INTERNATIONAL STANDARD

ISO 14692-3

First edition
2002-12-15

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

Part 3: System design

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

Partie 3: Conception des systèmes

Reference number
ISO 14692-3:2002(E)

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Published in Switzerland

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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.

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

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

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

ISO 14692-3 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

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

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

— *Part 2: Qualification and manufacture*

— *Part 3: System design*

— *Part 4: Fabrication, installation and operation*

Introduction

The objective of this part of ISO 14692 is to ensure that piping systems, when designed using the components qualified in ISO 14692-2, will meet the specified performance requirements. These piping systems are designed for use in oil and natural gas industry processing and utility service applications. The main users of the document will be the principal, design contractors, suppliers contracted to do the design, certifying authorities and government agencies.

An explanation of the pressure terminology used in this part of ISO 14692 is given in ISO 14692-1.

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

Part 3:
System design

1 Scope

This part of ISO 14692 gives guidelines for the design of GRP piping systems. The requirements and recommendations apply to layout dimensions, hydraulic design, structural design, detailing, fire endurance, spread of fire and emissions and control of electrostatic discharge.

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

2 Normative references

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

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

ISO 14692-2:2002, *Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping — Part 2: Qualification and manufacture*

ISO 14692-4:2002, *Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping — Part 4: Fabrication, installation and operation*

BS 7159:1989 *Code of practice for design and construction of glass-reinforced plastics (GRP) piping systems for individual plants or sites*

ASTM E1118, *Standard practice for acoustic emission examination of reinforced thermosetting resin pipe (RTRP)*

3 Terms and definitions

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

4 Symbols and abbreviated terms

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

5 Layout requirements

5.1 General

GRP products are proprietary, and the choice of component sizes, fittings and material types may be limited depending on the supplier. Potential vendors should be identified early in design to determine possible limitations of component availability. The level of engineering support that can be provided by the supplier should also be a key consideration during vendor selection.

Where possible, piping systems should maximize the use of prefabricated spoolpieces to minimize the amount of site work. Overall spool dimensions should be sized taking the following into consideration:

— limitations of site transport and handling equipment;

— installation and erection limitations;

— limitations caused by the necessity to allow a fitting tolerance for installation ("cut to fit" requirements).

The designer shall evaluate system layout requirements in relation to the properties of proprietary pipe systems available from manufacturers, including but not limited to:

a) axial thermal expansion requirements;

b) ultraviolet radiation and weathering resistance requirements;

c) component dimensions;

d) jointing system requirements;

e) support requirements;

f) provision for isolation for maintenance purposes;

g) connections between modules and decks;

h) flexing during lifting of modules;

i) ease of possible future repair and tie-ins;

j) vulnerability to risk of damage during installation and service;

k) fire performance;

l) control of electrostatic charge.

The hydrotest provides the most reliable means of assessing component quality and system integrity. Whenever possible, the system should be designed to enable pressure testing to be performed on limited parts of the system as soon as installation of those parts is complete. This is to avoid a final pressure test late in the construction work of a large GRP pipe system, when problems discovered at a late stage would have a negative effect on the overall project schedule.

Further guidance about GRP piping system layout is given in Annex A.

5.2 Space requirements

The designer shall take account of the larger space envelope of some GRP components compared to steel. Guidance on fitting sizes is given in Clause 7 of ISO 14692-2:2002. GRP fittings generally have longer lay lengths and are proportionally more bulky than the equivalent metal component and may be difficult to accommodate within confined spaces. If appropriate, the problem can be reduced by fabricating the pipework as an integral spoolpiece in the factory rather than assembling it from the individual pipe fittings.

If space is limited, consideration should be given to designing the system to optimize the attributes of both GRP and metal components.

5.3 System supports

5.3.1 General

GRP piping systems can be supported using the same principles as those for metallic piping systems. However, due to the proprietary nature of piping systems, standard-size supports will not necessarily match the pipe outside diameters. The use of saddles and elastomeric pads may allow the use of standard-size supports.

The following requirements and recommendations apply to the use of system supports.

a) Supports shall be spaced to avoid sag (excessive displacement over time) and/or excessive vibration for the design life of the piping system.

b) In all cases, support design should be in accordance with the manufacturer's guidelines.

c) Where there are long runs, it is possible to use the low modulus of the material to accommodate axial expansion and eliminate the need for expansion joints, provided the system is well anchored and guided.

d) Valves or other heavy attached equipment shall be independently supported.

