INTERNATIONAL STANDARD

ISO 14692-1

Second edition
2017-08

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

Part 1: Vocabulary, symbols, applications and materials

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

Partie 1: Vocabulaire, symboles, applications et matériaux

Reference number
ISO 14692-1:2017(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 14692-1:2002), which has been technically revised.

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

Introduction

0.1 General

The objective of ISO 14692 (all parts) is to provide the oil and gas industry, as well as the supporting engineering and manufacturing industry, with mutually agreed specifications and recommended practices for the purchase, qualification, manufacturing, design, handling, storage, installation, commissioning and operation of GRP piping systems.

This document, provides guidance in the use and interpretation of the other parts of ISO 14692. This document contains the following annexes:

— Annex A (informative) explaining the principle;

— Annex B (informative) providing guidance on scope limitations;

— Annex C (normative) containing the enquiry sheet;

— Annex D (normative) providing wall thickness definitions;

— Annex E (informative) describing selection of part factor $f_{3,est}$ in bid process;

— Annex F (informative) containing a worked example.

0.2 Basic steps in use of ISO 14692 (all parts)

Figure 1 identifies the eight basic steps involved in the use of ISO 14692 (all parts) that are further explained below.

Step 1: The bid process. The principal completes an enquiry sheet (see Annex C) that defines the design pressures and temperatures of the piping system as well as the application, required pipe sizes and required components (bends, tees, reducers, flanges, etc.). The principal also verifies that the scope of the application is within the limits of ISO 14692 (all parts) (see Annex B). The principal and manufacturer also comes to an agreement on the value of the estimated value of the part factor $f_{3,est}$ (see Annex E).

In some cases, the manufacturer can wish to offer a product that 1) meets or exceeds the requirements in the enquiry sheet and 2) has already been manufactured, qualified and inspected per ISO 14692-2. In this case, Steps 2 through 4 would not need to be repeated.

Step 2: Manufacturer's data. Recognizing that long-term regression testing can easily take two or more years to complete, the manufacturer will most likely have already selected target values for MPR_{xx}, the long-term envelope(s) and the minimum reinforced wall thicknesses. The manufacturer determines the appropriate gradient and $rd_{1\,000,xx}$ can then be calculated to suit the survival test duration. Additional basic data such as pipe sizes, wall thicknesses, SIFs, production processes and jointing instructions are also provided.

Step 3: Qualification process. The manufacturer conducts survival tests to qualify the pressure and temperature. If applicable, the manufacturer also qualifies fire performance and electrical conductivity properties. Elastic properties, potable water certification, impact and low temperature performance are also addressed in this step. Just as in Step 2, the manufacturer can have already completed part or all of the qualification process prior to Step 1.

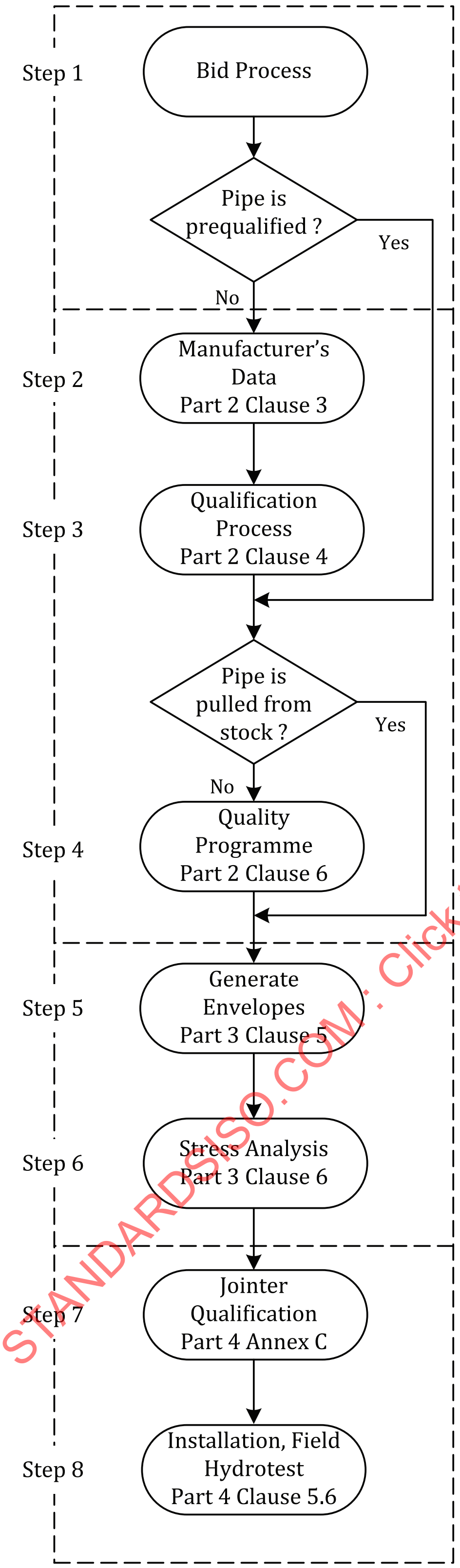
Step 4: Quality programme. The basic requirements for the manufacturer's quality management system are defined.

Step 5: Generate envelopes. This is the first major step in ISO 14692-3. Partial factors and part factors are identified and combinations of these factors are determined. Formulae are then provided to calculate the design envelope(s).

Step 6: Stress analysis. The flexibility factors and SIFs to be used in the stress analysis are identified. The allowable values for vertical deflection, stresses and buckling are also defined. An analytical formula for external pressure is provided.

Step 7: Bonder training and assessment. This is the first major step in ISO 14692-4 where the bonder training and assessment process is defined.

Step 8: Installation, field hydrotest. This is the last major step where installation issues are addressed.



Concepts

Enquiry sheet (Part 1 AnnexD)
Estimated f_3 (Part 1 Annex F)
Scope limits (Part 1 Annex C)
A_0, A_2, A_3, MPR_{xx} (Part 1, 3.1 and 3.2; Part 2, 3.3 and 3.4)

Pipe, fittings and joints that have already been qualified per ISO 14692-2 would not need to repeat steps 2 and 3. Manufacturer would select a product with an MPR_{xx} to meet the requirements in the Entquiry sheet

Long term envelopes (Part 2, 3.5 and AnnexD)
Gradients and $rd_{1000,xx}$ (Part 2, 3.2 and Annexes B and C)
$D_{r,min}$, $t_{r,min}$, *SIFs* (Part 2, 3.6, 3.8)
Production processes and jointing instructions (Part 2, 3.9)

Scaling rules (Part 2, 4.2)
Product qualification (Part 2, 4.3)
Elastic properties (Part 2, 4.4)
Fire performance, electrical conductivity, other (Part 2, 4.5)

Pipe, fittings and joints that have already been inspected per ISO 14692-2 would not need to repeat step 4

Mill hydrostatic test, degree of cure, glass content, visual inspection and key component dimensions (Part 2, 6.1 and 6.2)

Combinations of partial factors and the f_2 part factor (Part 3, 5.1 thru 5.3)
Generate design envelope(s) (Part 3, 5.4)

Flexibility factors and *SIFs* (Part 3, 6.3 thru 6.5 and Annex A)
Allowable deflections and stresses (Part 3, 6.7 and 6.8)
External pressure/vacuum rating (Part 3, 6.9)

Based on manufacturer's jointing procedures
Theoretical and pratical exam terms (Part 4, Annex C)
Jointer qualification on representative joint types and sizes (Part 4, Annex C)

System design output (Part 3, Clause 8)
Field hydrotest (Part 4, 5.6)
Manufacturer's jointing instructions (Part 2, 3.9)
Installation instructions (Part 4, 5.5)
Jointer certificates (Part 4, Annex C)

Figure 1 — Guidance on the use of ISO 14692 (all parts)

0.3 Other standards

GRP piping products are used in a wide variety of applications in both industrial and municipal service. For some applications, ISO 14692 (all parts) can be properly considered as the basis for piping and pipeline selection and design. In all applications, the selection of the appropriate standard for any particular application takes into consideration the design life of the project, the service temperature, the corrosive nature of the fluid, whether the intended installation is above ground or buried and what type of joining system is to be used. Depending on the service conditions, other GRP piping standards can be more appropriate and better suited than ISO 14692 (all parts) for the entire or part of the system. This is particularly the case for aqueous applications of both a municipal and industrial nature where the pipelines are generally buried and axial tensile loads are minimal.

Other widely used GRP piping standards include

— ISO 10639,

— ISO 10467,

— API 15HR,

— ASTM D3262-11,

— ASTM D3517-14,

— ASTM D3754-14,

— AWWA C950-07,

— EN 1796:2013, and

— EN 14364:2013.

ISO 14692 (all parts) is not intended to be applied to sewerage and drainage applications, although it can provide useful guidance in specific areas not addressed in alternative standards. ISO 14692 (all parts) is also not specifically intended for non-structural applications such as open drain systems and other low-pressure piping applications.

ISO 14692 (all parts) covers all the main components that form part of a GRP pipeline and piping system (plain pipe, bends, reducers, tees, supports and flanged joints) with the exception of valves and instrumentation.

0.4 Structure of ISO 14692 (all parts)

ISO 14692-2, ISO 14692-3 and ISO 14692-4 follow the individual phases in the life cycle of a GRP piping system, i.e. from qualification and manufacture through design to fabrication, installation, operation and decommissioning.

Each part is therefore aimed at the relevant parties involved in that particular phase.

— ISO 14692-1*: Vocabulary, symbols, applications and materials*. The scope is presented in Clause 1 and it provides guidance in the use of the other three parts of ISO 14692. Main users are envisaged to include all parties in the life cycle of a typical GRP piping system. This document should be used in conjunction with the part of specific relevance.

— ISO 14692-2*: Qualification and manufacture.* Its objective is to enable the supply of GRP components with known and consistent properties from any source. Main users of the document are envisaged to be the principal, the manufacturer, certifying authorities and government agencies.

— ISO 14692-3*: System design.* Its objective is to ensure that piping systems, when designed using the components qualified in ISO 14692-2, meet the specified performance requirements. Main users of the document are envisaged to be the principal, the manufacturer, design contractors, certifying authorities and government agencies.

— ISO 14692-4*: Fabrication, installation, inspection and maintenance*. Its objective is to ensure that installed piping systems meet the specified performance requirements throughout their service life. Main users of the document are envisaged to be the principal, the manufacturer, fabrication/installation contractors, repair and maintenance contractors, certifying authorities and government agencies.

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

Part 1: Vocabulary, symbols, applications and materials

1 Scope

This document defines the applications, pressure rating methodology, the classification of the products according to application, type of joint and resin matrix and the limitations to both the materials of construction and the dimensions. It also lists the terms, definitions and symbols used and provides guidance in the use and interpretation of ISO 14692-2, ISO 14692-3 and ISO 14692-4.

ISO 14692 (all parts) is applicable to GRP piping systems that 1) utilize joints that are capable of restraining axial thrust from internal pressure, temperature change and fluid hydrodynamic forces and 2) have a trapezoidal shape for its design envelope. It is primarily intended for offshore applications on both fixed and floating topsides facilities, but it can also be used for the specification, manufacture, testing and installation of GRP piping systems in other similar applications found onshore, e.g. produced-water, firewater systems and general industrial use.

For floating installations, reference is made to the design, construction and certification standards for the hull or vessel, since these can allow alternative codes and standards for GRP piping associated with marine and/or ballast systems. However, it is recommended that ISO 14692 (all parts) be used for such applications to the maximum degree attainable.

ISO 14692 (all parts) can also be used as the general basis for specification of pipe used for pump caissons, stilling tubes, I-tubes, seawater lift risers and other similar items.

Typical oil and gas industry applications for the use of GRP piping and pipelines include those listed in Table 1.

Table 1 — Typical current and potential GRP piping oil and gas applications

Ballast water	Hydrochloric acid
Boiler feed water	Inert gas
Brine	Jet-A fuel
Carbon Dioxide (CO_2)	Natural gas
Chlorine, gas, wet	Oil
Condensate (water and gas)	(Sour) Oil plus associated gas
Cooling water, sweet, brackish, seawater	Potable water
Demineralised water	Process water
Diesel fuel	Produced water
Drains	Seawater
Emulsions (water-oil-gas mixtures)	Service water
Fire water (ring main and wet or dry deluge)	Sewer (grey and red)
Formation water	Sodium hydroxide
NOTE Some applications, such as wet chlorine gas, hydrogen chloride gas, hydrochloric acid, sodium hydroxide and sodium hypochlorite, require a barrier liner and may require specific corrosion resistant resins. Consult the manufacturer for recommendations.	

Table 1 *(continued)*

Fresh water	Sodium hypochlorite
Fuel	Sour water
Gas (methane, etc.)	Unstabilized oil
Glycol	Vents
Hydrocarbon (with or without associated gas)	Wastewater
Hydrogen chloride gas (HCl)	Water disposal
Injection water	
NOTE Some applications, such as wet chlorine gas, hydrogen chloride gas, hydrochloric acid, sodium hydroxide and sodium hypochlorite, require a barrier liner and may require specific corrosion resistant resins. Consult the manufacturer for recommendations.	

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 14692-2:2017, *Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping — Part 2: Qualification and manufacture*

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 and operation*

3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the following terms and definitions 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/

3.1 General terms

3.1.1
authority having jurisdiction
third-party organization required to be satisfied with the standard of engineering proficiency and safety of a project

EXAMPLE A classification society, verification body or government regulatory body.

3.1.2
contractor
party which carries out all or part of the design, engineering, procurement, construction and commissioning for a project or operation of a facility

Note 1 to entry: The *principal* (3.1.9) can undertake all or part of the duties of the contractor.

3.1.3
designer
party which carries out all or part of the design for a project or facility

3.1.4
installer
party which carries out all or part of the construction and commissioning of composite piping installations and installation work for a project

3.1.5
installation inspector
person able to perform satisfactory and independent inspection of composite piping installations and installation work

3.1.6
installation supervisor
tradesman able to perform practical supervision of the installation and joining of composite piping

3.1.7
manufacturer
party which manufactures or supplies composite plain pipe and piping components to perform the duties specified by the contractoractive fire protection

3.1.8
operator
party which assumes ultimate responsibility for the operation and maintenance of the piping system

Note 1 to entry: The operator can be the same as the *principal* (3.1.9) or principal's agent.

3.1.9
principal
party that initiates the project and ultimately pays for its design and construction

Note 1 to entry: The principal generally specifies the technical requirements and is ultimately responsible for ensuring that safety and all other issues are addressed. The principal can also include an agent or consultant, authorized to act for the principal.

3.1.10
site
location where piping system is installed

3.2 Technical terms

3.2.1
accelerator
substance which, when mixed with a catalyst or a resin, will speed up the chemical reaction between catalyst and resin

Note 1 to entry: The misuse of a cobalt mixture directly with a peroxide (e.g methyl ethyl ketone peroxide (MEKP) -catalyst) might cause an explosion or fire.

3.2.2
active fire protection
method of extinguishing fire by application of substances such as halon, water, carbon dioxide, foam, etc.

3.2.3
adhesive joint
adhesive bond
glued joint
socket joint
rigid type of joint between two components made using an adhesive

Note 1 to entry: An adhesive joint generally consists of a slightly conical (tapered) bell end and a machined (cylindrical or tapered) spigot end.

