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Petroleum and natural gas industries –
Glass-reinforced plastics (GRP) piping –
Part 2: Qualification and manufacture (ISO 14692-2:2017);
English version EN ISO 14692-2:2017

Industries du pétrole et du gaz naturel –
Canalisations en plastique renforcé de verre (PRV) –
Partie 2: Qualification et fabrication (ISO 14692-2:2017);
Version anglaise EN ISO 14692-2:2017

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Nationales Vorwort

Der Text von ISO 14692-2:2017 wurde vom Technischen Komitee ISO/TC 67 „Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries“ der Internationalen Organisation für Normung (ISO) erarbeitet und als EN ISO 14692-2:2017 durch das Technische Komitee CEN/TC 12 „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie“ übernommen, dessen Sekretariat von NEN (Niederlande) gehalten wird.

Für Deutschland hat hieran der Arbeitskreis NA 109-00-01-06 AK „Verfahrenstechnische Anlagen und Ausrüstungen“ im DIN-Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) mitgearbeitet.

Diese Europäische Norm enthält unter Berücksichtigung des DIN-Präsidialbeschlusses 1/2004 nur die englische Originalfassung der ISO Norm.

Für die in diesem Dokument zitierten Internationalen Normen wird im Folgenden auf die entsprechenden Deutschen Normen hingewiesen:

ISO 1172 siehe DIN EN ISO 1172

ISO 11357-2 siehe DIN EN ISO 11357-2

ISO 14130 siehe DIN EN ISO 14130

ISO 14692-1 siehe DIN EN ISO 14692-1

ISO 14692-3 siehe DIN EN ISO 14692-3

ISO 14692-4 siehe DIN EN ISO 14692-4

Änderungen

Gegenüber DIN EN ISO 14692-2:2005-07 und DIN EN ISO 14692-2 Berichtigung 1:2007-02 wurden folgende Änderungen vorgenommen:

a) neuer Abschnitt 4 „Manufacturer's declarations“;

b) neuer Anhang A (normativ) „Gradients and temperature limits“;

c) neuer Anhang B (normativ) „Long term envelope data points“;

d) neuer Anhang C (normativ) „Survival tests“;

e) neuer Anhang D (normativ) „ Scaling rules“;

f) neuer Anhang E (normativ) „Representative products“;

g) neuer Anhang F (normativ) „Flange qualification“;

h) neuer Anhang G (informativ) „Major Poisson's ratio“;

i) neuer Anhang H (normativ) „Fire endurance testing“;

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j) neuer Anhang I (normativ) „Alternate material qualification“;

k) neuer Anhang J (normativ) „Visual inspection“;

l) neuer Anhang K (informativ) „Example of qualification summary form“;

m) redaktionelle Überarbeitung des gesamten Dokuments.

Frühere Ausgaben

DIN EN ISO 14692-2: 2005-07
DIN EN ISO 14692-2 Berichtigung 1: 2007-02

Nationaler Anhang NA
(informativ)

Begriffe, Symbole und Abkürzungen

Die Benummerung der folgenden Begriffe und Abkürzungen sind identisch mit der Benummerung in der englischen Fassung.

3 Begriffe, Symbole und Abkürzungen

Für die Anwendung dieses Dokuments gelten die Begriffe, Symbole und Abkürzungen nach ISO 14692-1.

ISO und IEC stellen terminologische Datenbanken für die Verwendung in der Normung unter den folgenden Adressen bereit:

— ISO Online Browsing Platform: unter http://www.iso.org/obp;

— IEC Electropedia: unter http://www.electropedia.org/.

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Nationaler Anhang NB
(informativ)

Literaturhinweise

DIN EN ISO 1172, *Textilglasverstärkte Kunststoffe — Prepregs, Formmassen und Laminate — Bestimmung des Textilglas- und Mineralfüllstoffgehalts; Kalzinierungsverfahren*

DIN EN ISO 11357-2, *Kunststoffe — Dynamische Differenz-Thermoanalyse (DSC) — Teil 2: Bestimmung der Glasübergangstemperatur und der Glasübergangsstufenhöhe*

DIN EN ISO 14130, *Faserverstärkte Kunststoffe — Bestimmung der scheinbaren interlaminaren Scherfestigkeit nach dem Dreipunktverfahren mit kurzem Balken*

