the joint is typically highest for the lowest pressure rated component. These scaling rules can require both low pressure rating and high pressure rated joints to be tested.

NOTE 2 In some cases, the manufacturer might wish to test a fitting with a higher-temperature MPR_{xx} than the pipe. This might occur on a pipeline project with a minimal number of fittings in order to minimize the testing costs of the fittings. This can result in a change in the geometry of the joint.

Annex E
(normative)

Representative products

The components to be tested can be any combination of diameter and pressure class. The range of products that is qualified by a single component is limited by Formulae (E.1) to (E.5). DN_1 and MPR_1 refer to the size and MPR of the product that has been tested. DN_2 and MPR_2 refer to the sizes and pressures of the products that may be considered represented by DN_1 and MPR_1. These formulae are also summarized in Table E.1. Figures E.1 and E.2 provide examples.

DN:

If $DN_1 \leq 300$:

$$0 \leq DN_2 \leq 1{,}6 \times DN_1 \quad \text{(E.1)}$$

If $DN_1 > 300$:

$$0{,}5 \times DN_1 \leq DN_2 \leq 1{,}6 \times DN_1 \quad \text{(E.2)}$$

MPR:

If $MPR_1 \leq 50$ bar:

$$0 \leq MPR_2 \leq 1{,}6 \times MPR_1 \quad \text{(E.3)}$$

If $MPR_1 > 50$ bar:

$$0{,}5 \times MPR_1 \leq MPR_2 \leq 1{,}6 \times MPR_1 \quad \text{(E.4)}$$

DN × MPR:

$$DN_2 \times MPR_2 \leq DN_1 \times MPR_1 \quad \text{(E.5)}$$

Table E.1 — Qualification ranges

Product that has been tested	Products that are considered represented by DN_1 and MPR_1
$DN_1 > 300$ $MPR_1 > 50$ bar	$0{,}5 \times DN_1 \leq DN_2 \leq 1{,}6 \times DN_1$ and $0{,}5 \times MPR_1 \leq MPR_2 \leq 1{,}6 \times MPR_1$ and $DN_2 \times MPR_2 \leq DN_1 \times MPR_1$
$DN_1 \leq 300$	Same as above except no limit on minimum DN: $DN_2 \leq 1{,}6 \times DN_1$ and $0{,}5 \times MPR_1 \leq MPR_2 \leq 1{,}6 \times MPR_1$ and $DN_2 \times MPR_2 \leq DN_1 \times MPR_1$
$MPR_1 \leq 50$ bar	Same as above except no limit on minimum MPR: $0{,}5 \times DN_1 \leq DN_2 \leq 1{,}6 \times DN_1$ and $MPR_2 \leq 1{,}6 \times MPR_1$ and $DN_2 \times MPR_2 \leq DN_1 \times MPR_1$