3.2.4
anisotropic
exhibiting different properties when tested along axes in different directions

3.2.5
carbon fibre
fibre produced by the pyrolysis of organic precursor fibres, such as rayon, polyacrylonitrile, in an inert environment

3.2.6
cavitation
formation of pockets of vapour in a liquid that suddenly collapse, causing very high localized pressures which can lead to serious erosion of boundary surfaces

3.2.7
chemical-resistant glass
ECR glass
Boron-free glass
C glass
AR (acid resistant) glass
glass fibre or synthetic veil having a specific chemical resistance against acids, alkalis or other aggressive chemicals

Note 1 to entry: Such glass can be used as a reinforcement for the resin-rich internal liner of GRP pipe or as a reinforcement in the structural portion of GRP pipe.

3.2.8
collapse pressure
external pressure differential which causes buckling collapse of a component

3.2.9
chopped roving
strands of glass fibre cut to a desired length from rovings

3.2.10
chopped strand mat
CSM
reinforcement structure in which short lengths of glass fibre tows, held together by an emulsion or powder binding agent, are dispersed in random directions within a single plane

Note 1 to entry: Chopped strand mat is not to be confused with chopped roving. The latter may not be in mat form and may be loose rovings from a chopper gun.

3.2.11
cure
change irreversibly the properties of a thermosetting resin by chemical reaction

Note 1 to entry: Examples of such chemical reaction are condensation, ring closure and addition.

Note 2 to entry: Cure can be accomplished by the addition of a curing agent and catalyst, with or without heat and pressure.

3.2.12
cure cycle
polymerization
time/temperature/pressure cycle used to cure a thermosetting resin system from a liquid to a solid

3.2.13
curing agent
catalytic or reactive agent that, when added to a resin, causes polymerization

Note 1 to entry: This is also called *hardener* (3.2.51), for epoxies.

3.2.14
delamination
separation of two adjacent plies or layers of material in a laminate resulting from lack of adhesion

Note 1 to entry: Delamination occur either locally or covering a wide area.

3.2.15
design envelope
long-term envelope reduced by the part factor f_2 and the partial factors A_0, A_2 and A_3

3.2.16
design external pressure
maximum positive external pressure differential, i.e. external minus internal pressure, intended to be experienced by a component during its service life

3.2.17
design pressure
P_{des}
purchaser nominated maximum pressure to which a piping system is designed to operate at the nominated design temperature (T_{des}) and for the nominated design life (L_{des})

Note 1 to entry: P_{des} is typically considered as a sustained pressure, though an additional P_{des} occasional can also be nominated. P_{des} will be selected based on the maximum operating pressure plus a purchaser selected uplift a) to accommodate pressure uncertainty, b) to avoid triggering of pressure safety devices, c) to match the rating of attached piping or equipment and d) to provide a design margin for other purposes.

3.2.18
design temperature
T_{des}
for each design condition, maximum fluid temperature that can be reached during service

3.2.19
differential scanning calorimetry
DSC
method for determining the glass transition temperature of a polymer

3.2.20
dynamic mechanical thermal analysis
DMTA
method for determining the glass transition temperature of a polymer or *GRP* (3.2.44) component

3.2.21
earth, v, GB
ground, v, US
provide electrical contact with earth

3.2.22
E-glass
glass fibre normally used to reinforce *GRP* (3.2.44) pipes, consisting mainly of SiO_2, Al_2O_3 and MgO

3.2.23
elastomeric bell-and-spigot seal lock joint
rubber seal lock joint
rubber sealed key lock joint
joint connection made up of a spigot end and a socket end with “O” or lip-sealing rings and some axial restraining device capable of resisting the full thrust from internal pressure

3.2.24
electrically conductive
conductive
having a volume resistivity equal to or lower than 10^4 Ω·m

3.2.25
environmental stress cracking
ESC
formation of cracks in a polymer or composite caused by exposure to a chemical or environment under stress

3.2.26
epoxide
epoxy
compound containing at least two epoxy or oxirane rings

Note 1 to entry: Chemically, an epoxy ring is a three-membered ring containing two carbon atoms and one oxygen atom.

Note 2 to entry: The most widely used epoxy resin is termed DGEBA (diglycidyl ether of bisphenol A). Epoxy resins are always used in conjunction with curing agents or hardeners, i.e. substances that react with the epoxy rings, producing hydroxyl groups and other products, and linking the originally linear molecules into a rigid three-dimensional network.

3.2.27
extrados
exterior curve of an elbow or torus

3.2.28
failure
loss of structural integrity and/or transmission of fluid leakage through the wall of a component or a joint

3.2.29
fibre
filamentary material with a finite length that is at least 100 times its diameter and prepared by drawing from a molten bath, spinning or deposition on a substrate

Note 1 to entry: Filaments are usually of extreme length and very small diameter, usually less than 25 µm. Normally, filaments are assembled as twisted (yarn) or untwisted (tow) bundles comprising hundreds or thousands of filaments.

3.2.30
filament winding
process for fabricating a composite structure in which continuous reinforcements, e.g. fibre tows, are either previously impregnated with a matrix material or impregnated during the winding

3.2.31
fire classification code
code designation of the fire performance of pipe component in terms of fire endurance and fire reaction properties

3.2.32
fire endurance
fire resistance
ability to maintain functional performance in a fire

3.2.33
fire-reaction property
material property which contributes to spread of fire, heat release and smoke/toxic emissions

3.2.34
fitter
jointer
pipe bonder
tradesman able to perform satisfactory and independent work in the installation and joining of composite piping

3.2.35
fitting
pressure-tight fluid-containing component with a geometry different from straight pipe

EXAMPLE Flanges, tees, elbows, reducers and fabricated branch.

3.2.36
flame retardant
chemical that is used to reduce or eliminate the tendency of a resin to burn, keep and propagate fire

3.2.37
flange joint
mechanical joint with face flanges for which the bolt circle and face dimensions conform to a recognized standard

3.2.38
flexibility factor
ratio of the flexibility in bending of a component/fitting to that of the flexibility of a straight pipe of the same lamination, Young's modulus and thickness having a length corresponding to the developed length of the fitting

3.2.39
free-end testing
pressure-testing arrangement using pipe end closures of a type such that internal pressure produces axial, as well as hoop and radial, stresses in the component wall

Note 1 to entry: See also *restrained-end testing* (3.2.107).

3.2.40
function
ability of the piping system to perform its primary purpose, i.e. to deliver a minimum quantity of fluid at a specified minimum pressure

3.2.41
furnace test
test in a compartment furnace where the time-temperature curve to be followed is to a defined standard

3.2.42
gel coat
quick-setting resin applied either a) to the surface of a mould and gelled before lay-up or b) to the exterior of a laminate as part of the external corrosion barrier

Note 1 to entry: The gel coat becomes an integral part of the finished laminate, and is usually used to provide specific service characteristics [see *liner* (3.2.69)].

3.2.43
glass-fibre-reinforced epoxy
GRE
epoxy resin-based composite that is reinforced with glass fibre

3.2.44
glass-fibre-reinforced plastic
GRP
fibreglass
composite
reinforced plastic
reinforced thermosetting resin plastic
RTR plastic
polymeric resin-based composite that is reinforced with glass fibre

Note 1 to entry: The predominant glass fibre is *E-glass* (3.2.22).

Note 2 to entry: ISO 14692 (all parts) is restricted to the use of thermosetting *resins* (3.2.116).

Note 3 to entry: GRE, GRUP and GRVE are types of GRP.

3.2.45
glass-fibre-reinforced unsaturated polyster
GRUP
unsaturated polyester resin-based composite that is reinforced with glass fibre

3.2.46
glass-fibre-reinforced vinyl ester
GRVE
epoxy vinyl ester resin-based composite that is reinforced with glass fibre

3.2.47
glass transition temperature
T_g
temperature at which the amorphous portion of the polymer undergoes a marked change in properties on passing from the rubbery to glassy state

Note 1 to entry: This observed change in properties is associated with the virtual cessation of local molecular motion in the polymer. Below their glass-transition temperature, amorphous polymers have many of the properties associated with ordinary inorganic glasses, while above this temperature the polymers possess rubbery characteristics.

3.2.48
gradient
slope
slope of internal pressure over time, on a logarithmic-logarithmic scale, of a static regression curve

Note 1 to entry: The slope, although negative, is published and used as a positive number.

3.2.49
grounding clamp
metal fitting attached to the pipe component to provide an electrical connection to earth

3.2.50
hand lay-up
process for fabricating a composite structure in which discontinuous reinforcements, e.g. woven mats, chopped strand mats, are impregnated with a matrix material and are manually applied on a mandrel or mold

3.2.51
hardener
substance or mixture added to a plastic composition to promote or control the curing action by taking part in it

Note 1 to entry: For epoxies, hardener is also called *curing agent* (3.2.13).

3.2.52
hazardous area
three-dimensional space in which a combustible or explolsive atmosphere can be expected to be present frequently enough to require special precautions for the control of potential ignition sources

Note 1 to entry: Hazardous areas are typically defined by local, national or international standards (e.g. the National Electric Code (NEC) in the United States).

3.2.53
heat-distortion temperature
HDT
temperature at which a standard test bar deflects a specified amount under a stated load

3.2.54
heat flux
density of heat flow rate
quantity of heat divided by area and time

3.2.55
hydrocarbon pool fire
fire caused by ignition of a pool of hydrocarbon liquid

3.2.56
hydrotest
pressure test to verify the pressure-retention integrity of a piping system after installation

Note 1 to entry: Hydrotest is also used as a *leak test* (3.2.68).

Note 2 to entry: See *mill hydrostatic test* (3.2.78).

3.2.57
impregnate
saturate the reinforcement with a resin

3.2.58
incendive discharge
electrostatic spark discharge of sufficient energy to ignite a flammable atmosphere

3.2.59
integrity
minimum structural capability required to enable the piping system to fulfil its function

3.2.60
intrados
interior curve of an elbow or torus

3.2.61
intumescent
passive fire-protection coating which, in the presence of fire, expands to create an inert insulating "char" layer

3.2.62
jet fire
turbulent diffusion flame resulting from the combustion of a fuel continuously released with significant momentum in a particular direction

3.2.63
joint
means of connecting two or more components

EXAMPLE Plain pipe to a fitting, or plain pipe to plain pipe.

3.2.64
laminae
thin sheet of reinforcing fibres in a resin matrix built up into a flat or curved arrangement

3.2.65
laminate
unite laminae with a bonding material, usually using pressure and heat

Note 1 to entry: Normally used with reference to flat sheets, but can also refer to tubes. A product made by such bonding is referred to as a laminate.

3.2.66
laminated joint
butt-and-wrap joint
butt-and-strap joint
butt-welded joint
joint consisting of plain-ended pipe and fittings laminated together with reinforcing fibres and resin/hardener mixture

3.2.67
laying length
actual length of a line, corresponding to the initial length plus the increase afforded by the fitting or integral joint when installed

3.2.68
leak test
pressure test to determine the presence of leaks at joints or within components of a piping system

Note 1 to entry: Usually carried out at a pressure lower than the *hydrotest* (3.2.56) and for a longer period.

3.2.69
liner
continuous resin-rich coating on the inside surface of a pipe or fitting component, used to protect the laminate from chemical attack or to prevent leakage under stress

Note 1 to entry: The liner can also be used to provide enhanced abrasion and erosion resistance.

3.2.70
long-term envelope
envelope that defines the stress levels that are just below those that can potentially cause irreversible damage during continuous or occasional loading conditions at a specified temperature

3.2.71
lower confidence limit
LCL
97,5 % lower bound value of the nominal long-term regression line for hydrostatic pressure or stress based on a 20-year lifetime

3.2.72
lower prediction limit
LPL
97,5 % lower bound value for an individual component failure, based on the long-term hydrostatic pressure or stress for a 20-year lifetime

Note 1 to entry: The LPL will always be lower than the *LCL* (3.2.71) for the nominal regression line (i.e. the prediction interval will always be larger than the confidence interval).

3.2.73
mandrel
core tool around which resin-impregnated reinforcement is wound to form pipes, fittings and structural shell shapes

3.2.74
maximum pressure rating
MPR_{xx}
pressure rating given by the manufacturer in product literature

Note 1 to entry: MPR_{xx} is the maximum pressure rating at sustained conditions for a 20-year design life at the temperature of xx °C. MPR_{xx} is the maximum catalogue value published by the manufacturer.

3.2.75
matrix
homogeneous resin or polymer material in which the fibre system is imbedded in a laminar arrangement

3.2.76
mechanical joint
joint between GRP piping components which can resist thrust from internal pressure and is not made by bonding

Note 1 to entry: A mechanical joint typically involves use of proprietary devices.

Note 2 to entry: A *prescribed threaded joint* (3.2.98) is a type of mechanical joint.

3.2.77
megohmmeter
high-voltage instrument used for measuring electrical resistance

3.2.78
mill hydrostatic test
short-term hydrotest at the mill, or factory, used as a quality control check which is carried out at a pressure above the design pressure

3.2.79
minor Poisson's ratio
ν_{ah}
hoop strain resulting from a stress in the axial direction

Note 1 to entry: GRP pipes will typically contract in the hoop direction when subjected to an axial stress.

3.2.80
modulated differential scanning calorimetry
MDSC
type of *DSC* (3.2.19) that enables reversible reactions to be distinguished from irreversible processes such as additional polymerization of the resin during the test

3.2.81
nominal diameter
DN
numerical designation of size that is common to all components in a piping system, other than components designated by outside diameters or by thread size

Note 1 to entry: It is a convenient round number for reference purposes and is only loosely related to manufacturing dimensions.

3.2.82
operating pressure
OP
normal or anticipated standard internal pressure difference, i.e. internal minus external pressure, to be experienced by the pipe or piping system which should not exceed the design pressure

3.2.83
ovality
irregularity of the circular section of a component, quantified by the difference in the largest and smallest cross-sectional axes

3.2.84
part factor
f_2
derating factor related to confidence in the pipework system, the nature of the application and the consequences of failure

3.2.85
part factor
$f_{3,est}$
derating factor that de-rates a component, taking account of non-pressure-related axial loads, e.g. bending and externally-applied direct-acting axial forces so that the combined hoop and axial stresses are still within the design envelope for each individual load case

Note 1 to entry: $f_{3,est}$ is estimated at the bid stage. The $f_{3,est}$ part factor cannot be confirmed until a stress analysis is conducted. The $f_{3,est}$ part factor can vary from one load case to another.

3.2.86
passive fire protection
method of minimizing fire damage by use of sacrificial or non-combustible coatings

3.2.87
performance standard
defined limit placed on characteristics of materials, products or services

3.2.88
phenolic
class of polymer resins made from phenol and formaldehyde, and cured by air drying or heat baking

Note 1 to entry: Chemical resistance can be further increased via heat and catalyst treatment.

3.2.89
pipe support
pipe fixture or structural attachment which transfers the load from the pipe or structural attachment to the supporting structure or equipment

Note 1 to entry: Fixtures include hanging-type fixtures such as hanger rods, spring hangers, sway braces, counterweights, turnbuckles, struts, chains, guides and anchors; and bearing-type fixtures such as saddles, bases, rollers, brackets and sliding supports.

Note 2 to entry: Structural attachments include elements which are bonded or moulded into the pipe, such as clips, lugs, saddles, rings, clamps, clevises, straps and skirts.

3.2.90
piping
assemblies of piping components used to convey, distribute, mix, separate, discharge, meter, control or restrict fluid flows

3.2.91
piping component
component
mechanical element suitable for joining or assembly into a pressure-tight fluid-containing piping system

EXAMPLE Pipe, fittings, flanges, gaskets, bolting, valves, and devices such as expansion joints, flexible joints, pressure hoses, liquid traps, strainers and in-line separators.