NOTE Valves are often equipped with heavy control mechanisms located far from the pipe centreline and can cause large bending and torsional loads.

e) GRP pipe shall not be used to support other piping, unless agreed with the principal.

f) GRP piping should be adequately supported to ensure that the attachment of hoses at locations such as utility or loading stations does not result in the pipe being pulled in a manner that could overstress the material.

g) Consideration shall be given to the possible design requirements of the support to provide electrical earthing in accordance with the requirements of 5.8 and clause 10.

Pipe supports can be categorized into those that permit movement and those that anchor the pipe.

5.3.2 Pipe-support contact surface

5.3.2.1 Guidelines

The following guidelines to GRP piping support should be followed.

a) Supports in all cases should have sufficient width to support the piping without causing damage and should be lined with an elastomer or other suitable soft material. The minimum saddle width, in millimetres, should be $\sqrt{30D}$, where D is the mean diameter of the pipe, in millimetres.

b) Clamping forces, where applied, should be such that crushing of the pipe does not occur. Local crushing can result from a poor fit and all-round crushing can result from over-tightening.

c) Supports should be preferably located on plain-pipe sections rather than at fittings or joints.

d) Consideration shall be given to the support conditions of fire-protected GRP piping. Supports placed on the outside of fire protection could result in loads irregularly transmitted through the coating, which could result in shear/crushing damage and consequent loss of support integrity.

5.3.2.2 Supports permitting pipe movement

Pipe resting in fixed supports that permit pipe movement shall have abrasion protection in the form of saddles, elastomeric materials or sheet metal.

5.3.2.3 Supports anchoring pipe

The anchor support shall be capable of transferring the required axial loads to the pipe without causing overstress of the GRP pipe material. Anchor clamps are recommended to be placed between two double 180° saddles, adhesive-bonded to the outer surface of the pipe. The manufacturer's standard saddles are recommended and shall be bonded using standard procedures.

5.3.3 Support and guide spacing

The spanning capability of GRP piping spans is generally less than that for steel pipe, due to the lower modulus of the material. Supports shall be spaced to avoid sag (excessive displacement over time) and/or excessive vibration for the design life of the piping system.

GRP pipes, when filled with water, should be capable of spanning at least the distances specified in Table 1 while meeting the deflection criterion of 0,5 % of span or 12,5 mm centre, whichever is smaller. Spans are assumed to be simply supported. In some cases, bending stresses or support contact stresses may become a limiting factor (see 8.6), and the support spacing may have to be reduced.

Table 1 — Guidance to span lengths (simply supported)

Pipe nominal diameter mm	Span m
25	2,0
40	2,4
50	2,6
80	2,9
100	3,1
150	3,5
200	3,7
250	4,0
300	4,2
350	4,8
400	4,8
450	4,8
500	5,5
600 ⩾	6,0

Larger spans are possible, and the designer should verify that stresses are within allowable limits according to 8.6. The designer shall take into consideration the effect of buckling (8.7). The effect of temperature on the axial modulus of the GRP material shall also be considered.

5.4 Isolation and access for cleaning

The designer should make provision for isolation and easy access for maintenance purposes, for example for removal of scale and blockages in drains. The joint to be used for isolation or access should be shown at the design stage and should be located in a position where the flanges can in practice be jacked apart, e.g. it should not be in a short run of pipe between two anchors.

5.5 Vulnerability

5.5.1 Point loads

Point loads should be minimized and the GRP piping locally reinforced where necessary.

5.5.2 Abuse

The designer should give consideration to the risk of abuse to GRP piping during installation and service and the need for permanent impact shielding.

Sources of possible abuse include:

a) any area where the piping can be stepped on or used for personnel support;

b) impact from dropped objects;

c) any area where piping can be damaged by adjacent crane activity, e.g. booms, loads, cables, ropes or chains;

d) weld splatter from nearby or overhead welding activities.

Small pipe branches (e.g. instrument and venting lines), which are susceptible to shear damage, should be designed with reinforcing gussets to reduce vulnerability. Impact shielding, if required, should be designed to protect the piping together with any fire-protective coating.

NOTE Further guidance on the design of gussets can be found in BS 4994 [1].

5.5.3 Dynamic excitation and interaction with adjacent equipment and piping

The designer should give consideration to the relative movement of fittings, which could cause the GRP piping to become overstressed. Where required, consideration shall be given to the use of flexible fittings.

The designer should ensure that vibration due to the different dynamic response of GRP (as compared with carbon steel piping systems) does not cause wear at supports or overstress in branch lines. The designer should ensure that the GRP piping is adequately supported to resist shock loads that may be caused by transient pressure pulses, e.g. operation of pressure safety valves, valve closure etc.