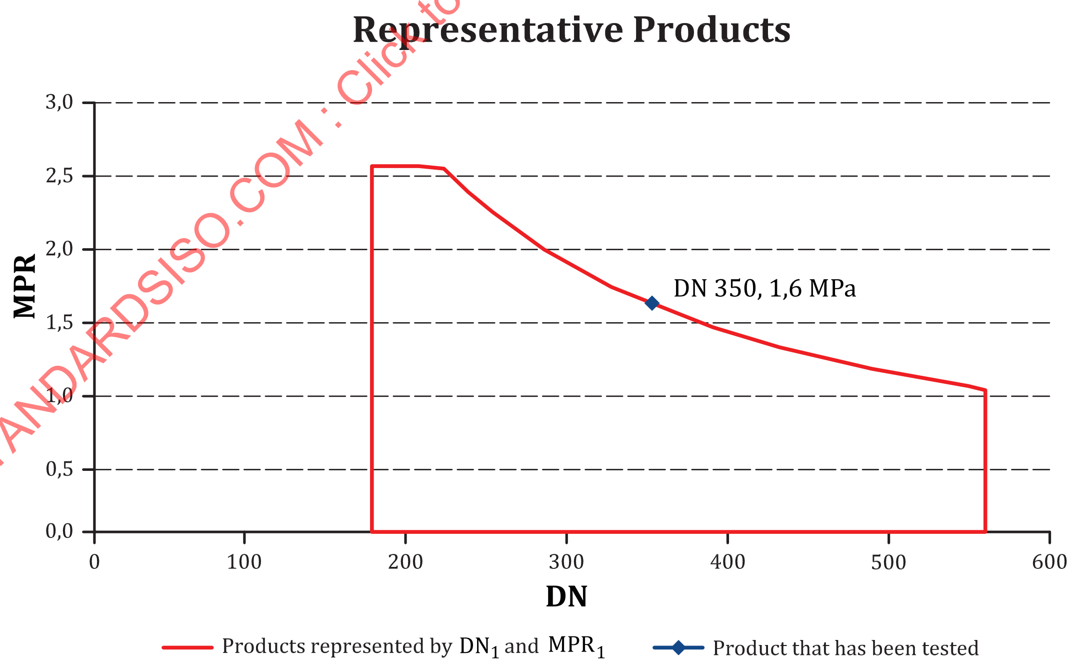


Figure E.1 — Example where DN_1 = 350 mm and MPR_1 = 1,6 MPa

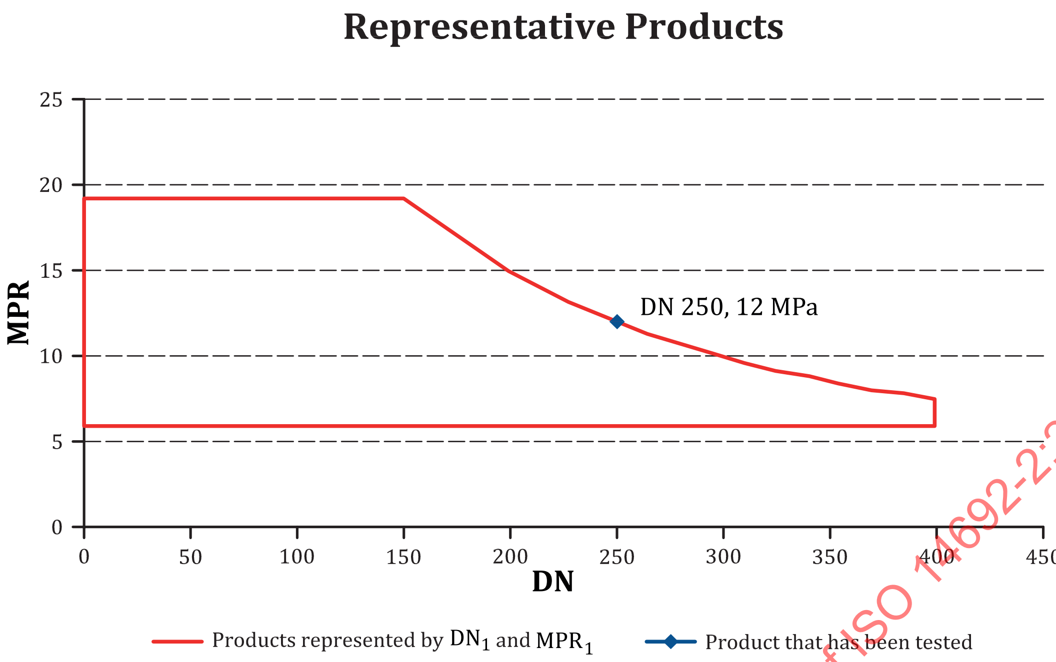


Figure E.2 — Example where DN_1 = 250 mm and MPR_1 = 12 MPa

NOTE The concept of a product family, product sectors, product sector representatives and component variants that was used in ISO 14692-2:2002 is not used in this document. For a comparison, the concept in this annex might be referred to as a floating product sector where the component to be tested is defined by the manufacturer and the corresponding product sector is defined by this annex. This concept removes the burden of testing specific sizes and pressure classes and gives more flexibility to the manufacturer while maintaining the rigour of a robust qualification programme.