3.2.92
piping system
interconnected piping subject to the same set or sets of design conditions

Note 1 to entry: The piping system also includes pipe supports, but does not include support structures.

3.2.93
pipeline system
pipe with components subject to the same design conditions and typically used to transport fluids between wells and field facilities, field facilities and processing plants, processing plants and storage facilities

3.2.94
Poisson's ratio
major Poisson's ratio
ν_{ha}
axial strain resulting from a stress in the hoop direction

Note 1 to entry: GRP pipes will typically contract in the axial direction when subjected to a hoop stress.

Note 2 to entry: For GRP pipes wound at a 54° winding angle, the Poisson's ratio will typically be smaller in magnitude than the *minor Poisson's ratio* (3.2.79).

3.2.95
postcure
additional elevated-temperature cure, usually without pressure, to improve final resin properties and/or complete the cure or polymerization of the resin matrix, or decrease the percentage of volatiles in the compound

Note 1 to entry: In certain resins, complete cure and ultimate mechanical properties are attained only by exposure of the cured resins to temperatures higher than those of curing (typically within to 30 °C to 50 °C of the maximum possible T_g).

3.2.96
pot life
length of time that a catalysed thermosetting resin system retains a viscosity low enough to enable processing and sufficient reactivity to achieve specified properties after processing

3.2.97
potable water
water that is fit to drink

Note 1 to entry: In most developed countries, water supplied to commerce and industry is fit to drink even though a small amount is actually consumed or used in food preparation.

3.2.98
prescribed threaded joint
mechanical joint that complies with API 15 HR

Note 1 to entry: A prescribed threaded joint is a type of *mechanical joint* (3.2.76).

3.2.99
pressure rating
rated pressure
rating for a component, relating to its long-term resistance to failure when subjected to either static or standardized cyclic internal pressure loading

3.2.100
proportional limit
greatest stress that a material is capable of sustaining without deviation from linear proportionality of stress and strain

Note 1 to entry: The proportional limit can be different in the axial direction compared to the hoop direction.

3.2.101
qualification
process of demonstrating that a component is in accordance with the requirements of ISO 14692-2

3.2.102
***R*-ratio**
ratio of the hoop stress to the axial stress in a particular test condition

EXAMPLE In a hydrostatic test condition where a) the test sample is unrestrained, b) the hoop stress component is represented by half the pressure times diameter divided by wall thickness (*PD/2t*) and c) the axial stress component is represented by one-fourth the pressure times diameter divided by wall thickness (*PD/4t*), the R-ratio would be exactly 2,0. In the same test condition, if the axial stress component is represented by force over area (*F/A*) instead of *PD/4t*, the *R*-ratio will most likely be slightly higher than 2,0.

Note 1 to entry: Data points on the *long term envelope* (3.2.70), *threshold envelope* (3.2.117) and *design envelope* (3.2.15) can be referred to as *R* = *x* or *Rx* or *x:y* data points where x and *y* are integers (e.g. *R = 2*, *R*2 or 2:1) and/or real numbers (*R* = 0,7, *R*0,7 or 0,7:1). In some cases, the *x* value can be an approximation of the R-ratio.

3.2.103
rated temperature
maximum design temperature at the *rated pressure* (3.2.99) determined in accordance with ISO 14692-2 and ISO 14692-3

3.2.104
reducer
component that allows pipes of different sizes to be connected

3.2.105
reinforcement
strong material embedded into a matrix to improve its mechanical properties

Note 1 to entry: Reinforcements are usually long fibres, whiskers, particulates, etc. The term is not to be used synonymously with filler.

3.2.106
roving
number of strands, tows or ends collected into a parallel bundle with little or no twist

3.2.107
restrained-end testing
axial load-free testing
pressure-testing arrangement using a pipe-sealing device or mechanism such that internal pressure produces hoop and radial stresses only in the component wall

3.2.108
sheath
unreinforced external liner or coating

3.2.109
saddle
length of an arc of GRP material adhesively bonded to the outside of the pipe

3.2.110
sizing agent
coating on glass fibres used to promote bonding of glass-reinforcement to resin

3.2.111
spoolpiece
permanent assembly of pipe and fittings fabricated in the factory or in field (pipe-shop) using laminated or adhesive joints

3.2.112
standard laboratory temperature
SLT
temperature as defined by a recognized standard with standard tolerance

EXAMPLE 23 °C ± 2 °C.

3.2.113
stress intensification factor
SIF
ratio of the actual or effective longitudinal stress in a component or fitting under external load to the nominal stress in that component or fitting as determined based on a straight pipe run with the same MPR_{xx} as the component fitting

3.2.114
system
assembled section of piping consisting of a representative range of pipes, fittings, connections, attachments, supports, penetrations and associated coatings, e.g. for thermal insulation or fire protection, as can be found in service

3.2.115
thermoset
plastic which, when cured by application of heat and/or chemical reaction, changes into a substantially infusible and insoluble material

Note 1 to entry: Unlike in thermoplastics, the curing process in thermosets creates a chemical bond that prevents the material from being remelted.

3.2.116
thermosetting resin
polymer-based liquid that becomes solid upon curing

Note 1 to entry: Curing is achieved, typically during fabrication, using chemicals, heat and/or radiation.

3.2.117
threshold envelope
envelope that defines the short-term stress levels to avoid incremental damage to the pipe composite laminate

Note 1 to entry: 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 can declare a more conservative threshold envelope.

3.2.118
tow
untwisted fibrous bundle
tow tex
mass of a fibrous bundle expressed per unit length

Note 1 to entry: A higher tow tex indicates a heavier roving. Tow tex is inversely proportional to yield. Consequently, a lower yield indicates a heavier roving. Tow tex is typically expressed as grams per kilometer. Yield is typically expressed as yards per pound. Tow tex = 496 054,6/yield.

3.2.119
tribocharging
generation of electrostatic charge caused by moving contact of one insulating material over another

3.2.120
type
components of common function

Note 1 to entry: Pipes, prime connections, flanges, reducers, tees and elbows are examples of different component types.

3.2.121
ultraviolet radiation
UV radiation
electromagnetic radiation in the frequency band just above the visible spectrum

3.2.122
unsaturated polyester
class of thermosetting resin formed by the condensation reaction between difunctional acids and glycols

Note 1 to entry: Cure is accomplished, as with vinyl esters, by copolymerization with other vinyl monomers such as styrene.

3.2.123
vinyl ester
class of thermosetting resin containing esters of acrylic and/or methacrylic acids, many of which have been made from epoxy resin

Note 1 to entry: Cure is accomplished, as with unsaturated polyesters, by copolymerization with other vinyl monomers such as styrene.

3.2.124
water hammer
shock load or high-pressure surge caused by sudden halting of flow in a pipeline or piping system

3.2.125
winding angle
angle of main reinforcement to pipe axial axis

Note 1 to entry: The angle can be either positive or negative.

3.2.126
woven roving
WR
cloth reinforcement structure in which fibre bundle tows are woven together in a single plane to provide reinforcement which is usually orientated to provide strength in the orthogonal 0° and 90° directions

3.3 Symbols and abbreviated terms

3.3.1 Symbols

A_0 partial factor for design life

A_2 partial factor for chemical resistance

A_3 partial factor for cyclic service

A_i pipe inside bore area

A_p pipe wall axial cross section

A_r minimum reinforced pipe wall cross section (used in place of $A_{r,min}$)

$A_{r,min}$ $= A_r$

$A_{r,act}$	actual reinforced pipe wall cross section area
α	coefficient of thermal expansion in the axial direction
C	installed curve radius
C_1	ratio between MOP and OP
C_2	ratio between P_d and MOP
D	nominal mean diameter
D_m	average optical density
D_r	nominal mean diameter of the reinforced pipe wall
$D_{r,act}$	actual mean diameter of the reinforced pipe wall
$D_{r,min}$	mean diameter of the minimum reinforced pipe wall
DLT	design life time
DN	nominal diameter
$\mathrm{d}L$	length change
$\mathrm{d}L_p$	length change due to internal pressure
$\mathrm{d}L_t$	length change due to temperature
$\mathrm{d}T$	temperature change
E	elastic modulus
E_a	axial tensile modulus
E_h	hoop tensile modulus
E_{hb}	hoop (or circumferential) bending modulus
ε	strain
$\varepsilon_{a,F}$	axial strain from localised axial force
$\varepsilon_{a,p}$	axial strain from pressure
F	localised axial force
F_{hyd}	hydrotest factor
f_2	part factor for loading
f_3	part factor to take account of limited axial load capability of GRP pipe
$f_{3,est}$	f_3 part factor estimated at the bid stage of the project
G	gradient of regression line
G_{xx}	gradient of regression line at xx °C
G_{21}	gradient of regression line at 21 °C

G_{65} gradient of regression line at 65 °C

g gravity (acceleration)

I moment of inertia

I_r minimum reinforced pipe wall moment of inertia (used in place of $I_{r,min}$)

ID inside diameter

ID_r inside diameter of the reinforced pipe wall

L length

M bending or torsion moment

MOP maximum allowable operating pressure

MPR_{xx} maximum pressure rating at xx °C

MPR_{21} maximum pressure rating at 21 °C

MPR_{65} maximum pressure rating at 65 °C

m mass per unit length

OD outside diameter

OD_{min} minimum outside diameter of the pipe wall

OD_r nominal outside diameter of the reinforced pipe wall

$OD_{r,act}$ actual outside diameter of the reinforced pipe wall

$OD_{r,min}$ minimum outside diameter of the reinforced pipe wall

OP operating pressure

P internal pressure

P_{des} design pressure

$P_{hyd,fd}$ field hydrotest pressure

$P_{hyd,sh}$ shop hydrotest pressure

$P_{LT,xx}$ long-term pressure at xx °C

P_{thr} short-term threshold pressure

$P_{T1000,xx}$ pressure of 1000 h test carried out at xx °C

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

Q_{CFE} critical flux at extinguishment

Q_p peak heat release

Q_{sb} heat for sustained burning

Qt total heat release

R	ratio of hoop stress to axial stress
ρ	mass density
rd_{1000}	1 000 h to 20 yr scaling ratio
$rd_{1000,xx}$	1 000 h to 20 yr scaling ratio at xx °C
SIF_{ai}	axial in-plane stress intensification factor
SIF_{ao}	axial out-of-plane stress intensification factor
σ	stress
σ_{ab}	axial stress from bending moment
σ_{ac}	axial stress from roping or other curving effects on the pipe
σ_{af}	axial stress from external forces NOTE An example of axial stress from external forces would be axial compressive stress due to thermal expansion in an anchored piping system or axial tensile stress due to poisson's effect (from internal pressure) in an anchored piping system.
σ_{ap}	axial stress from internal pressure
$\sigma_{ap,avg}$	average axial stress from internal pressure
σ_{at}	axial stress from thermal loads in a piping system where thermal growth is restrained by external anchors (i.e. a piping system that is fully restrained)
$\sigma_{a,des,0:1}$	allowable design envelope axial stress for a pure axial loading condition
$\sigma_{a,des,0:-1}$	allowable design envelope axial compressive stress for a pure axial loading condition
$\sigma_{a,des,1:1}$	allowable design envelope axial stress for a partially restrained, hydraulic (1:1) condition
$\sigma_{a,des,2:1}$	allowable design envelope axial stress for an unrestrained, hydraulic (2:1) condition
$\sigma_{a,des,Rtest}$	allowable design envelope axial stress for the hydraulic (R_{test}) condition
$\sigma_{a,LT,2:1,xx}$	long-term envelope axial stress for an unrestrained, hydraulic (2:1) condition at xx °C
$\sigma_{a,LT,Rtest,xx}$	long-term envelope axial stress for a partially restrained, hydraulic (R_{test}) condition at xx °C
$\sigma_{a,LT,0:1,xx}$	long-term envelope axial stress for a pure axial loading condition at xx °C
$\sigma_{a,LT,0:-1,xx}$	long-term envelope axial compressive stress for a pure axial loading condition at xx °C
$\sigma_{a,sum}$	sum of all axial stresses
$\sigma_{a,thr,Rtest}$	threshold envelope axial stress for a partially restrained, hydraulic (R_{test}) condition
$\sigma_{a,thr,0:1}$	threshold envelope axial stress for a pure axial loading condition
$\sigma_{a,thr,0:-1}$	threshold envelope axial compressive stress for a pure axial loading condition
$\sigma_{a,thr,2:1}$	threshold envelope axial stress for an unrestrained, hydraulic (2:1) condition
$\sigma_{h,1\,000,2:1,xx}$	1 000 h hoop stress from an unrestrained, hydraulic (2:1) test at xx °C

σ_{hd} short-term hoop stress limit to avoid incremental damage to the pipe laminate

$\sigma_{h,des,1:1}$ allowable design envelope hoop stress for a partially restrained, hydraulic (1:1) condition

$\sigma_{h,des,2:1}$ allowable design envelope hoop stress for an unrestrained, hydraulic (2:1) condition

$\sigma_{h,des,Rtest}$ allowable design envelope hoop stress for the hydraulic (R_{test}) condition

$\sigma_{hl,xx}$ 20 yr sustained failure hoop stress from an unrestrained, hydraulic (2:1) test at xx °C

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

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

σ_{hp} hoop stress from internal pressure

$\sigma_{hp,avg}$ average hoop stress from internal pressure

$\sigma_{h,sum}$ sum of all hoop stresses

$\sigma_{h,thr,Rtest}$ threshold envelope hoop stress for a partially restrained, hydraulic (R_{test}) condition

$\sigma_{h,thr,2:1}$ threshold envelope hoop stress for an unrestrained, hydraulic (2:1) condition

σ_{hu} hoop stress from soil burial load

T temperature

T_{des} design temperature

T_g glass transition temperature

t wall thickness

t_l internal liner thickness of the pipe wall

t_{min} minimum pipe wall thickness

t_r nominal reinforced pipe wall thickness

$t_{r,min}$ minimum reinforced pipe wall thickness

$t_{r,act}$ actual reinforced pipe wall thickness

t_s outer sheath thickness of the pipe wall

$t_{var\%}$ percentage variation of the reinforced pipe wall thickness

ν_{ah} minor Poisson's ratio, hoop strain resulting from a stress in the axial direction

ν_{ha} major Poisson's ratio, axial strain resulting from a stress in the hoop direction

W local mass

w distributed mass

Z axial section modulus

Z_r minimum reinforced pipe wall axial section modulus (used in place of $Z_{r,min}$)

$Z_{r,min}$ = Z_r

3.3.2 Abbreviated terms

ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
BSI	British Standards Institution
CSM	chopped strand mat
DIN	Deutsches Institut für Normung
DMTA	dynamic mechanical thermal analysis
DSC	differential scanning calorimetry
ESC	environmental stress cracking
GRE	glass-fibre reinforced epoxy
GRP	glass-fibre reinforced plastics
GRUP	glass-fibre reinforced unsaturated polyester
GRVE	glass-fibre reinforced vinyl ester
HSE	Health and Safety Executive (United Kingdom)
IMO	International Maritime Organization
JIP	Joint Industry Program
LCL	lower confidence limit
LPL	lower prediction limit
MDSC	modulated differential scanning calorimetry
MOP	maximum operating pressure
MPR	maximum pressure rating
NDE	non-destructive examination
NDT	non-destructive testing
OP	operating pressure
PBMS	performance-based material selection
SIF	stress intensification factor
SINTEF	The Foundation for Scientific and Industrial Research (Norway)