DIN EN ISO 14692-1, *Erdöl- und Erdgasindustrie — Glasfaserverstärkte Kunststoffrohrleitungen (GFK) — Teil 1: Begriffe, Symbole, Anwendungen und Werkstoffe*

DIN EN ISO 14692-3, *Erdöl- und Erdgasindustrie — Glasfaserverstärkte Kunststoffrohrleitungen (GFK) — Teil 3: Systemauslegung*

DIN EN ISO 14692-4, *Erdöl- und Erdgasindustrie — Glasfaserverstärkte Kunststoff-Rohrleitungen (GFK) — Teil 4: Fertigung, Installation und Betrieb*

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Industries du pétrole et du gaz naturel - Canalisations en plastique renforcé de verre (PRV) - Partie 2: Qualification et fabrication (ISO 14692-2:2017)

Erdöl- und Erdgasindustrie - Glasfaserverstärkte Kunststoffrohrleitungen (GFK) - Teil 2: Zulassung und Herstellung (ISO 14692-2:2017)

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European foreword

This document (EN ISO 14692-2:2017) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" in collaboration with Technical Committee CEN/TC 12 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries” the secretariat of which is held by NEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2018 and conflicting national standards shall be withdrawn at the latest by March 2018.

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

This document supersedes EN ISO 14692-2:2002.

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Endorsement notice

The text of ISO 14692-2:2017 has been approved by CEN as EN ISO 14692-2:2017 without any modification.

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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.

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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.

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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*

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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.

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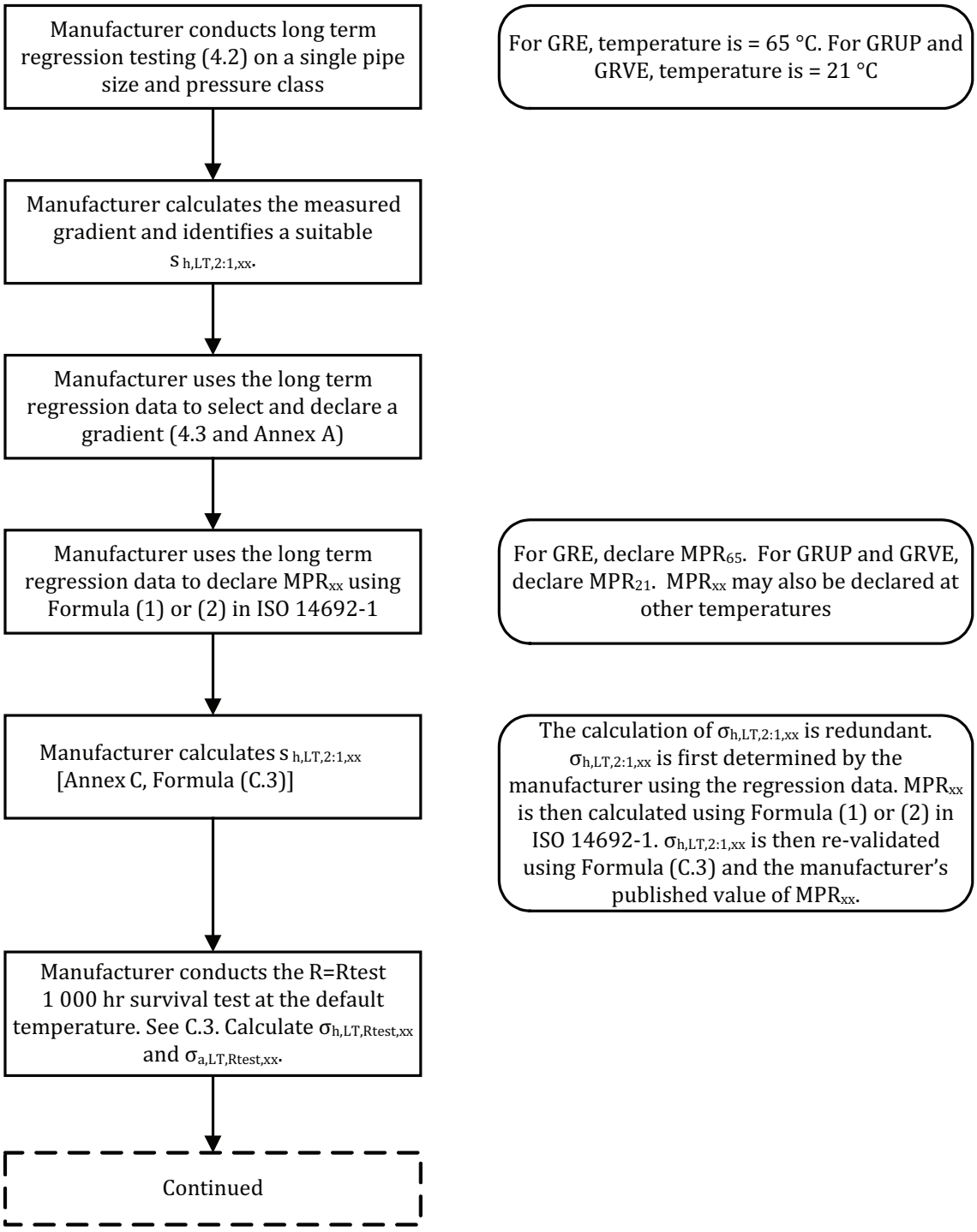