Representative product types

A representative product type is a component type that is taken to be representative of a particular series of products having the same function (e.g. plain pipe, pip/joint, bend, etc.).

Representative product types shall at least include:

a) plain pipe;

b) pipe plus joint. Each type of joint (e.g. taper/taper adhesive bonded joint, conical/cylindrical adhesive bonded joint, laminated joint, elastomeric bell-and-spigot seal lock joint, threaded joint, saddles) shall be taken as a separate representative product type;

c) elbows;

d) reducers;

e) tees;

f) flanges;

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

Annex F
(normative)

Flange qualification

F.1 Qualification procedure for flanges

F.1.1 Test overview

The manufacturer shall conduct the following four tests to qualify flanges:

a) a survival test;

b) a 10-cycle pressure test;

c) a vacuum test;

d) a combined load test.

The third test, the vacuum test, is optional for those flanges that are not rated for vacuum conditions nor external pressure.

F.1.2 Survival test

The manufacturer shall conduct survival tests on flanges in accordance with 5.3.1.

To enable sealing at the elevated temperature and/or pressure levels, a higher rated gasket/seal may be used. The machining of a groove in the GRP flange to seat and seal an o-ring gasket is acceptable.

Flanges are allowed to show damage (e.g. cracking in the neck of the flange, or between the bolt holes), as long as they pass the survival test without failure (i.e. the spool is able to maintain pressure without leakage).

In case of leakage past the flange face, the test may be interrupted to seal the flanges by increasing the bolt torques to an appropriate value. Testing may then be continued to the required test duration.

F.1.3 10-cycle pressure test

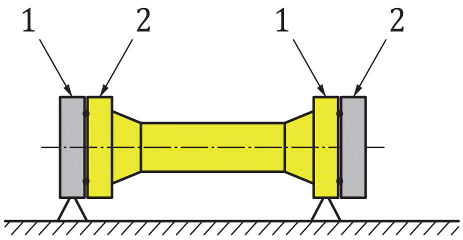
In addition to the survival test, the manufacturer shall also conduct a 10-cycle pressure test. Figures F.1 and F.2 provide examples of the test assembly. The test assembly shall be assembled using the gasket and bolt torque as recommended by the supplier. The test assembly shall then be subjected to 10 pressure cycles from 0 bar to 1,5 × MPR_{xx}. Testing shall take place at ambient conditions to facilitate inspection. One cycle shall consist of:

a) a steady pressurization of the test assembly to 1,5 × MPR_{xx},

b) a 5 min period where the spool remains at 1,5 × MPR_{xx}, and

c) full pressure release.

Leakage past the gasket, or through the flanged spool, at any point of the test shall constitute failure. If leakage past the gasket occurs, it is permitted to increase the recommended bolt torque for the flanged joint and re-start the cyclic test sequence from the beginning.

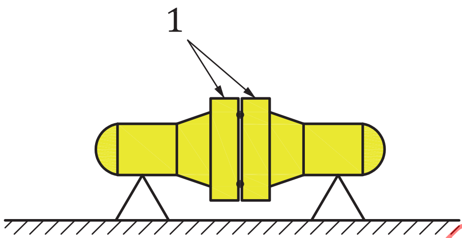


Key

1 steel blind flange

2 GRP flange

Figure F.1 — Sample arrangement for 10 cycle pressure test



Key

1 GRP flange

Figure F.2 — Sample arrangement for 10 cycle pressure test

F.1.4 Vacuum test

Upon successful completion of the 10-cycle pressure test, a vacuum test shall be conducted on the same test assembly for 1 h at a negative pressure of −0,05 MPa (0,05 MPa absolute). Up to 30 min may be allowed to stabilize the negative pressure. The maximum permissible pressure increase during the 1 h period shall be 0,01 MPa.