SLT standard laboratory temperature

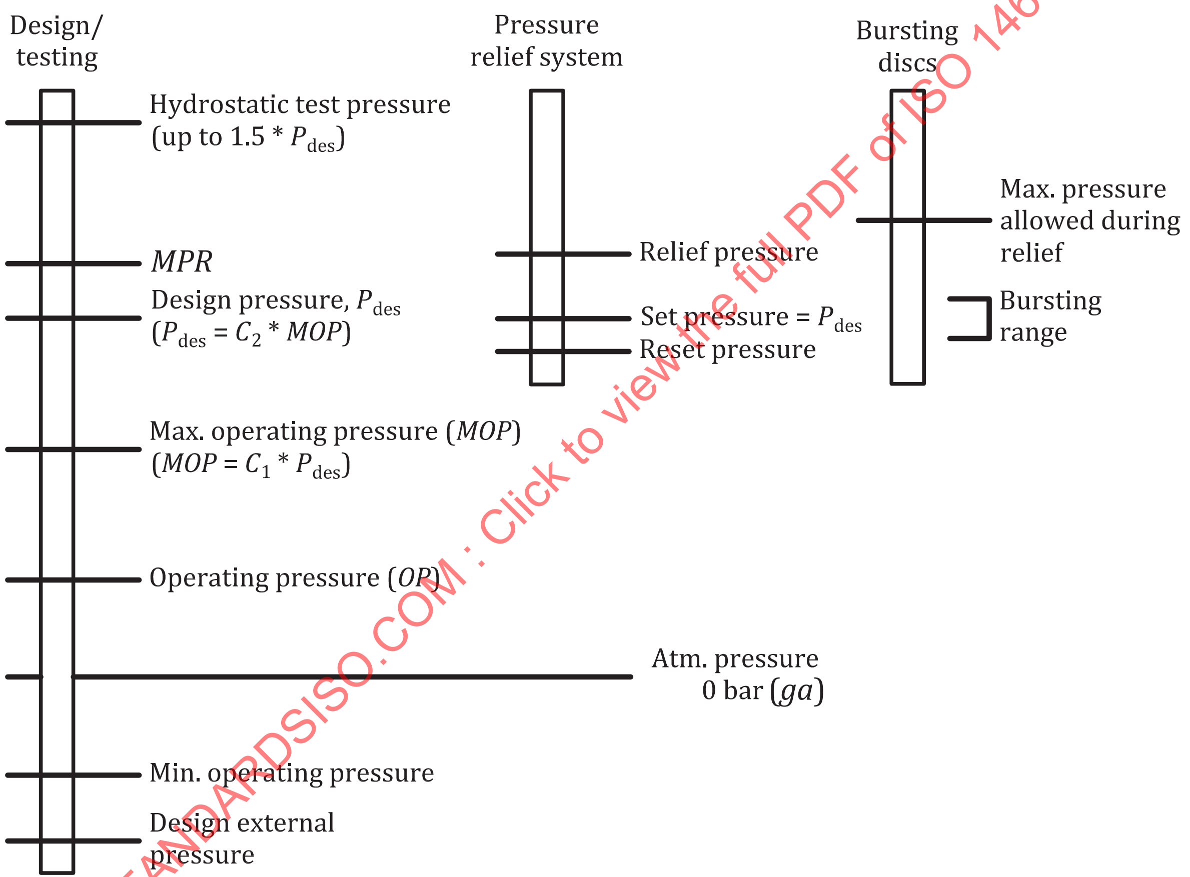
UV ultraviolet

WR woven roving

4 Pressure rating

4.1 *MPR*$_{xx}$

MPR$_{xx}$ is the maximum pressure rating at sustained conditions for a 20-year design life at the temperature of xx °C. *MPR*$_{xx}$ shall be the maximum catalogue value published by the manufacturer. *MPR*$_{xx}$ shall be defined at 65 °C for GRE (*MPR*$_{65}$) and 21 °C for GRUP and GRVE (*MPR*$_{21}$). The manufacturer shall also publish MPR$_{xx}$ at other temperatures if these are required. Refer to ISO 14692-2:2017, 4.3. The pressure terminology is presented in Figure 2.



NOTE C_1 may vary from 1,05 to 1,25 depending on the application. C_2 may range from 1,10 to 1,25. Values outside of these ranges are also possible. The intention of this figure is not to specify C_1 and C_2, but rather to show the relationship between *OP*, *MOP*, P_{des} and MPR_{xx}. C_1 is system dependant based on many design parameters (e.g. pump type, elevation changes, flow velocity). C_2 is typically a margin included by the client's process engineer and can vary widely (e.g. the engineer may set this to a flange rating limit or the rating of adjacent equipment not related to the operating pressure or to provide a margin to prevent early triggering of safety relief devices).

Figure 2 — Pressure terminology

For GRE, MPR_{65} can be determined with Formula (1):

$$MPR_{65} \leq \frac{0,67 \times 2 \times t_{r,min} \times \sigma_{h,LT,2:1,65}}{D_{r,min}} \quad (1)$$

For GRUP and GRVE, MPR_{21} can be determined with Formula (2):

$$MPR_{21} \leq \frac{0,67 \times 2 \times t_{r,min} \times \sigma_{h,LT,2:1,21}}{D_{r,min}} \quad (2)$$

where

MPR_{65} is the maximum pressure rating at 65 °C, expressed in MPa,

MPR_{21} is the maximum pressure rating at 21 °C, expressed in MPa,

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

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

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

At the bid stage, an estimated value of MPR_{xx} can be determined using Formula (3):

$$MPR_{xx}(est) = \frac{P_{des}}{f_{3,est} \times A_0 \times A_2 \times A_3} \quad (3)$$

where

MPR_{xx} (est) is the maximum pressure rating at T_{des}, expressed in MPa,

P_{des} is the design pressure, expressed in MPa,

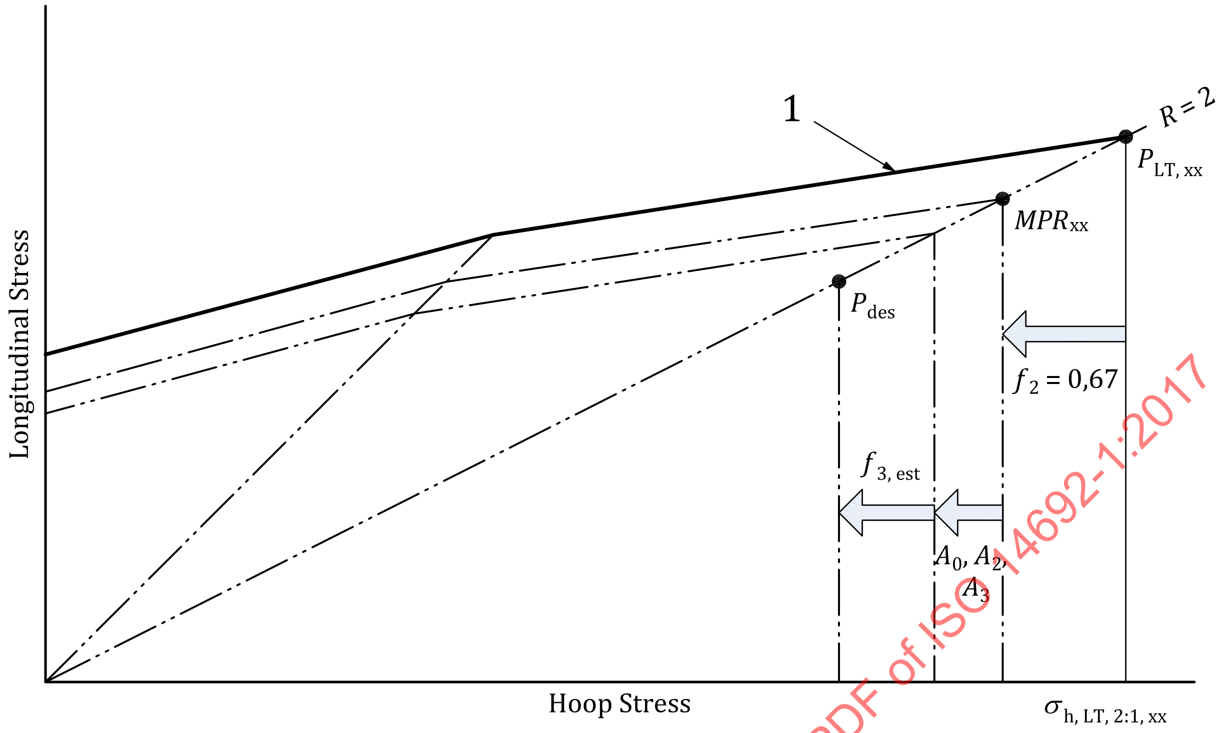
$f_{3,est}$ is the f_3 part factor estimated at the bid stage of the project,

A_0 is the partial factor for design life,

A_2 is the partial factor for chemical resistance,

A_3 is the partial factor for cyclic service.

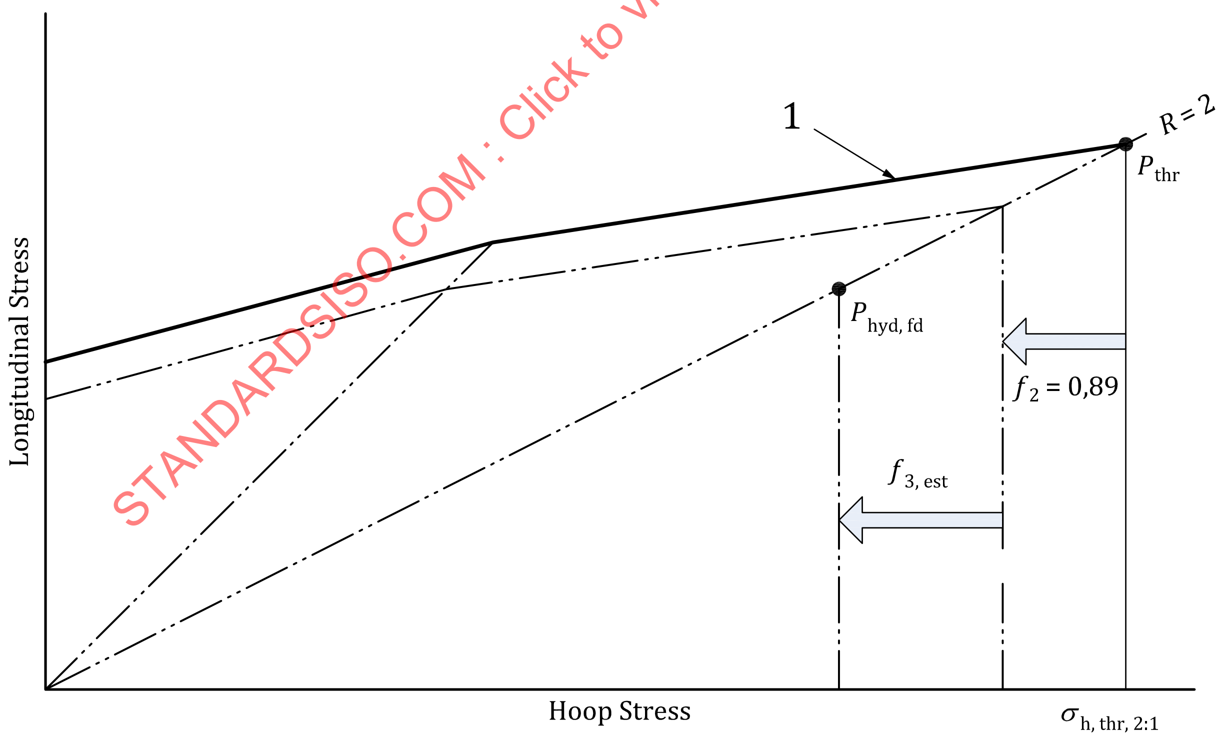
The relationship of MPR_{xx} to the long term envelope and to P_{des} is presented in Figure 3. The relationship of P_{thr} to $P_{hyd,fd}$ is presented in Figure 4.



Key

1 long-term envelope

Figure 3 — Relationship of MPR_{xx} to the long-term envelope and to P_{des}



Key

1 threshold envelope

Figure 4 — Relationship of P_{thr} to $P_{hyd,fd}$

Accordingly, for GRE, MPR_{65} should always be equal to or greater than P_{des}. For GRUP and GRVE, MPR_{21} should always be equal to or greater than P_{des}.

NOTE Since MPR_{65} is the default MPR_{xx} for GRE, this will tend to add some factor of safety in the design of the hydrotest loading case (since the hydrotest loading case is conducted at ambient temperature, but the design envelope for the hydrotest loading case will be based on the long-term envelope at 65 °C). The same is not true for GRUP and GRVE.

4.2 Part factors and partial factors

4.2.1 Part factor f_2 for loading

f_2 shall be used to scale the long-term envelope to the design envelopes for the various different loading cases (see ISO 14692-3:2017, 6.2).

4.2.2 Part factor $f_{3,est}$ for the limited axial load capability of GRP piping

$f_{3,est}$ shall be used to de-rate MPR_{xx}, taking account of non-pressure-related axial loads, e.g. bending and externally-applied direct-acting axial forces (see Annex E).

4.2.3 Partial factor A_0 for design life

A_0 shall be used to scale the long term envelope to the design envelopes at design lives other than 20 years (see ISO 14692-3:2017, 6.1.1).

4.2.4 Partial factor A_2 for chemical resistance

A_2 shall be used to scale the long term envelope to the design envelopes to account for the effect of chemical degradation (see ISO 14692-2:2017, 4.4.2).

4.2.5 Partial factor A_3 for cyclic loading

A_3 shall be used to scale the long-term envelope to the design envelopes to account for the effects of cyclic loading (see ISO 14692-3:2017, 6.1.3 and Annex B).

5 Classification

5.1 Joints

5.1.1 Unrestrained joints

ISO 14692 (all parts) applies only to those piping systems utilizing joints that can take axial loads, i.e. restrained joints or bi-axially loaded joints. Examples of restrained joints include, but are not limited to, adhesive-bonded joints, laminated joints and prescribed threaded joints.

Unrestrained joints, such as the o-ring bell-and-spigot (without locking strip), are not covered by this document.

NOTE Restrained joints apply significant axial stress from thrust and therefore incorporate the concept embodied in the trapezoidal design envelope to be properly specified and analysed.

5.1.2 Classification of joints

5.1.2.1 Concepts of classification

Joints shall be classified as either

— prescribed threaded joints, or

— restrained joints other than prescribed threaded joints.

This classification has an effect on the following topics (see Table 2):

a) the selection process for the gradient, based on either measured gradients or default gradients (see 6.1.2.1 and 6.1.2.2);

b) the test pressure for training (see ISO 14692-4:2017, Annex C);

c) mill hydrostatic testing (see ISO 14692-2:2017, 7.2.2).

Table 2 — Concepts involving classification of joints

Joint type	Gradient	Jointer qualification test	Mill hydrostatic test
Prescribed threaded joints	Derived from either measured gradients or default gradients	2,0 × MPR_{65} (GRE) 2,0 × MPR_{21} (GRUP and GRVE)	100 % for pipes; ends are to be unrestrained
Restrained joints other than prescribed threaded joints	Derived from default gradients	2,5 × MPR_{65} (GRE) 2,5 × MPR_{21} (GRUP and GRVE)	5 % for pipes; ends may be unrestrained or restrained

5.1.2.2 Prescribed threaded joints

Recognizing that the gradient of plain pipe may not be representative of prescribed threaded joints, piping systems that utilize prescribed threaded joints (i.e. mechanical joints that meet the requirements of API 15 HR) shall be designed using a gradient derived from either measured gradients or default gradients for regression based on industrywide experience. The minimum gradient shall be 0,030 irrespective of the measured gradient.