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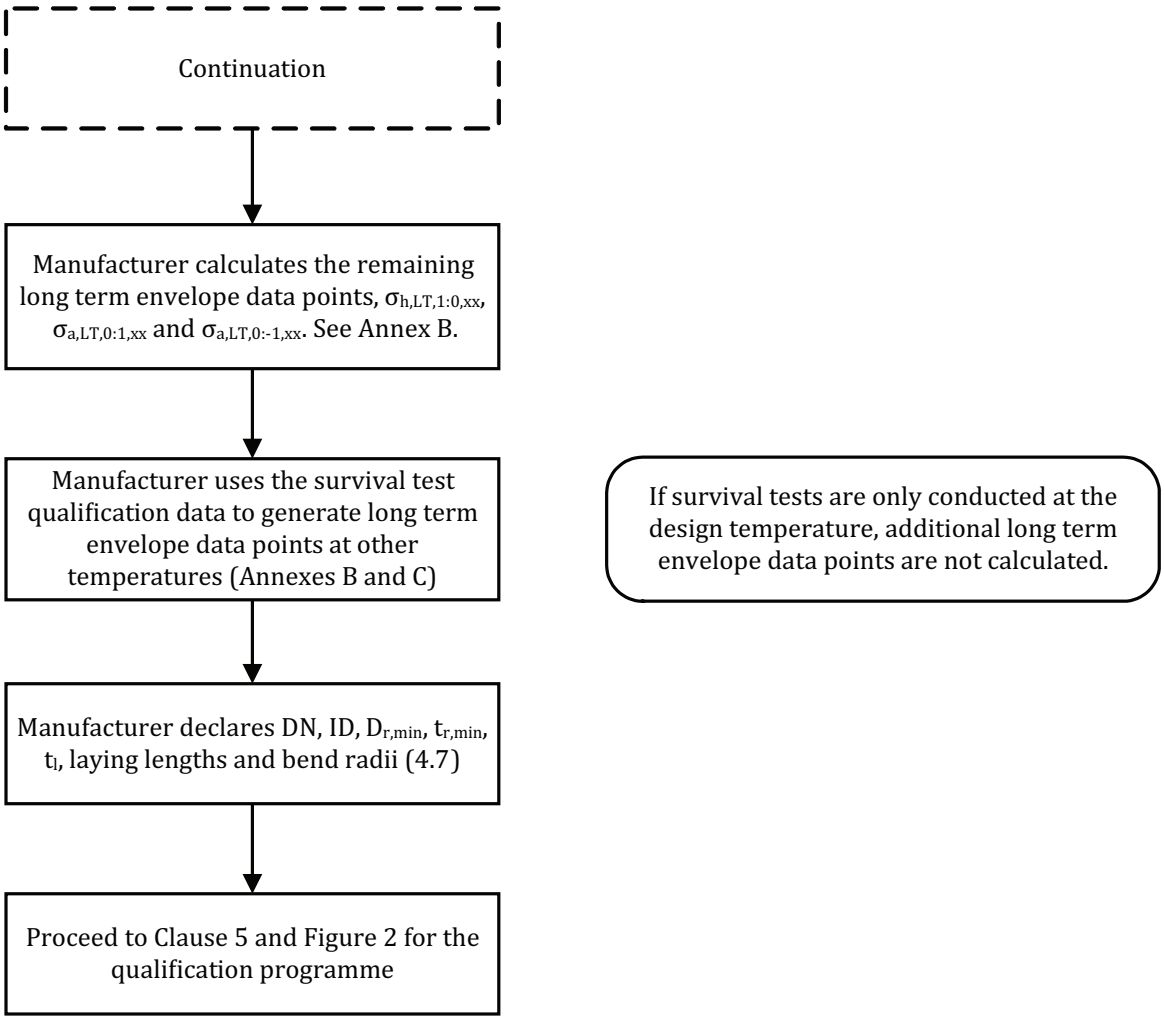

Figure 1 — Procedure for declaring manufacturer's data

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).