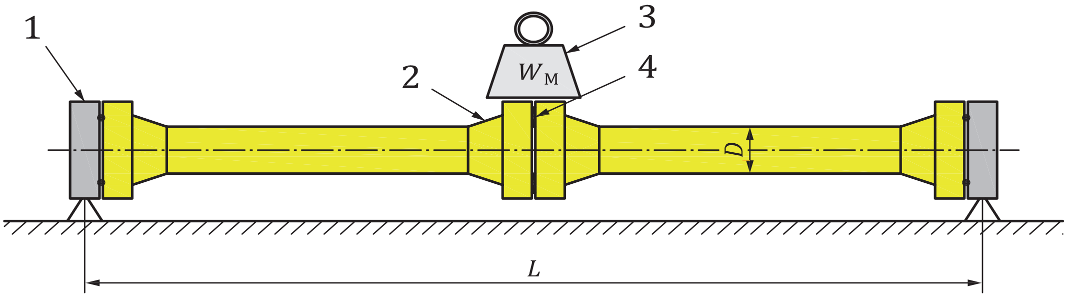
For flanges that are not rated for vacuum conditions nor external pressure, the vacuum test is optional. If the vacuum test is not conducted, the manufacturer shall specify that the flange(s) are not qualified for vacuum conditions nor external pressure.

Upon completion of the vacuum test, the test assembly shall be disassembled and the flange(s) shall be visually inspected for any signs of damage. Any cracks or structural damage (e.g. cracking in the neck/between bolt holes) to the flange shall constitute failure.

The manufacturer shall have the option of performing the first three tests (the 10 cycle pressure test, vacuum test and survival test) on one test assembly. This will require the 10 cycle pressure test and vacuum test to be executed satisfactorily first, followed by the survival test.

F.1.5 Combined loading test

The fourth test that the manufacturer shall conduct is a combined loading test which is a survival test with a bending moment applied to a flanged connection (see Figure F.3). The pressure applied in this test shall be half of the pressure applied in the survival test (R = 2 condition). The weight applied shall create additional bending stress to generate an R_{test} ratio between 0,5 and 1,0. The weight applied should account for the mass of the spools, the mass of the test fluid and W_M.



Key

1 steel blind flange
2 GRP flange
3 weight
4 gasket
L length between supports
D nominal diameter of test sample
W_M external mass applied to test sample

Figure F.3 — Sample arrangement for combined loading test

Due to the complexity of the test, the manufacturer shall conduct this test at 21 °C (for GRE, GRUP and GRVE).

Annex G
(normative)

Major Poisson's ratio

G.1 General

The major Poisson's ratio, ν_{ah}, shall be determined by measuring elongation in a pipe sample subjected to an unrestrained hydrostatic pressure and calculating ν_{ah} using Formula (G.1):

$$\nu_{ah} \times \frac{E_a}{E_h} = 0{,}5 \times \left(1 - \frac{\delta_a}{L} \times \frac{E_a \times 4 \times t_{r,min}}{P \times D_{r,min}} \right) \quad \text{(G.1)}$$

where

δ_a	change in length, expressed in mm;
L	length of the test assembly, expressed in mm;
P	internal pressure applied to the test assembly, expressed in MPa;
E_a	axial tensile modulus, expressed in MPa;
$t_{r,min}$	minimum reinforced pipe wall thickness, expressed in mm;
$D_{r,min}$	mean diameter of the minimum reinforced pipe wall, expressed in mm.

NOTE For stress, this document uses mean diameter ($D_{r,min}$) for hoop calculations. This is very close to the thick wall stress, so it is higher than the thin-wall stress. Thin-wall stress is more accurately calculated using the pipe *ID* not the mean diameter. For determining the ν_{ha} elastic property, it can be simpler to use *ID* instead of $D_{r,min}$. This can provide a reasonable estimate of the average hoop stress for properly predicting hoop modulus and can eliminate variation from various D/t ratios, but can introduce some error in the value of ν_{ha}. However, to maintain consistency in the formulae between elastic properties in this document and the stress calculations in ISO 14692-3, $D_{r,min}$ is being used. This can require consideration of measuring ν_{ha} at different D/t ratios.

G.2 Apparatus

G.2.1 Hydrostatic test system. Any device that is capable of applying a constant internal pressure on the test specimen. The device shall be capable of holding the pressure within ±2 %. The test specimen shall be unrestrained to allow for biaxial loading (i.e. "free" ends).