NOTE Gradients are specified as positive numbers even though the slope of the regression line is negative.

5.1.2.3 Restrained joints other than prescribed threaded joints

Recognizing that the regression analysis from long-term testing, such as ASTM D2992, provides an indication of performance, not an exact, repeatable measure, piping systems utilizing restrained joints other than the prescribed threaded joints shall be designed using a gradient derived from default gradients for regression based on industrywide experience.

While default gradients are used in the selection process, the manufacturer shall still be required to provide a single regression curve data set per Clause 1. The manufacturer's gradient shall be compared to the default gradient (see ISO 14692-2:2017, Annex A).

5.2 Resin matrix

The resin matrix for the products shall be classified as:

a) GRE,

b) GRUP,

c) GRVE, or

d) other resin system.

This classification has an effect on the following topics (see Table 3):

1) the default temperature (65 °C for GRE and 21 °C for GRUP and GRVE);

2) the default gradient (see ISO 14692-2:2017, Annex A).

Table 3 — Concepts involving resin system

Pipe type	Default temperature (°C)
GRE	65
GRVE	21
GRUP	21

6 Materials

Application of ISO 14692 (all parts) shall be limited to the manufacture of rigid components made from fibre-reinforced thermosetting resins. Typical resins are epoxy, polyester, vinyl ester and phenolic. Thermoplastic resins are excluded.

NOTE 1 The resins as listed are generic compounds. Their performance and properties of thermal, mechanical and chemical resistance vary significantly depending on the resin and curing agent used to cure them. The user is cautioned to ascertain that the resin and curing agent are known for the resin system planned to be used.

The principal reinforcement material of the component wall shall be glass fibre, e.g. continuous and/or woven rovings. Other types of fibre reinforcement, such as carbon or aramid fibre, may be used to provide local strengthening within joints and fittings. Use of low electrical resistivity fibres, e.g. carbon, for non-structural purposes to provide electrical conductivity shall be permitted.

ISO 14692 (all parts) is not applicable to piping systems that incorporate internal thermoplastic or elastomeric liners. This is because such materials can introduce significant changes in performance characteristics of the GRP piping.

NOTE 2 The use of a thermoplastic liner will result in change of the failure mode for pressure retention.

The maximum allowable temperature is determined by the resin type, curing system and state of cure.

The minimum recommended temperature for GRP regardless of the resin system is −35 °C, although lower temperatures may be considered.

NOTE 3 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. A 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.

ISO 14692 (all parts) is not applicable to piping systems that incorporate fillers or aggregates except when the additive or filler material is used as a liner on the inside of the piping to provide enhanced performance, e.g. wear resistance and electrical conductivity. The liner material shall be compatible with the service conditions.

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

7 Dimensions

For guidance purposes, the typical maximum pressure-diameter range of piping in fluid service (e.g. water/hydrocarbon service) covered by ISO 14692 (all parts) is indicated in Figure 5 that represents a compromise between the current application experience envelope of GRP pipelines and piping systems and commercial availability.

The curve in Figure 5 can be approximated by using Formula (4):

$$DN \times MPR_{xx} = 3\,000 \tag{4}$$

where

DN is the nominal diameter, expressed in mm,

MPR_{xx} is the maximum pressure rating at xx °C, expressed in MPa.

In Figure 5, MPR_{xx} is a maximum of 27,5 and DN is a maximum of 4 000.

A different constant applies for gas service.

There are no restrictions on the thickness to diameter ratios used in the structural calculations given in ISO 14692 (all parts).

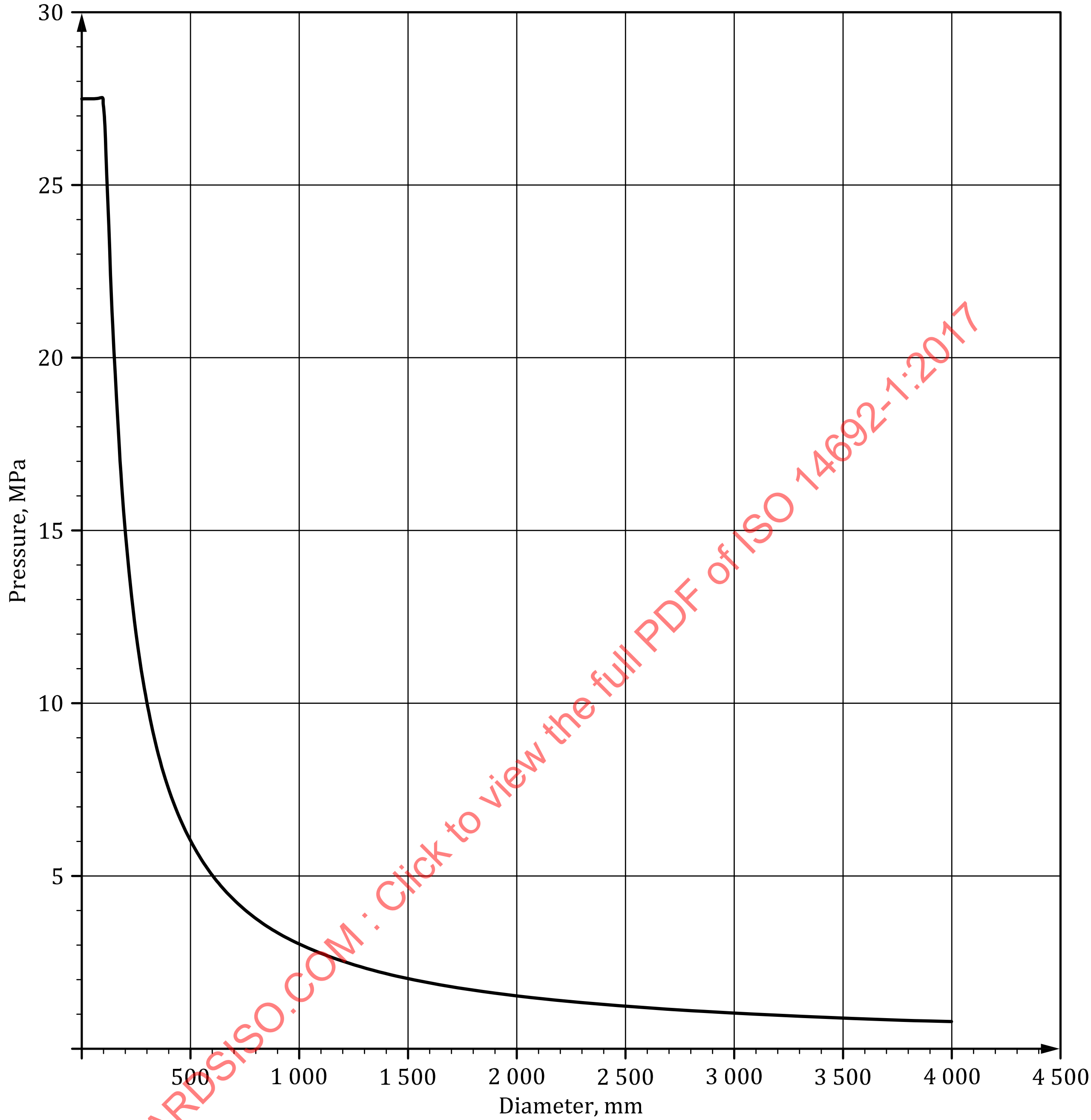


Figure 5 — Envelope of pressure/diameter range of GRP pipeline and piping systems based on current experience

Annex A
(informative)

Principle

A.1 General

ISO 14692 (all parts) advocates the use of a standard methodology for materials selection that is based on performance and not specification, called "performance-based material selection" (PBMS). PBMS reflects true functional needs, excludes arbitrary requirements and does not specify materials. The four key steps to PBMS are

a) identification and documentation of all performance factors relevant to the application,

b) quantification of functional performance requirements,

c) qualification of materials for technical acceptability, and

d) final selection.

The above methodology provides a standardized auditable approach to material selection.

A.2 Regression analysis and modes of failure

A.2.1 General

Experience has shown that regression analysis can not always produce repeatable results and is only an indication of performance, not an exact number as is often presented by suppliers and understood by the end users. The values from regression analysis can often give variation in the results for the following reasons.

a) Severe micro-cracking of the resin matrix under high stress, short-term loading allows physical permeation through the micro-cracked resin matrix to the interface between the glass and resin.

b) The higher-stress, shorter-term failure points do not have time to be fully saturated with water during the test.

c) The slope of the regression curve is obtained by a sum of the least squares fit in covariant analysis which naturally emphasises the value of the short-term and long-term failure points more than the failure points in the middle.

d) The time-to-failure is a random event in the test protocol, which means the actual distribution of the data points versus time significantly affects the results of the analysis.

e) In some test protocols, several modes of failure can be mixed into the regression analysis including pipe wall failures, thread shear failures and bell pull-off failures.

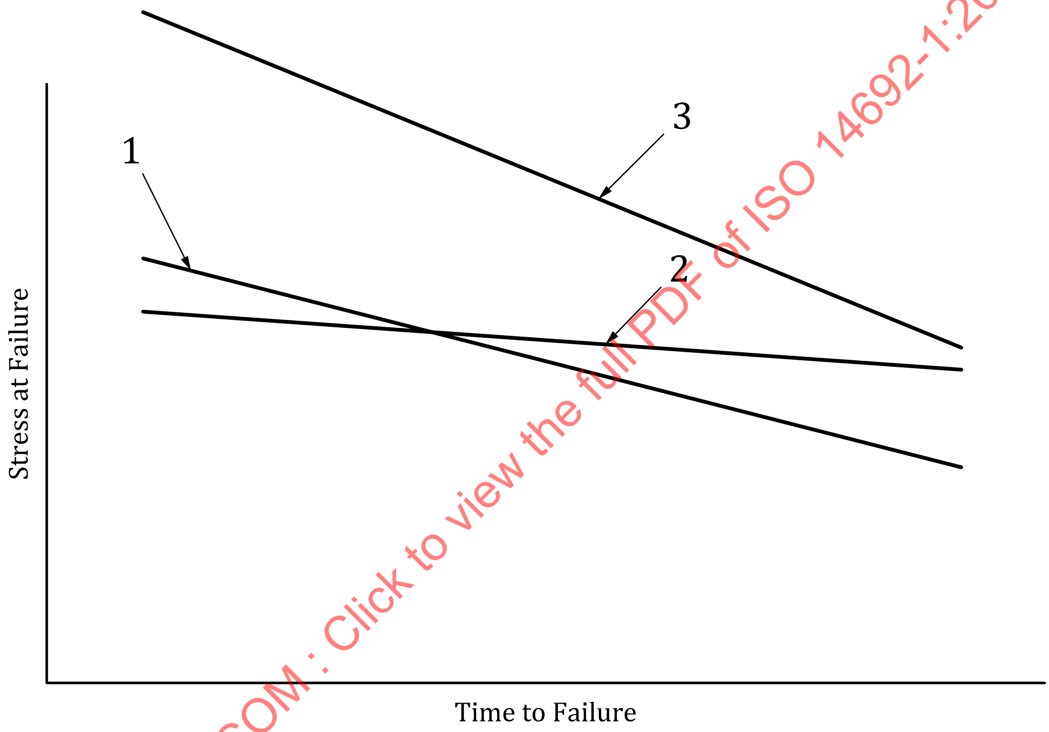
f) Insisting on joints in pipe wall regression analysis for the primary purpose of determining a pipe wall design stress increases the risk of mixing failure modes. The first rule of any regression analysis should be to require the same failure mode of all tested components.

Three separate modes of failure can exist in most structurally reinforced composites (see Figure A.1):

a) Resin matrix dominated failure (perpendicular to the fibre direction) which is the most common mode for ±54° laminates and is most often the dominate failure mode in the short term and medium term. The degradation rate is slower than the fibre degradation rate, but the initial failure stress is lower, so this line can cross the glass fibre dominated line.

b) Interlaminar or intralaminar shear failure (parallel to the fibre) which has the potential to occur in any item where shear dominates such as the thread shear for an 8-round joint. The initial value can be low, depending on geometry, but the degradation rate is low. The simple reason for the slow degradation rate is that the load is parallel to the fibre, which means there is lot of cross-sectional area, so the shear stress applied to the fibre interface is low and the resulting degradation rate is low (shallow slope).

c) Glass fibre dominated failure (in the fibre direction) where the the initial failure stress is high, but the slope can also be steep. This mode of failure has the potential for crossing the resin matrix dominated failure line.



Key

1 theoretical resin matrix dominated failure regression line

2 theoretical shear dominated failure regression line

3 theoretical glass fibre dominated failure regression line

Figure A.1 — Modes of failure

Resin matrix dominated failure will be the limiting design stress for all pipe and fittings for most if not all of the design life. As such, conservative or reasonable regression gradients that are based on resin matrix dominated modes of failure are the most representative for predicting long-term performance of the overall pipe and fitting system. Thread shear has a lower gradient than cross ply resin matrix cracking and can be the initial mode of failure for a joint. It is, however, reasonable that this regression will cross over the resin matrix dominated regression long term, but this is dependent on the geometry and ratio of shear to cross ply stress values.

NOTE 1 Although the potential for fibre dominated failure exists for E-glass, it cannot exist for boron-free E-glass since the failure stresses for boron-free E-glass would be higher and its fibre dominated failure line cannot cross the resin matrix dominated failure line. The gradient, or slope, of the regression line is shallower for boron-free E-glass, not the initial failure stress.

NOTE 2 Regression gradients for fittings can be different than for plain pipe. However, cross ply resin matrix cracking will exist in all joints and fittings, so the gradients might not be that different. The effort to develop regression values for all components at all temperatures is not feasible, especially when mandated for each resin system and each factory. The use of representative default gradients and 1 000 h qualification tests for all components makes the task at least manageable.

A.2.2 Justification for a resin-matrix failure mode

A uni-directionally loaded composite can and will likely demonstrate glass fibre rupture (both long term and short term). In fact, a 54° pipe will show a fibre dominated “rupture” in short-term testing when loaded in the pure hoop direction, but there is a transition to resin matrix failures at certain *R*-ratios.

There are many composite “global” failure theories for composite structures. The “global” failure criteria proposed by various researchers are typically quadratic equations with terms for principle stresses, shear and an “interaction factor” λ. Researchers such as Puck, Halphin and Tsai have proposed various failure criteria. However, “global” failure criteria such as Puppo/Evensen, Puck and others only work for part of the trapezoidal failure envelope because they are anticipating a particular mode of failure. Therefore, the prediction model should change if a different mode of failure is encountered at different *R*-ratios. Some models accurately predict fibre dominated failure under pure hoop loading, but are not accurate for resin matrix dominated failure between $R = 0$ to $R \approx 3$. Other models accurately predict resin matrix dominated failure between $R = 0$ and $R \approx 3$, but not fibre dominated failure under pure hoop loading. The simple answer is the prediction model should anticipate the mode of failure. All current laminte plate theory prediction models only predict short-term failure and cannot predict long-term degradation rates without testing.