5.5.4 Effect of external environment

5.5.4.1 Exposure to light and ultraviolet radiation (UV)

Where GRP pipe is exposed to the sun, the designer should consider whether additional UV protection is required to prevent surface degradation of the resin. If the GRP is a translucent material, the designer should consider the need to paint the outside to prevent possible algae growth in slow-moving water within the pipe.

5.5.4.2 Low temperatures and requirements for insulation

The designer shall consider the effects of low temperatures on the properties of the pipe material, for example the effect of freeze/thaw. For liquid service, the designer should pay particular attention to the freezing point of the internal liquid. For completely filled lines, solidification of the internal fluid may cause an expansion of the liquid volume, which could cause the GRP pipe to crack or fail. For water service, the volumetric expansion during solidification or freezing is more than sufficient to cause the GRP pipe to fail.

The pipe may require to be insulated and//or fitted with electrical surface heating to prevent freezing in cold weather or to maintain the flow of viscous fluids. The designer shall give consideration to:

a) additional loading due to mass and increased cross-sectional area of the insulation;

b) ensuring that electrical surface heating does not raise the pipe temperature above its rated temperature.

Heat tracing should be spirally wound onto GRP pipe in order to distribute the heat evenly round the pipe wall. Heat distribution can be improved if aluminium foil is first wrapped around the pipe.

5.6 Joint selection

5.6.1 General

Various types of bonded and mechanical joints are available. These tend to be proprietary in nature but can generally be categorized into the following types:

— adhesive-bonded joints;

— laminated joints;

— elastomeric bell-and-spigot sealed joints (with/without locks);

— flanged joints;

— threaded joints;

— metallic/GRP interfaces;

— other mechanical joints.

A description and further guidance about the use of these joint types is given in Annex B. The designer should take into account the following factors when selecting the jointing method:

a) criticality;

b) reliability;

c) ease of joint assembly;

d) ease of repair, and future modifications and tie-ins.

5.6.2 Criticality and reliability

The designer should give consideration to the requirements for evaluating the performance of the joint during service.

The selection of the joint shall take into account the environmental conditions likely to be present during assembly, e.g. temperature and humidity.

The selection of the joint should take into account the presence of significant axial and in-plane axial bending stresses, which are more likely to expose the weakness of poorly made up joints than pressure alone.

The selection of joint shall take into account possible movement of the pipe caused by flexing of the hull, in the case of a floating offshore installation or flexing of the module during lifting operations.

5.6.3 Ease of joint assembly

The designer should give consideration to ensure the layout enables a site joint to be assembled to the correct dimensions and without the need to pull the joint into position such that the material is subject to overstress.

The selection of site joint should take into account the ease of access required by fitters to assemble the connection correctly. Site joints should be located in accessible locations away from supports and fittings.

The designer should give consideration to the preferred location of the last site joint in a piping loop to ensure the necessary access is available since this joint is often the most difficult to complete.

5.6.4 Ease of repair and access for future modifications and tie-ins

If bell-and-spigot joints are used in locations where future modifications are likely, the designer should consider the need for axial displacement of the pipe to enable the joints to be opened without the need to cut the pipe.

5.6.5 Metallic/GRP interfaces

Interfaces with metallic tanks, vessels, equipment or piping shall be by flanged (i.e. mechanical) connection.

In order to achieve reliable flange sealing, even with relatively low bolt-tensioning, steel-ring-reinforced elastomer gaskets should be used. Only soft type elastomers should be used, preferably with a hardness within the range Shore A 55 to A 75. The gasket material shall match the pressure, temperature and chemical resistance capabilities of the piping system. In general, PTFE envelope-type gaskets are not recommended and should not be used for pipes of large diameters (> 600 mm) and at high pressures (> 3,2 MPa).

The making of connections by other means, e.g. overwrapping of metallic pipe ends with GRP, is not acceptable unless qualified in accordance with 6.2.3.2 in ISO 14692-2:2002.

5.7 Fire and blast

5.7.1 General

The effect of a fire event (including blast) on the layout requirements should be considered. The possible events to be considered in the layout design of a GRP piping system intended to function in a fire include:

a) blast;

b) fire protection of joints and supports;

c) interface with metal fixtures;

d) formation of steam traps;

e) jet fire;

f) heat release and spread of fire;

g) smoke emission, visibility and toxicity.

The methodology for assessing fire performance is given in Clause 9.

5.7.2 Blast

If components may be exposed to explosion hazards, the effect of blast overpressure, drag forces and projectile impacts should be considered (see 7.6.1), including the possible effect on support spacing.

5.7.3 Steam traps

Consideration should be given to the possibility of steam traps forming in pipe containing stagnant water, which would reduce the conduction of heat away by water.