G.2.2 Pressure gauge. A pressure gaue having an accuracy of ±2 %.

G.2.3 Extension indicator. A suitable instrument for determining the distance between the end points on the test specimen.

NOTE If the test specimen is 5,0 m in length, it is anticipated that the extension indicator will need to be able to measure the length change with an accuracy of ±0,5 mm.

G.3 Test specimen

The test specimen shall be a section of pipe at least 5,0 m in length. End closures on the test specimen shall allow for biaxial loading (i.e. "free" ends). Diameter, wall thickness and MPR of the test specimen shall be selected by the manufacturer.

NOTE The section of pipe needs to be of a sufficient length in order to generate a significant length change. Longer lengths will generate greater length changes.

There shall be a total of at least three specimens tested.

G.4 Procedure

The test shall be conducted at ambient temperature.

A change in temperature during the test will contribute to a length change in the specimen. Temperature shall be held constant during the test.

The test shall be conducted in accordance with the following procedure:

a) Determine $t_{r,min}$ in accordance with 7.2.8. Determine $D_{r,min}$ in accordance with 7.2.8 and ISO 14692-1:2017, Annex E.

b) Measure the length of the test specimen. Specify this length as L1.

c) Attach the end closures to the specimen and attach the specimen to the hydrostatic test system. Fill the test specimen completely with potable water. Ensure that there is no entraped air in the test specimen.

d) Condition the specimen as follows: Samples are to be subject to an internal pressure test at MPR_{21} for 168 h with unrestrained ends.

e) Increase the pressure uniformly to MPR_{21}.

f) Measure the length of the test specimen. Specify this length as L2.

   NOTE 1 It can be necessary to allow the test specimen to "stabilize" at each test pressure. Consideration may be given to holding the test pressure for a short period (e.g. 15 min), then measuring the L2 length over a period of time (e.g. every 10 min for a total of 30 min) and calculating L2 as the average of those three results.

g) Increase the pressure uniformly to 2,0 × MPR_{21}. Measure the length of the test specimen. Specify this length as L3.

h) Increase the pressure uniformly to 3,0 × MPR_{21}. Measure the length of the test specimen. Specify this length as L4.

Table G.1 summarizes the length changes as a function of applied pressure.

NOTE 2 The pressure force on the unrestrained ends of the test specimen will lengthen the test specimen while Poisson's effect will shorten the test specimen. The net effect is an increase in length of the test specimen.

Repeat the above procedure for all three test specimens.

Calcuate ν_{ha} as an average of all 18 length changes and pressures (six per test specimen).

Table G.1 — Summary of length changes and pressures for one test specimen

δ_A	P
L2 – L1	MPR_{21}
L3 – L1	2,0 × MPR_{21}
L4 – L1	3,0 × MPR_{21}
L3 – L2	MPR_{21}
L4 – L2	2,0 × MPR_{21}
L4 – L3	MPR_{21}

NOTE 3 Averaging the results using all six length changes per test specimen assumes the length reduction due to Poisson's effect is linear. The manufacturer might wish to evaluate the linearity of the calculations when analyzing the results.

Annex H
(normative)

Fire endurance testing

H.1 Qualification procedure

H.1.1 Fire classification code overview

Products shall be assigned a fire classification code. The fire classification code is a five-field number: A-B-C/xxx-(D-E) where service function A, fire type B, integrity C, spread of fire and heat release D and smoke obscuration and toxicity E are assigned prescribed levels in decreasing order of severity.

A **= service**

= **DE**: dry or empty

= **DF**: initially dry or empty for minimum of 5 min followed by flowing water

= **ST**: stagnant water

= **SF**: initially stagnant water for minimum of 5 min followed by flowing water

= **WF**: flowing water

= **FG**: flammable gas

= **HL**: hydrocarbon liquid

= **OC**: other chemical

B **= fire type**

= **JF**: jet fire

= **HF**: hydrocarbon pool fire

= **IF**: hydrocarbon impinging flame

= **CF**: cellulosic fire

C **= integrity**

= **EA**: capable of maintaining the test pressure without leakage during or after the test

= **EB**: no leakage or slight weeping during the fire test

Capable of maintaing the test pressure after cooling with leakage not exceeding 0,2 l/min for 15 min.