The jurisdiction of ISO 14692 (all parts) has been limited to restrained joint pipe that produces large axial stresses from internal pressure. Bi-directionally loaded pipe will produce resin matrix dominated failures at *R*-ratios between $R = 1$ and $R = 4$. The simple reason is the failure strain transverse to the fibre is much lower than the failure strain in the direction of the fibre. There are significant strains transverse to the fibres for loading between $R = 1$ to $R = 4$. Strain in the fibre in the plus ply direction produces strain transverse to the fibres in the adjacent minus ply direction in ±54° pipe. In dual angle pipe with hoop glass and longitudinal glass reinforcement, an *R*-ratio between 1 and 2 will produce large strains transverse to the hoop plies from axial stress and large strains transverse to the longitudinal plies from hoop stress, resulting in transverse cracking in both plies and resulting weep leakage. Only at extreme *R*-ratios is it possible to produce fibre dominated failures.

A.2.3 Crack propagation in resin matrix dominated failures

A fracture mechanics approach can accurately predict cracking in a ply parallel to the fibres (caused by loading transverse in the fibre direction), resulting in weep on a 54° filament wound pipe. The fracture energy balance is the increased stored energy in the cracked composite versus the fracture energy required to crack a ply. If the change in stored strain energy in the cracked composite versus the uncracked composite is greater than the fracture energy required to crack the ply from transverse loading, the cracks will generate in the ply. The formulae for stored strain energy are similar to stored energy in a deflected spring.

The fracture energy required for a crack to propagate will degrade with time by swelling of the resin matrix and a chemical breakdown (hydrolysis) of the bond between the resin and fibres. Water can quickly permeate a resin matrix without any physical cracks. The water molecules can permeate to the interface and attack the bond, so the degradation rate is still there, even at low applied strain levels with little or no cracking. Review of virtually all regression data shows a steeper slope for data points above 1 000 h where the crack density is much lower. The reason is the data points above 1 000 h more closely represent the regression slope from permeation and not from substantial micro cracking for the earlier data points. The micro cracking in the earlier data points (less than 1 000 h) causes the laminate to degrade faster due to high crack density providing physical paths for water permeation and the resulting faster degradation of the remaining laminate.

It is correct that a static load cannot cause a crack of a certain size to propagate to failure. However, long term regression per ASTM D2992 with potable water is not a static condition. Thus, within the scope of ISO 14692 (all parts), there is not a strain limit below which cracks can not propagate. Furthermore, the size of the crack is not static. When that crack increases beyond a certain critical length, it can propagate until failure occurs.

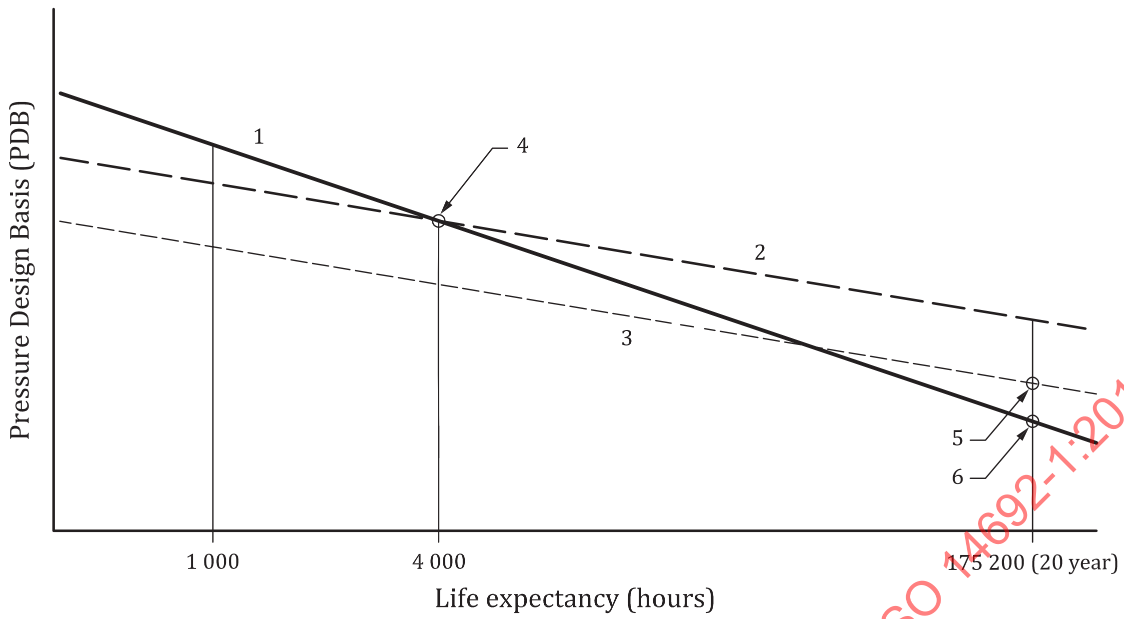
A.3 Gradient choices

A.3.1 Default gradients

Extensive plain pipe wall regression data (ASTM D2992) was reviewed in drafting ISO 14692 (all parts) and arriving at the tabled default gradients. The published default gradients are believed representative of typical plain pipe performance and conservative for components and joints, thus a component qualification program based on all components (pipe, joints, fittings) surviving 1 000 h tests per default gradients is deemed an overall conservative approach. For this approach to be valid, joints, fittings and components other than plain pipe should have a shallower regression slope than the pipe default values published here, as shown in Figure A.2. Note the default gradients still allow a supplier to demonstrate superior performance by the absolute pressure used in the 1 000 h qualification tests, thus maintaining the performance based testing fundamental to ISO 14692 (all parts).

A.3.2 Measured gradients

ASTM D2992 allows for long-term joint and component performance to be measured separately from pipe walls. API 15 HR specifies a standard joint API round threads (a prescribed joint) and allows for component qualification based on the fact that components and joints can have a shallower gradient than the pipe wall. To qualify, the shallower gradient components (joints and fittings), a pressure design basis (PDB) of joints and components should be shown to be greater than the pipe PDB of the pipe wall at maximum temperature and life expectancy, as shown in Figure A.3. Although more onerous than default gradient survival testing, this qualification method is acceptable if the manufacturer opts to perform the additional testing required per ISO 14692-2.



Key

1 base pipe default gradient PDB regression line

2 survival with default G for longer periods

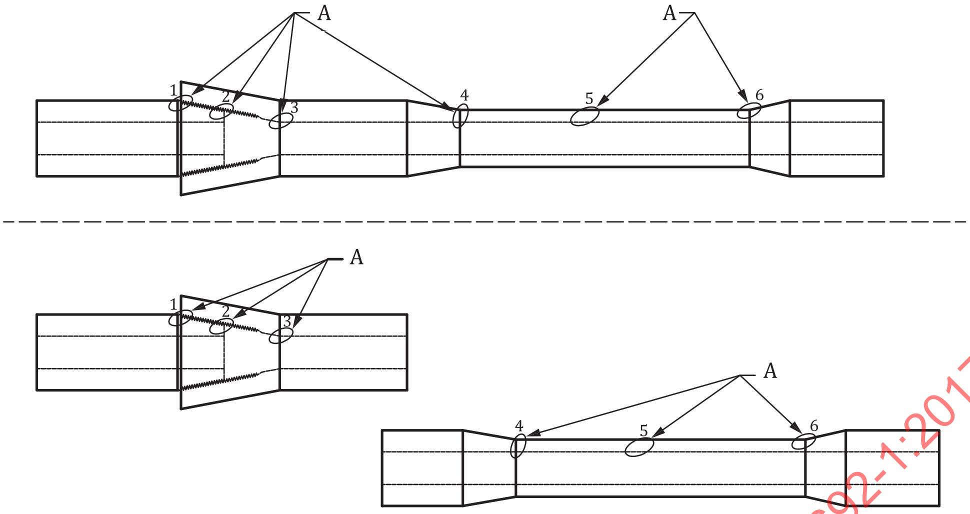
3 prescribed joint components measured gradient

4 joint/component qualified by survival longer hours calculated with default G

5 joint/component qualified by measured gradient compared to pipe

6 plain pipe MPR based on default G

Figure A.2 — Illustration of qualifying components with prescribed joints



Key

A critical areas in pipe + joint testing stress concentrations and minimum walls

1 joint connection – end of female thread

2 joint connection – end of male thread

3 pipe, joint connection (female)

4 wall thickness – pipe, joint connection (female)

5 wall thickness – plain pipe

6 wall thickness – pipe, joint connection (male)

Figure A.3 — Separating prescribed joints/components from pipe wall qualification

A.4 Qualification of prescribed threaded joint

Seperating the pipe from the joint captures all relevant critical stress concentrations, allowing plain pipe to be tested per default gradients and joints/components to be tested per measured gradients for prescribed threaded joints.

Components including pipe joints using prescribed threaded joints should have joint-related failures during short-term pressure testing and meet the scaling rules defined in scaling rules per ISO 14692-2:2017, Annex F.

The method is to develop a base regression analysis for each prescribed joint type, i.e. API round joint is considered a single type. A single joint size of each type is regression tested per API 15 HR where the primary output of this regression analysis is to determine the prescribed joint gradient. Alternative diameter joints of the same type can then be qualified by (2×) 1 000 h survival tests using the measured gradient.

Annex B
(informative)

Guidance on scope limitations

Guidelines for determining if ISO 14692 (all parts) is applicable to a product are given in Figure B.1

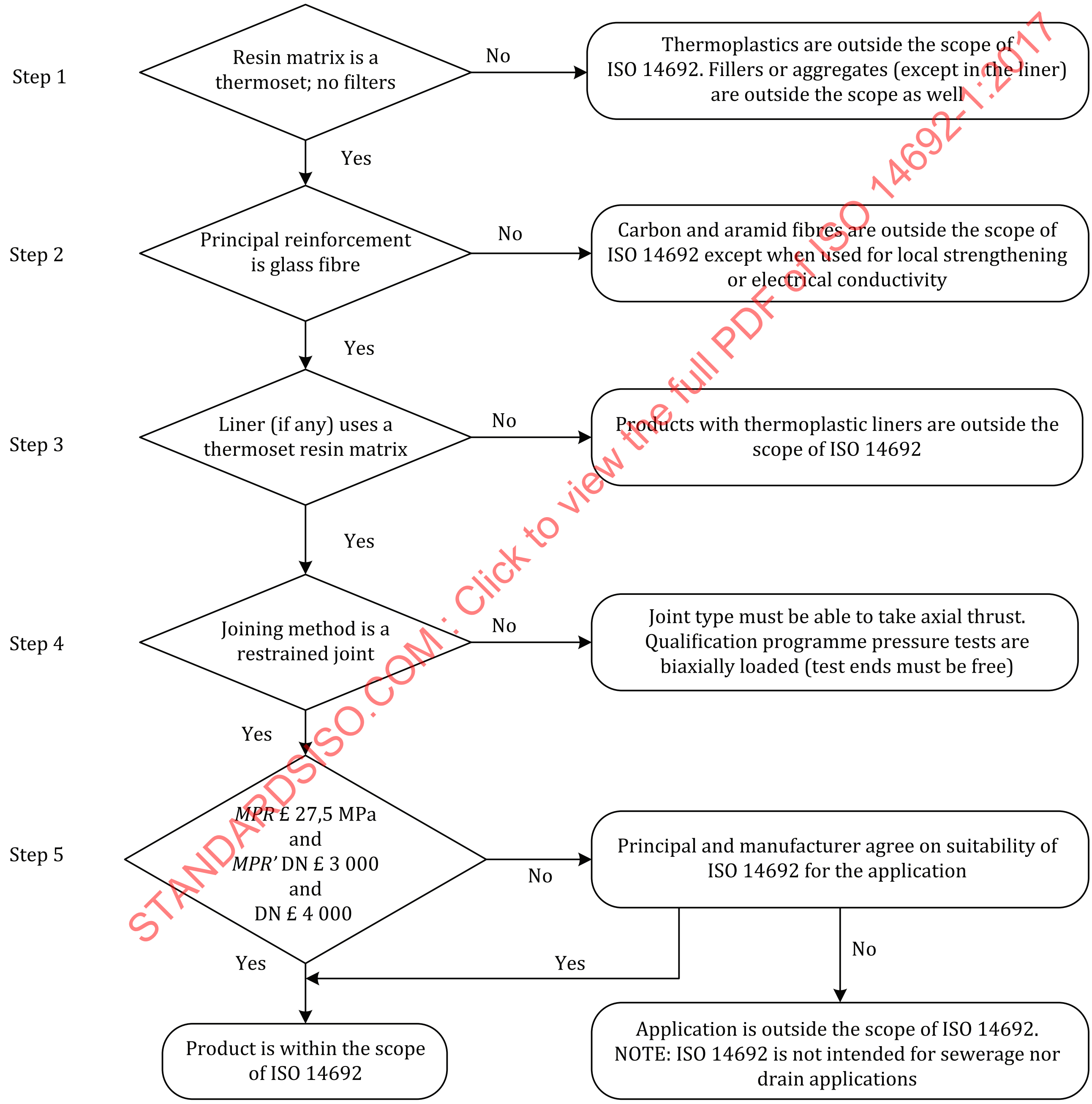


Figure B.1 — Flowchart for verifying the applicability of ISO 14692 (all parts)

Annex C
(normative)

Enquiry sheet

Principal/Agent		
	Principal	Agent
Company		
Contact		
Address		
Telephone		
Telefax		
Email		

Project	
Project name/description	
Principal's reference or designation number (if any)	
Installation location(s)	
Required pipe sizes and required components (e.g. pipes, bends, tees)	
Does the project fall within the scope of ISO 14692 (see Annex B)?	
Special conditions, if any	

Service conditions	
Above-ground or buried system?	
Pipeline or process piping?	
Fluid composition (chemical names, concentration, exposure time, pH range)	
Fluid specific gravity	
Flow velocity	
Particulate content	
Hydrotest pressure (MPa)	
Estimated value of $f_{3,est}$	
Installed curve radius	
Design life (years)	

Service conditions		
	Normal operating	Design
Internal pressure (MPa)		
External pressure (MPa)		
Max. fluid temperature (°C)		
Min. fluid temperature (°C)		
Min. ambient temperature (°C)		
Max. ambient temperature (°C)		
Installation temperature (°C)		
Burial depth (m) (buried systems only)		
Vehicular traffic loads (buried systems only)		
Composite soil modulus, M_S (buried systems only)		
Environmental loads (e.g. wind, snow, ice, UV exposure)		
Inertia loads (e.g. daily wave action, ship motions, motion during transportation or storms)		
Water hammer or other pressure transients		
Cyclic loading ratio and number of cycles		
Impact loads		
Heat tracing		
Fire performance requirements (fire endurance, surface spread of flame, heat release, smoke obscuration and toxicity) (also specify the authority having jurisdiction)		
Blast over-pressures (specify whether dynamic load factor is included)		
Electrical conductivity requirements		
Does the service fluid(s) or soil(s) contain aromatic hydrocarbons and/or toxic fluids (i.e. are there any permeation issues, such as contamination of drinking water or contamination of soil)?		

Additional items	
Is supervision of installation by the manufacturer required?	
Is potable water health certification required?	
If "yes" above, specify applicable health authorities	
Restrictions on resin/curing agent (if any)	

Additional items	
Is a resin-rich liner required? (see Table 1)	
Any additional QC tests required by the prinicipal (see ISO 14692-2:2017, 7.3.4)?	
Any other requirements specified by the principal?	

Annex D
(normative)

Wall thickness definitions

Wall thickness definitions are presented schematically in Figure D.1.