5.7.4 Jet fires

Jet fires pose a significant threat to all types of piping systems because of the very high heat flux and erosive conditions that they produce. Whilst GRP pipe systems can be designed to withstand jet fires for a required period, the layout should be designed, if possible, to route piping away from areas which could be exposed to direct impingement by a jet fire.

5.7.5 Heat release and spread of fire

Consideration should be given to the contribution to the fire inventory and the risk of surface spread of flame to other areas, particularly if the pipes are empty and/or are no longer in service. The designer should consider the effect of the orientation of the piping and the possibility of thermal feedback from nearby reflective surfaces on the fire performance of the pipe.

5.7.6 Smoke emission, visibility and toxicity

Performance criteria for smoke and toxic emissions are primarily applied to the use of GRP piping in confined spaces, escape routes or areas with limited ventilation and where personnel are at risk. Consideration should be given to the risk of the spread of smoke and toxic emissions to other areas, particularly if the pipes are empty and/or are no longer in service.

5.7.7 Penetrations

Penetrations (wall, bulkhead, deck) shall not weaken the division that they penetrate. The main requirements are to prevent passage of smoke and flames, to maintain structural integrity and to limit the temperature rise on the unexposed side. Penetrations shall therefore comply with the same requirements that apply to the relevant hazardous divisions. This requires the penetration to have been fire-tested and approved for use with the specific type of GRP pipework under consideration.

5.8 Control of electrostatic discharge

GRP piping and associated systems may be required to be electrically conductive/electrostatic dissipative and earthed, depending on service and location.

The location of the pipe determines the magnitude of external electrostatic charge-generation mechanisms to which the pipe may be exposed, and determines the consequences of an incendive discharge. For example, the effect of changing atmospheric electrical fields is mitigated by the shielding provided by metal walkways and decks located above the pipe.

In hazardous areas, the designer should be aware of the proximity of process pipe and other sources of high-pressure gas effluxes that may provide a strong external electrostatic-generation mechanism. The designer should also be aware of other potential sources of electrostatic-generation mechanisms, such as tribocharging and the presence of charged mists and soots produced in tank cleaning operations. In such locations and where practicable, the designer shall minimize the presence of unearthed metal objects attached to the pipe and take into account the proximity of nearby earthed metal objects when considering the risk analysis, see 10.1.

Further guidance for assessing the requirements for control of electrostatic discharge is given in Clause 10 and Annex G.

5.9 Galvanic corrosion

Galvanic corrosion is unlikely to be a concern at the interface of metal and GRP piping components if the GRP component incorporates small quantities of carbon fibre to provide electrical conductivity. This is because the exposed area of the carbon fibre (the cathode) is likely to be small compared to the adjacent metal component. The converse of a high cathode to anode ratio is usually needed to give rise to rapid corrosion.

However, if GRP components incorporate significant quantities of carbon or other cathodic material, e.g. for additional strengthening purposes, then precautions may be required to electrically isolate the carbon fibre at the interface with the metal component. Under such circumstances, the use of an impressed current from a cathodic protection system is not recommended.

6 Hydraulic design

6.1 General

The aim of hydraulic design is to ensure that GRP piping systems are capable of transporting the specified fluid at the specified rate, pressure and temperature throughout their intended service life. The selection of nominal pipe diameter depends on the internal diameter required to attain the necessary fluid flow consistent with the fluid and hydraulic characteristics of the system.

6.2 Flow characteristics

Fluid velocity, density of fluid, interior surface roughness of pipes and fittings, length of pipes, inside diameter of pipes, as well as resistance from valves and fittings shall be taken into account when estimating pressure losses. Guidance for the calculation of pressure losses is given in ISO 13703[2]. The smooth surface of the GRP may result in lower pressure losses compared to metal pipe. Conversely the presence of excessive protruding adhesive beads will increase pressure losses.

6.3 General velocity limitations

Concerns that limit velocities in piping systems include:

a) unacceptable pressure losses;

b) prevention of cavitation at pumps and valves;

c) prevention of transient overloads (water hammer);

d) reduction of erosion;

e) reduction of noise;

f) reduction of wear in components such as valves;

g) pipe diameter and geometry (inertia loading).

The designer shall take into account these concerns when selecting the flow velocity for the GRP piping system. For typical GRP installations, the mean linear velocity for continuous service of liquids is between 1 m/s and 5 m/s with intermittent excursions up to 10 m/s. For gas, the mean linear velocity for continuous service is between 1 m/s and 10 m/s with intermittent excursions up to 20 m/s. Higher velocities are acceptable if factors that limit velocities are eliminated or controlled, e.g. vent systems that discharge into the atmosphere.