= **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 to be quantified).

= ED: leakage permitted (≥0,5 l/min) during fire test

Capable of maintaining the test pressure after cooling with known leakage (leakage rate to be quantified).

= EE: leakage permitted (≥0,5 l/min) during fire test

Pressure that can be maintained after cooling with known leakage to be quantified.

= EF: no endurance required

D = surface spread of flame and heat release

= 1: no spread of fire permitted

= 2: representative of confined areas where spread of flame is required to be limited

Properties to satisfy IMO Resolution A.653(16): $Q_{\text{CFE}} \geq 20{,}0$ kW/m^2, $Q_{\text{sb}} \geq 1{,}5$ MJ/m^2,$Q_{\text{t}} \leq 0{,}7$ MJ, $Q_{\text{p}} \leq 4{,}0$ kW

= 3: representative of areas where spread of flame is required to be limited

Properties to be quantified using the procedures in IMO Resolution A.653(16).

= 4: no spread of fire requirement

E = smoke obscuration and toxicity

= 1: no emissions of smoke nor toxicity permitted

= 2: representative of confined areas where levels are to be limited

Properties not to exceed IMO MSC.61(67), Annex 1, Part 2: $D_{\text{m}} < 400$, 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 smoke obscuration and toxicity are required to be limited

Properties to be quantified using the procedures in IMO MSC.61(67), Annex 1, Part 2.

= 4: no smoke obscuration nor toxicity requirement

When measuring integrity, the test pressure shall be the design pressure.

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

NOTE When measuring integrity, slight weeping is not quantitatively defined, but is to be determined by a laboratory that meets ISO/IEC 17025.

H.1.2 Fire endurance

When specified by the principal, pipe components shall be tested in accordance with this annex at a laboratory that meets ISO/IEC 17025, acceptable to the authority having jurisdiction. This applies to all pipe and fittings intended to be used, methods of joining, and any internal or external liners, coverings and coatings required to comply with the performance criteria.

H.1.3 Surface spread of flame and heat release

When specified by the principal, surface spread of flame and heat release shall be evaluated in accordance with IMO Resolution A653(16). Modifications, to take account of the curved surface of the pipe, in accordance with IMO Resolution A753(18) may be made.

H.1.4 Smoke obscuration and toxicity

When specified by the principal, smoke emission, obscuration and toxicity shall be evaluated in accordance with IMO MSC.61(67), Annex 1, Part 2. Modifications, to take account of the curved surface of the pipe, in accordance with IMO Resolution A753(18) may be made.

H.2 Test procedures

This test method covers the determination of the fire endurance of GRP pipe, fittings and joints. The test pressure shall be the design pressure.

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.

NOTE 1 Unlike internal pressure testing, it is often acceptable to extrapolate fire endurance test results to larger sizes. For example, if a fire endurance test was conducted in the 150 mm size, this may be used to qualify sizes from 150 mm to 300 mm. Conversely, the test result in the 150 mm size may not be used to qualify sizes smaller than 150 mm.

NOTE 2 Above 300 mm, it becomes less practical to test GRP in a fire endurance test due to the size of the test equipment required to conduct the test.

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.

The fire type and test configuration shall be in accordance with H.4.1, H.4.2 or H.4.3.

The fire test procedures defined in H.5 allow the 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.

H.3 Test specimen and set-up requirements

H.3.1 General

The test specimen shall be prepared with the joints, fittings and fire-protective coverings, if any, intended for use in the proposed application.

It is recognized that the joint can 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.

NOTE Testing in an impinging flame or hydrocarbon pool fire per IMO A.753(18) may not allow the inclusion of several components in a single test. The impinging flame test in IMO A.753(18) is typically designed to allow the testing of a section of pipe, a joint and flanges on each end of the specimen.

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 reach an air-dry condition. This condition shall be defined as equilibrium with 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.