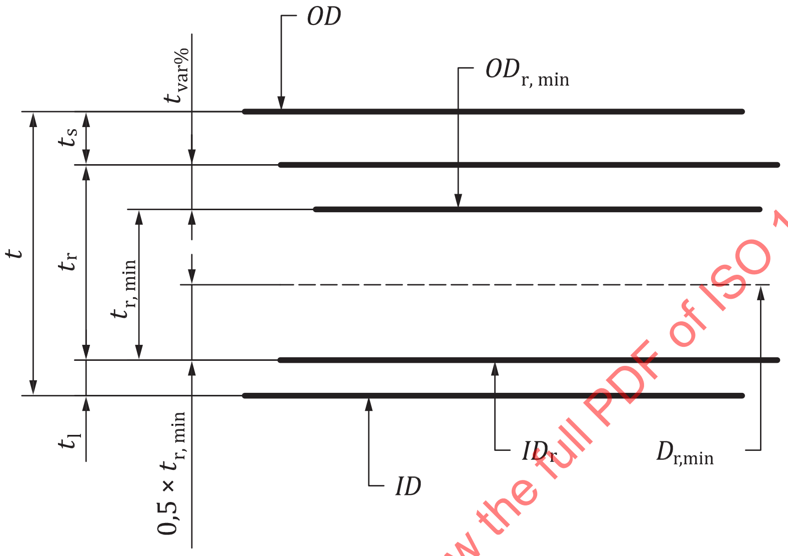


Figure D.1 — Wall thickness definitions

The wall thickness definitions presented in Figure D.1 shall be calculated as follows:

$$t = \frac{OD - ID}{2} \tag{D.1}$$

$$t_r = t - t_l - t_s \tag{D.2}$$

$$ID_r = ID + 2 \times t_l \tag{D.3}$$

$$OD_{r,min} = ID_r + 2 \times t_{r,min} \tag{D.4}$$

$$D_{r,min} = ID_r + t_{r,min} \tag{D.5}$$

$$t_{var\%} = \frac{t_r - t_{r,min}}{t_r} \tag{D.6}$$

$$A_i = \frac{\pi}{4} \times ID^2 \tag{D.7}$$

$$A_r = \frac{\pi}{4} \times (OD_{r,min}^2 - ID_r^2) \tag{D.8}$$

$$I_r = \frac{\pi}{64} \times (OD_{r,min}^4 - ID_r^4) \quad (D.9)$$

$$Z_r = \frac{\pi}{32} \times \frac{(OD_{r,min}^4 - ID_r^4)}{OD_{r,min}} \quad (D.10)$$

$$m_p = \rho_p \times \frac{\pi}{4} \times (OD_{r,min}^2 - ID^2) / 1\ 000\ 000 \quad (D.11)$$

where

t is the wall thickness, expressed in mm,

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

t_l is the is the internal liner thickness of the pipe wall, expressed in mm,

t_s is the outer sheath thickness of the pipe wall, expressed in mm,

OD is the outside diameter, expressed in mm,

ID is the inside diameter, expressed in mm,

ID_r is the inside diameter of the reinforced pipe wall, expressed in mm,

$OD_{r,min}$ is the minimum outside diameter of the reinforced pipe wall, expressed in mm,

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

t_r is the nominal reinforced pipe wall thickness, expressed in mm,

A_i is the internal area of the pipe, expressed in square mm^2,

A_r is the minimum reinforced pipe wall cross section, expressed in mm^2,

I_r is the minimum reinforced pipe wall moment of interia, expressed in mm^4,

Z_r is the minimum reinforced pipe wall section modulus, expressed in mm^3,

m_p is the pipe mass per unit length, expressed in kg per metre, and

ρ_p is the pipe mass density, expressed in kg per m^3.

NOTE A_r, I_r, Z_r and m_p are calculated based on the minimum reinforced pipe wall, $t_{r,min}$ and not t nor t_r.

Annex E
(informative)

Selection of part factor $f_{3,est}$ in the bid process

E.1 Selection process

There are two methods available for selecting the $f_{3,est}$ part factor as shown in Figure E.1.

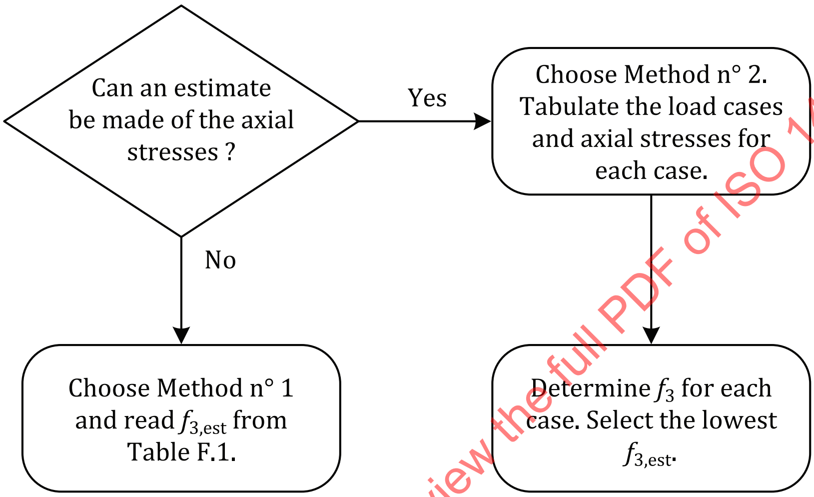


Figure E.1 — Selection process for $f_{3,est}$

NOTE When comparing bids from two or more manufacturers, a variation in the value of $f_{3,est}$ from one manufacturer to another can have an effect when comparing the wall thickness, and consequently the cost, of the components from one manufacturer to another. The intention during the bid stage is for the Principal, in consultation and agreement with the manufacturers, to specify the $f_{3,est}$ factor on the enquiry sheet (see Annex C) and thus eliminate this variation.

E.1.1 Determing $f_{3,est}$ — Method No.1

Since the project is at the bid stage, there will be no stress analysis available and estimates will have to be made of these axial stresses. Guidelines for determining the part factor $f_{3,est}$ at the bid stage are provided in Table E.1.

Table E.1 — Guidelines for determining $f_{3,est}$ at the bid stage

Application	$f_{3,est}$	Notes
Process piping, above-ground, offshore & marine, max. 1,5 × P_{des} hydrotest	0,65 – 0,75	Occasional loads from wind and/or ship motions typically require a low f_3. Special design conditions such as wave loads can require a much lower $f_{3,est}$.
Process piping, above-ground, industrial, max. 1,5 × P_{des} hydrotest	0,65 – 0,80	Higher temperature changes (e.g. above 40 °C) may require a lower $f_{3,est}$ due to axial and bending stress from thermal loads. Applications in some seismic zones can require a lower $f_{3,est}$.
Process piping, above-ground, oil field, max. 1,5 × P_{des} hydrotest	0,65 – 0,80	Same as aboveground industrial process piping.
Pipelines, above-ground, oil field, max. 1,25 × P_{des} hydrotest	0,70 – 0,85	Pipelines should have lower non-pressure axial stresses, so $f_{3,est}$ can be higher than for process piping applications. For process piping, the hydrotest case is likely to govern whereas for pipelines, a design case is likely to govern.
Process piping, underground, industrial, max. 1,5 × P_{des} hydrotest	0,75 – 0,85	Hoop (circumferential) loads can dominate the design. Higher pressure (between 10 and 30 bar) undergound pipelines with many fittings or direction changes where the longitudinal bending loads can be significant due to the axial thrust generated from the internal pressure. These systems can warrant an $f_{3,est}$ between 0,65 and 0,8.
Pipelines, underground, oilfield, max. 1,25 × P_{des} hydrotest	0,85 – 1,00	See note above for process piping, underground, industrial

NOTE 1 In buried pipelines, the inclusion of elbows and tees can be accompanied by significant axial and bending loads and can require pipe with a much thicker wall for up to a pipe length each side of the fitting, plus can require fittings with a much higher MPR_{xx} to take into account the large bending stresses and axial SIF for the fitting at the directional change.

NOTE 2 For large-scale projects which include a mixture of the applications in this table, the project can be broken down into the individual sections where the relevant $f_{3,est}$ factor is used for each one. This can result in multiple pipe wall thicknesses for a single project. If the principal wishes for a common pipe to be used, then the lowest $f_{3,est}$ should be determined.

NOTE 3 The guidelines for $f_{3,est}$ in this table are based primarily on 55° filament wound pipe. For those pipes or other components manufactured by a method that has a higher axial strength capacity, a higher $f_{3,est}$ factor can be warranted. A component with equal amounts of reinforcement in both the axial and hoop direction can warrant an $f_{3,est}$ factor of 1,0. Evidence should be provided to justify a higher $f_{3,est}$ factor.

Process piping can also be referred to as industry piping — these are lines that typically have a large number of fittings/flanges/joints in relation to the total length of pipe. Pipelines typically have a small number of fittings/flanges in relation to the total length of pipe.

NOTE In undergound piping systems (both pipelines and piping) where the soil and live loads can be significant, it can be necessary to select a product with an MPR_{xx} higher than what is needed for internal pressure alone. In this instance, predict the deflection due to the soil and live loads and then calculate the hoop bending stress and hoop pressure stress. Then determine the equivalent pressure necessary to generate the same hoop stress. This can be done in the early stages of the project so that an appropriate MPR_{xx} and product can be selected.

E.1.2 Determining $f_{3,est}$ — Method No.2

The second method for determining $f_{3,est}$ at the bid stage is to consider the non-pressure-generated axial stresses that could occur on the piping system. Non-pressure-generated axial stresses arise from

a) σ_{ab},

b) σ_{ac},

c) σ_{af}, and

d) σ_{at}.

It should be possible to estimate typical values for these axial stresses for the proposed pipe installation. The first step is to identify a suitable GRP product type and a typical associated long-term axial strength, $\sigma_{a,LT,0:1,xx}$. This can be obtained from published vendor data. A value of 36,0 MPa is used in the example provided in Table E.2.

Table E.2 — Example of a summary of critical design cases

	Case 1 (sustained)	Case 2 (sustained + self-limiting)	Case 3 (occasional)	Case 4 (hydrotest)
$\sigma_{a,LT,0:1,xx}$ (MPa)	36,0	36,0	36,0	36,0
f_2	0,67	0,83	0,89	0,89
A_0	1,00	1,00	1,00	1,00
A_2	1,00	1,00	1,00	1,00
A_3	1,00	1,00	1,00	1,00
$\sigma_{a,des,0:1}$ (MPa)	24,1	29,9	32,0	32,0

The second step is to identify likely partial factors for critical design cases and the effect these will have on the design strength of the pipe material.

Now, estimated values should be provided for the non-pressure axail stresses for each load case. Values can be obtained through past design experience or through simple manual calculations for pipe support spans, roping curvature, etc. as shown in Table E.3 and Table E.4.

Table E.3 — Descriptions of non-pressure-generated axial stresses

	Case 1 (sustained)	Case 2 (sustained + self-limiting)	Case 3 (occasional)	Case 4 (hydrotest)
σ_{ab} (MPa)	Note 1	Note 1	Note 2	Note 1
σ_{ac} (MPa)	Note 3	Note 4	Note 4	Note 4
σ_{af} (MPa)	Note 5	Note 6	Note 7	Note 8
σ_{at} (MPa)	Note 9	Note 10	Note 10	Note 11

NOTE 1 Usually bending from self-weight at maximum unsupported span.

NOTE 2 Adds occasional loads such as wind or earthquake.

NOTE 3 Zero, since stresses from roping are not a sustained load.

NOTE 4 Bending stress from roping.

NOTE 5 Externally applied axial forces such as self-weight in a vertical run of piping.

NOTE 6 Sustained loads plus other externally applied forces such as a reaction at a thrust block, friction at pipe supports.

NOTE 7 May be different from case 2 because of pressure surges that cause axial expansion.

NOTE 8 Will generally be higher than case 2 or 3 due to the higher pressure from the hydrotest.

NOTE 9 Zero, since stresses from temperature changes are not a sustained load.

NOTE 10 Includes bending in expansion loop or reaction to thrust blocks from temperature changes.

NOTE 11 Typically zero since the hydrotest is at ambient temperature.

Table E.4 — Example of non-pressure-generated axial stresses

	Case 1 (sustained)	Case 2 (sustained + self-limiting)	Case 3 (occasional)	Case 4 (hydrotest)
σ_{ab} (MPa)	8,0	8,0	8,0	8,0
σ_{ac} (MPa)	0,0	0,0	0,0	0,0
σ_{af} (MPa)	0,0	1,0	1,0	5,0
σ_{at} (MPa)	0,0	1,0	3,0	0,0

Values for $f_{3,est}$ can now be calculated for each design case, as shown in Table E.5.

Table E.5 — Example of a summary of critical design cases

	Case 1 (sustained)	Case 2 (sustained + self-limiting)	Case 3 (occasional)	Case 4 (hydrotest)
$\sigma_{a,des,0:1}$ (MPa)	24,1	29,9	32,0	32,0
$\sigma_{ab} + \sigma_{ac} + \sigma_{af} + \sigma_{at}$ (MPa)	8,0	10,0	12,0	13,0
$f_{3,est}$	0,73	0,73	0,70	0,68

For the purposes of pipe selection, use of the lowest of the identified $f_{3,est}$ values should be considered (in this example, 0,68). When selecting a pipe for the project, it is essential that the hydrotest is considered as a design case.

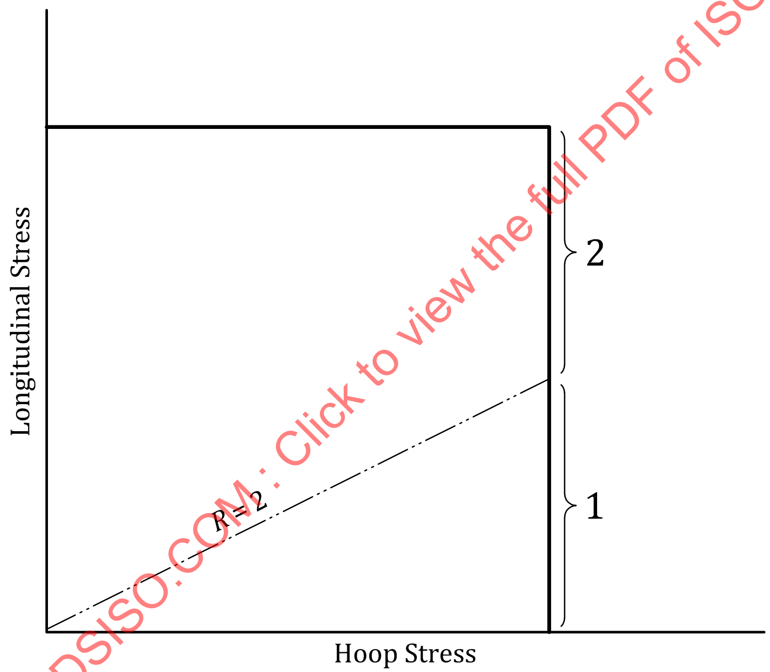
Use Formula (E.1) for calculating $f_{3,est}$ in Table E.5:

$$f_{3,est} = 1 - \frac{\sigma_{ab} + \sigma_{ac} + \sigma_{af} + \sigma_{at}}{\frac{\sigma_{a,des,0:1}}{0,8}} \quad \text{(E.1)}$$

NOTE The value of 0,8 comes from Formula (C.2) in ISO 14692-2:2017, Annex C. Since the R_{test} data is at an R-ratio of 1,0 or less (actually 0,5 and 1,0) and if it is expected that $f_{3,est}$ will be 0,5 or larger, then the 0,8 value is required so that adjustments are made along the slope of the line from $R = R_{test}$ to $R = 2$.