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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.

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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

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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.

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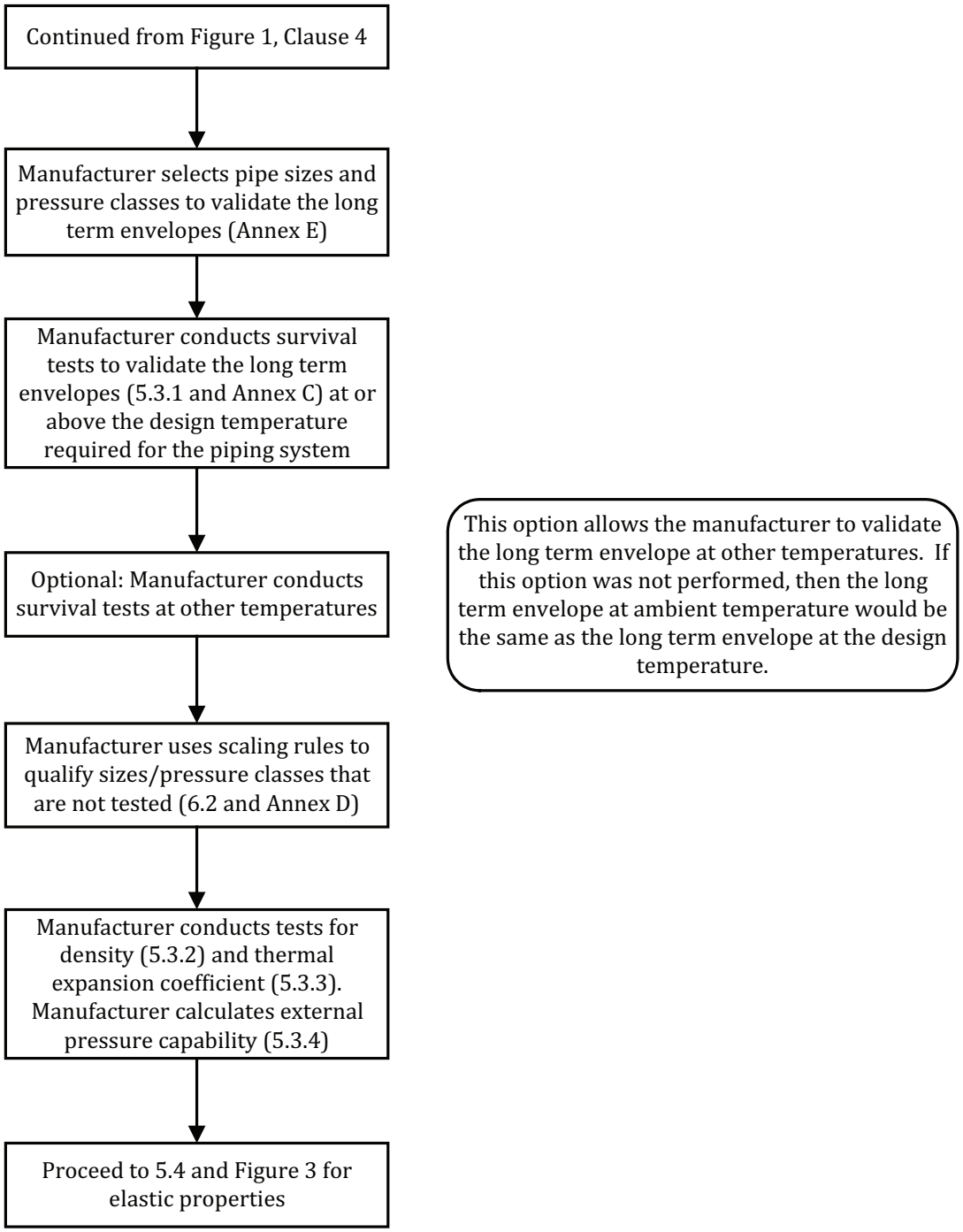

Figure 2 — Procedure for the product qualification portion of the qualification programme

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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.