If the piping 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.

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

Instrumentation shall be provided to record fuel flowrate, water pressure, water flowrate and water leakage rate from the pipe assembly or individual components. The pressure gauge shall be capable of being read with an accuracy of 5 %. Thermocouples may be mounted on the specimen to record temperature conditions during the testing. A thermometer or thermocouple may be used to measure internal water temperature.

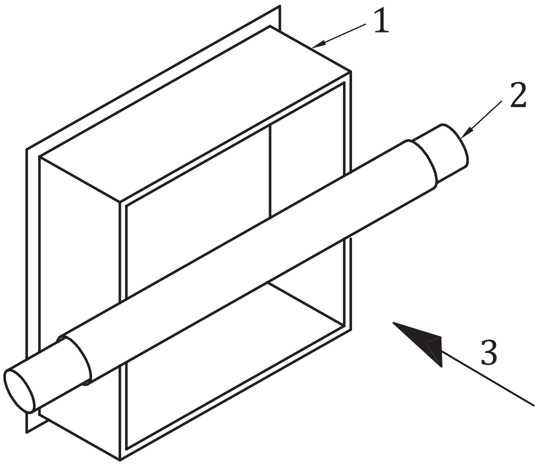
If the test is carried out indoors, the test building shall be suitably constructed in order to ensure that a hazardous amount of heat or smoke does not accumulate during or after the test.

H.3.2 Jet fire testing

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 H.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.

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

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.



Key

1 steel box

2 GRP pipe under test

3 jet fire

Figure H.1 — General view of jet fire testing

H.3.3 Furnace and impinging flame testing

The pipe ends and closures may be outside the furnace.

If the general orientation of the specimen is horizontal, it shall be supported adequately. One of the supports may be fixed while the others shall allow free movement (horizontally and laterally). V-shaped pipe supports shall be considered suitable.

NOTE Fire testing of water-filled pipes in closed furnaces carries the risk of possible explosion, although past testing 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

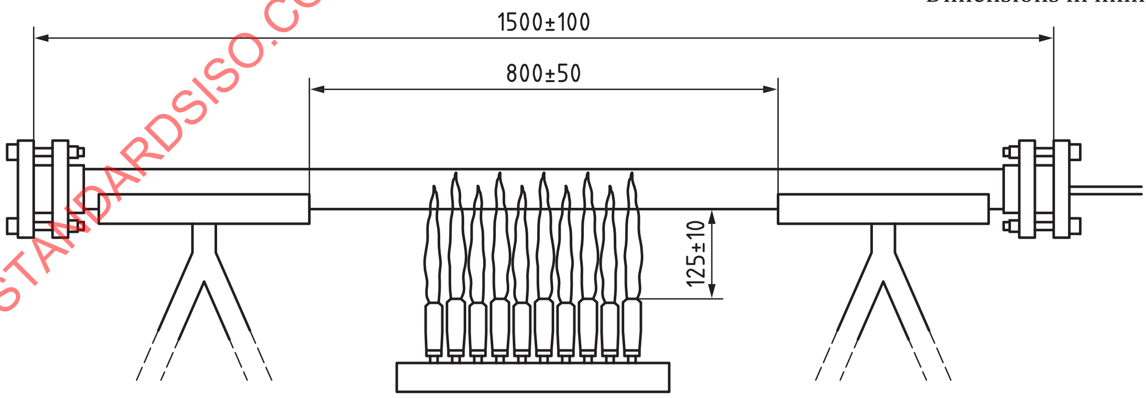


Figure H.2 — General view of impinging flame test arrangement

H.4 Fire specification

H.4.1 Jet fire

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.

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

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

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

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. 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.

H.4.2 Furnace fire

H.4.2.1 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.

H.4.2.2 Hydrocarbon fire curve

The set-up and control of the fire test shall be as specified in ASTM E1529-14, Clauses 6 to 11 or in an equivalent standard acceptable to the authority having jurisdiction.

NOTE The exposure conditions in ASTM E1529 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.

H.4.2.3 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.

H.4.3 Impinging flame

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 H.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.

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