E.2 Background

With isotropic materials, there is no need for an $f_{3,est}$ part factor since σ_{ap} only uses half of the allowable axial stress on the design envelope as shown in Figure E.2.



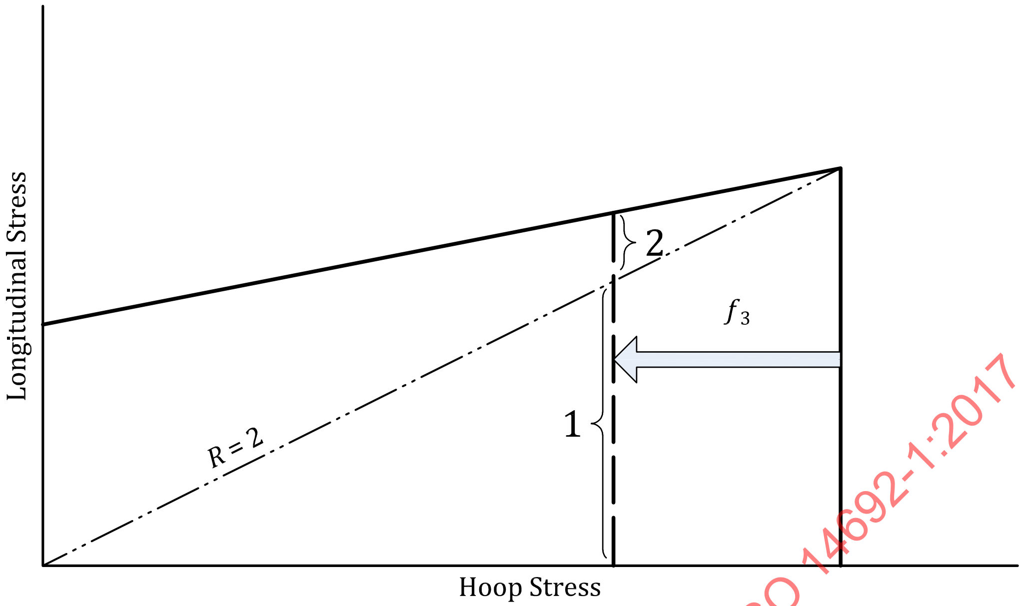
Key

1 axial stress due to internal pressure, σ_{ap}

2 axial stress available for stresses from bending (σ_{ab}), roping/curving (σ_{ac}), external forces (σ_{af}) and thermal loads (σ_{at})

Figure E.2 — Typical design envelope for an isotropic material

Filament wound GRP pipe, however, is a non-isotropic material that is typically optimized for loading due to internal pressure as shown in Figure E.3.



Key

1 axial stress due to internal pressure, σ_{ap}

2 axial stress available for stresses from bending (σ_{ab}), roping/curving (σ_{ac}), external forces (σ_{af}) and thermal loads (σ_{at})

Figure E.3 — Typical simplified envelope for GRP before and after $f_{3,est}$

$f_{3,est}$ part factors less than 1,0 are applicable to non-isotropic GRP components which have a hoop strength larger than its axial strength AND which are used in applications subject to loads that can create additional axial stress other than that from internal pressure. 55° filament wound pipe used in aboveground piping applications is the best example of this type of component. At 55°, filament wound GRP is optimized for internal pressure, but not for any additional axial loads. Furthermore, piping in aboveground applications is typically exposed to loads that create axial stress in addition to that from internal pressure. However, not all GRP piping components and not all applications, such as some buried pipelines, require an $f_{3,est}$ part factor less than 1,0.

Annex F
(informative)

Worked example

The following is a worked example of a theoretical project. In total, there are eight steps in the worked example.

Step 1 is broken up into two parts, 1A and 1B.

Step 1A. The bid process

The following information is entered into the enquiry sheet by the principal:

Principal/Agent		
	Principal	Agent
Company	XYZ Company	N/A
Contact	XYZ	N/A
Address	XYZ Street	N/A
Telephone	123-456-7890	N/A
Telefax	123-456-7890	N/A
Email	xyz@xyz.com	N/A

Project	
Project name/description	XYZ Project
Principal's reference or designation number (if any)	N/A
Installation location(s)	Offshore platform, Gulf of Mexico
Required pipe sizes and required components (e.g. pipes, bends, tees)	Pipe sizes DN50 thru DN400 Required components: pipe, bends, tees, reducers, joints, saddles (olets) and flanges
Does the project fall within the scope of ISO 14692 (see Annex B)?	Yes, the project specifications call for a thermoset resin matrix (structural cage and liner) and glass fibre as the principal reinforcement; the joining method is to be a restrained joint and *MPR*×*DN* is less than 3 000. *MPR* is also less than or equal to 27,5 bar and *DN* is less than or equal to 4 000. Manufacturer to verify other scope requirements in Annex B.
Special conditions, if any	None identified

Service conditions		
Above-ground or buried system?	Aboveground	
Pipeline or process piping?	Process piping	
Fluid composition (chemical names, concentration, exposure time, pH range)	Seawater	
Fluid specific gravity	1,03	
Flow velocity	≤4 m/s	
Particulate content	None identified	
Hydrotest pressure (MPa)	2,4 MPa	
$f_{3,est}$	To be determined with manufacturer	
Installed curve radius	N/A	
Design life (years)	20 years	
	Normal operating	Design
Internal pressure (MPa)	1,0	1,6
External pressure (MPa)	0,074	0,1 (full vacuum)
Max. fluid temperature (°C)	50	65
Min. fluid temperature (°C)	10	5
Min. ambient temperature (°C)		10
Max. ambient temperature (°C)		30
Installation temperature (°C)		10 to 30
Burial depth (m) (buried systems only)		N/A
Vehicular traffic loads (buried systems only)		N/A
Composite soil modulus, M_s (buried systems only)		N/A
Environmental loads (e.g. wind, snow, ice)		183 kph wind loads
Inertia loads (e.g. daily wave action, ship motions, motion during transportation or storms)		Not identified at this time, but inertia loads are expected due to platform motions
Water hammer or other pressure transients		Not identified at this time
Cyclic loading ratio and number of cycles		N/A
Impact loads		Not quantified at this time; recommend minimum wall thickness of 5,0 mm.
Heat tracing		Not required

Service conditions		
Fire performance requirements (fire endurance, surface spread of flame, heat release, smoke obscuration and toxicity) (also specify the authority having jurisdiction)		Products are intended for use in applications requiring fire endurance, surviving a hydrocarbon impinging flame type fire for 30 m filled with stagnant water. During the test, slight weeping is acceptable. After cooling, leakage from the post-fire test shall be less than or equal to 0,2 lpm for a period of 15 m. There are no requirements for surface spread of flame, heat release, smoke obscuration nor toxicity.
Blast over-pressures (specify whether dynamic load factor is included)		None identified
Electrical conductivity requirements		Not required

Additional items	
Is supervision of installation by the manufacturer required?	Not required, but strongly preferred
Is potable water health certification required?	No
If "yes" above, specify applicable health authorities	N/A
Restrictions on resin/curing agent (if any)	No restrictions. Resin may be GRE, GRVE or GRUP.
Is a resin-rich liner required? (see Table 1)	No.

The principal verifies the scope per Annex B:

Resin is a thermoset (epoxy, vinyl ester or polyester); no fillers or aggregates are used.

Principal reinforcement is glass fibre.

A liner, if used, will use a thermoset resin.

Joining method is a restrained type joint. Pipe is filament wound at 55°, therefore of a trapezoidal design shape.

$MPR \times DN = 1{,}6 \times 400 = 640$ which is ≤3 000 and $MPR = 1{,}6$ MPa which is ≤27,5

NOTE 1 MPR_{xx} is not known at this time, only design pressure is known. Per 4.1, it is known that MPR_{xx} is greater than or equal to P_{des}. So, during the bid stage, P_{des} in lieu of MPR_{xx} is used to verify the scope limits.

The application is not sewerage nor drainage, so ISO 14692 (all parts) applies.

Due to the wind loads and the possibility of inertia loads, the manufacturer and principal agree on a value of 0,7 for $f_{3,est}$ for 55° filament wound pipes. This value matches the recommendation in Annex E for offshore process piping.

Because of the need for the low $f_{3,est}$ value, the manufacturer proposes fittings and joints with a construction method that provides more axial reinforcement than in the filament wound pipe. Per Note 3 in Table E.1, the manufacturer provides data to support an $f_{3,est}$ value of 0,95 for those components.

To comply with the requirement that the fittings and joints are as strong or stronger than the pipe, the fittings and joints can require additional thickness or more reinforcement in the hoop direction.

NOTE 2 If the fittings and joints do not have a trapezoidal shape for their design envelope, they would not meet the requirement in Clause 1 nor the flowchart in Annex B and thus ISO 14692 (all parts) is not applicable to these components.

NOTE 3 A possible alternative to providing more reinforcement in the hoop direction would be for the manufacturer to reduce $\sigma_{h,LT,2:1,21}$. The design envelope, of course, would also be reduced accordingly.

The design life is 20 years, so A_0 = 1,0. A_2 is 1,0 per ISO 14692-2:2017, 4.4.2. A_3 is 1,0 since there are no cyclic conditions.

Step 1B. Pre-qualified and pulled from stock

The manufacturer has already performed the qualification process on the product line it wishes to offer and has published the required manufacturer's data. Therefore, Steps 2 and 3 have been completed prior to the bid stage. Product that has already been manufactured and is in stock would be available for use on this project provided the product met the requirements in Step 4. Product that has yet to be manufactured would need to comply with Step 4.

For clarity, details on Steps 2, 3 and 4 are provided.

Step 2. Manufacturer's data

The manufacturer selects a product using a vinyl ester resin (GRVE). The manufacturer has regression data at 50 °C. Since the resin matrix is GRVE, 50 °C is an acceptable test temperature for the long-term regression data. $G_{50,measured}$ = 0,078 and $\sigma_{h,LT,2:1,50,measured}$ = 75 MPa.

NOTE 4 The test temperature for long-term regression only needs to be at or above the default temperature, not at or above the design temperature.

For gradients, the manufacturer follows the flowchart in ISO 14692-2:2017, Annex A:

Step 1: The joining system is not a prescribed threaded joint, so the manufacturer will be using default gradients.

Step 2: The resin matrix is GRVE.

Step 3: The manufacturer conducted the qualification tests at 50 °C, which is within the values of ISO 14692-2:2017, Table A.1 for GRVE (–35 °C and 65 °C).

Step 4: N/A

Step 5: The measured gradient is 0,078. This is above the value of 0,065 for GRVE at 65 °C.

Step 6: The measured gradient is 120 % of the 0,065 value in ISO 14692-2:2017, Table A.1 for GRVE at 50 °C. The manufacturer decides to use default gradients:

G_{-35} = 0,055

G_{21} = 0,055

G_{50} = 0,065

G_{65} = 0,075

Other gradients can be interpolated in between these values.

With $\sigma_{h,LT,2:1,50,measured}$ = 75 MPa, the manufacturer has defined MPR_{50} = 3,0 MPa to meet Formula (2). Since there is no other data at 21 °C, MPR_{21} = MPR_{50} = 3,0 MPa and $\sigma_{h,LT,2:1,21,measured}$ = 75 MPa.

To complete the required tests for the long-term envelope at the default temperature of 21 °C, the manufacturer conducts the $R = R_{test}$ 1 000 h survival test on a piece of pipe at 21 °C. $\sigma_{h,LT,Rtest,21}$ =

22,0 MPa and $\sigma_{a,LT,Rtest,21}$ = 28,5 MPa. R_{test} = 0,77 which is between 0,5 and 1,0, therefore the data is acceptable. The rest of the data points for the long-term envelope at 21 °C can be calculated using the formulae in ISO 14692-2:2017, Annex C.

For the long-term envelope at 65 °C, a survival test at R=2:1 should be conducted at 65 °C to determine $\sigma_{h,LT,2:1,65}$ and MPR_{65}. With this testing, the manufacturer determines $\sigma_{h,LT,2:1,65,measured}$ = 68,0 MPa. To meet Formula (2) at 65 °C, the manufacturer declares $\sigma_{h,LT,2:1,65}$ = 63,7 MPa and MPR_{65} = 2,67. Additional survival tests will need to be conducted in Step 3 to further validate the long-term envelopes.

Design temperatures above 65 °C are not allowed since there are no default gradients published for GRVE above 65 °C and the manufacturer does not have regression data above 65 °C.

With P_{des} = 1,6 MPa and $f_{3,est}$ = 0,7, A_0 = 1,0, A_2 = 1,0 and A_3 = 1,0, the estimated minimum MPR_{21} is 2,29 MPa [see Formula (3)]. The manufacturer has a standard product range with MPR_{21} = 3,0 and $\sigma_{h,LT,2:1,21}$ = 71,5 MPa as indicated in Table F.1.

Table F.1 — Manufacturer's dimensional properties and mechanical data

DN (mm)	50	80	100	150	200	250	300	350	400	450
OD (mm)	56	84	111	165	220	275	330	390	445	663
ID (mm)	50,8	76,2	101,6	152,4	203,2	254	304,8	362	412,8	615,9
T (mm)	2,6	3,9	4,7	6,3	8,4	10,5	12,6	14	16,1	23,55
t_l (mm)	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
t_s (mm)	0	0	0	0	0	0	0	0	0	0
t_r (mm)	2,1	3,4	4,2	5,8	7,9	10	12,1	13,5	15,6	23,05
$t_{r,min}$ (mm)	1,67	2,49	3,31	4,95	6,59	8,23	9,87	11,71	13,35	19,9
$t_{var\%}$	20 %	27 %	21 %	15 %	17 %	18 %	18 %	13 %	14 %	14 %
ID_r (mm)	51,8	77,2	102,6	153,4	204,2	255	305,8	363	413,8	616,9
$OD_{r,min}$ (mm)	55,14	82,18	109,22	163,3	217,38	271,46	325,54	386,42	440,5	656,7
$D_{r,min}$ (mm)	53,47	79,69	105,91	158,35	210,79	263,23	315,67	374,71	427,15	636,8
$\sigma_{h,LT,2:1,21}$ (MPa)	71,5	71,5	71,5	71,5	71,5	71,5	71,5	71,5	71,5	71,5
MPR_{21} (MPa)	3	3	3	3	3	3	3	3	3	3

The $t_{var\%}$ is included for information only [see Formula (D.6)].

The manufacturer has the option to reduce $t_{r,min}$ across the range and re-rate the pipes to an MPR_{21} of 2,29 MPa, but decides to provide the 3,0 MPa pipe for this project. This decision means that $f_{3,est}$ will be lower than the agreed 0,7 value ($f_{3,est}$ = 3,0/1,6 = 0,53).

The minimum required t_r for this project is 5 mm, so it is necessary to increase $t_{r,min}$ and OD for the DN50, DN80 and DN100 pipe sizes to suit as indicated in Table F.2.

Table F.2 — Manufacturer's dimensional properties, adjusted for project requirements

DN (mm)	50	80	100	150	200	250	300	350	400	450
OD (mm)	62	88	113	165	220	275	330	390	445	663
ID (mm)	50,8	76,2	101,6	152,4	203,2	254	304,8	362	412,8	615,9
T (mm)	5,6	5,65	5,7	6,3	8,4	10,5	12,6	14	16,1	23,55
t_l (mm)	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
t_s (mm)	0	0	0	0	0	0	0	0	0	0