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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 $R = R_{test}$ 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 $P_{T1\ 000,xx}$ of the pipe will be higher than the $P_{T1\ 000,xx}$ 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.

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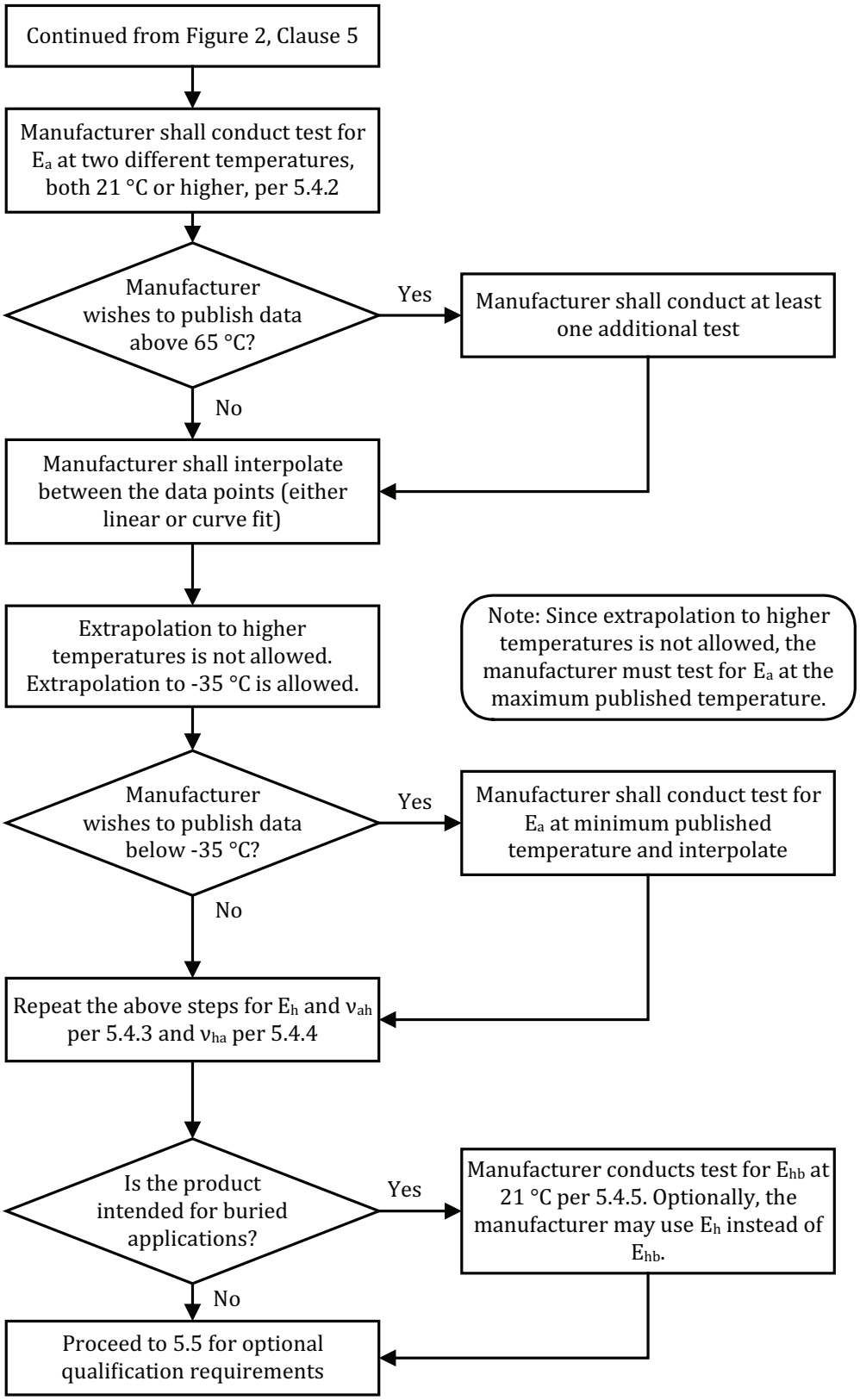

Figure 3 — Procedure to determine elastic properties

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

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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.

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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):

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

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.

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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.

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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.

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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.

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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

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