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**Petroleum, petrochemical and natural  
gas industries — Composite repairs  
for pipework — Qualification and  
design, installation, testing and  
inspection**

*Industries du pétrole, de la pétrochimie et du gaz naturel —  
Réparations en matériau composite pour canalisations — Conformité  
aux exigences de performance et conception, installation, essai et  
inspection*

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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](http://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](http://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](http://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 24817:2015), which has been technically revised.

## Introduction

The objective of this document is to ensure that pipework, pipelines, tanks and vessels repaired using composite systems that are qualified, designed, installed and inspected using this document will meet the specified performance requirements. Repair systems are designed for use within the petroleum, petrochemical and natural gas industries, and also within utility service applications. The main users of this document will be plant and equipment owners of the pipework and vessels, design contractors, suppliers contracted to provide the repair system, certifying authorities, installation, maintenance and inspection contractors.

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# Petroleum, petrochemical and natural gas industries — Composite repairs for pipework — Qualification and design, installation, testing and inspection

## 1 Scope

This document gives requirements and recommendations for the qualification and design, installation, testing and inspection for the external application of composite repair systems to corroded or damaged pipework, pipelines, tanks and vessels used in the petroleum, petrochemical and natural gas industries.

## 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 75-3, *Plastics — Determination of temperature of deflection under load — Part 3: High-strength thermosetting laminates and long-fibre-reinforced plastics*

ISO 527-1, *Plastics — Determination of tensile properties — Part 1: General principles*

ISO 527-4, *Plastics — Determination of tensile properties — Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites*

ISO 868, *Plastics and ebonite — Determination of indentation hardness by means of a durometer (Shore hardness)*

ISO 10952, *Plastics piping systems — Glass-reinforced thermosetting plastics (GRP) pipes and fittings — Determination of the resistance to chemical attack for the inside of a section in a deflected condition*

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

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

ISO 14692, *Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping*

ASTM C581, *Standard Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Reinforced Structures Intended for Liquid Service*

ASTM D543, *Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents*

ASTM D696, *Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between Minus 30°C and 30°C with a Vitreous Silica Dilatometer*

ASTM D1598, *Standard Test Method for Time-to-Failure of Plastic Pipe under Constant Internal Pressure*

ASTM D1599, *Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings*

ASTM D2583, *Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor*

ASTM D2992, *Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings*

ASTM D3039, *Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials*

ASTM D3165, *Standard Test Method for Strength Properties of Adhesives in Shear by Tension Loading of Single-Lap-Joint Laminated Assemblies*

ASTM D3681, *Standard Test Method for Chemical Resistance of Fiberglass (Glass-Fiber-Reinforced Thermosetting Resin) Pipe in a Deflected Condition*

ASTM D5379, *Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method*

ASTM D6604, *Standard Practice for Glass Transition Temperatures of Hydrocarbon Resins by Differential Scanning Calorimetry*

ASTM E831, *Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis*

ASTM E1640, *Standard Test Method for Assignment of the Glass Transition Temperature by Dynamic Mechanical Analysis*

ASTM E2092, *Standard Test Method for Distortion Temperature in Three-Point Bending by Thermomechanical Analysis*

ASTM G8, *Standard Test Methods for Cathodic Disbonding of Pipeline Coatings*

BS 7910, *Guide to methods for assessing the acceptability of flaws in metallic structures*

EN 59, *Methods of testing plastics — Glass reinforced plastics — Measurement of hardness by means of a Barcol impressor (BS 2782-10, Method 1001, Measurement of hardness by means of a Barcol impressor)*

EN 1465, *Adhesives — Determination of tensile lap shear strength of rigid-to-rigid bonded assemblies*

### 3 Terms and definitions

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 anisotropic**  
exhibiting different physical properties in different directions

**3.2 Barcol hardness**  
measure of surface hardness using a surface impresser

**3.3 blister**  
air void between layers within the laminate visible on the surface as a raised area

**3.4 composite**  
thermoset resin system that is reinforced by fibres

**3.5 crack**  
split in the laminate extending through the wall (perpendicular to the surface) such that there is actual separation with opposite surfaces visible



**3.6****cure  
curing**

setting of a thermosetting resin system, such as polyester or epoxy, by an irreversible chemical reaction

**3.7****cure schedule**

time-temperature profile qualified to generate a specified  $T_g$  or HDT

**3.8****defect type A**

defect within the substrate, not through-wall and not expected to become through-wall within the repair design lifetime of the repair system

**3.9****defect type B**

through-wall defect or a defect within the substrate where at the end of service life the remaining wall thickness is less than 1 mm

**3.10****defined lifetime**

actual application or service lifetime of the repair

**3.11****delamination**

area between the repair laminate and the substrate which should be bonded together but where no bond exists, or an area of separation between layers in the repair laminate

**3.12****design lifetime**

maximum application lifetime of the repair

**3.13****differential scanning calorimetry****DSC**

method of determining the glass transition temperature of a thermosetting resin

**3.14****dry spot or un-impregnated/dry fibre**

area of fibre not impregnated with resin, with bare, exposed fibre visible

**3.15****engineered repair**

repair which has been designed and applied under a specified, controlled process so that under the design conditions, there is a high degree of confidence that the repair will maintain its integrity over the design lifetime

**3.16****exposed fibre**

area of fibre not impregnated with resin that projects from the body of the repair

**3.17****foreign matter**

any substance other than the reinforcing fibre or other materials that form part of the repair system

**3.18****finishing materials**

final layer of material to help compact the repair laminate, typically a polymeric film or a fabric

Note 1 to entry: They should be fully removed after the repair has hardened and before the repair is inspected or painted.

**3.19**

**glass transition temperature**

temperature at which a resin undergoes a marked change in physical properties

**3.20**

**hardener**

component added to a thermosetting resin to effect cure

**3.21**

**heat distortion temperature**

**HDT**

temperature at which a standard test bar deflects by a specified amount under a given load

**3.22**

**installer**

person who is qualified to apply a composite repair system

**3.23**

**filler material**

material used to repair external surface imperfections prior to the application of the composite laminate

**3.24**

**laminate**

**repair laminate**

part of a repair system that is the composite

Note 1 to entry: Most composites considered in this document are composed of discrete lamina or layers which are wrapped or stacked, one on top of the other. This stacked construction is the laminate.

**3.25**

**layer**

individual layer or wrap within the composite laminate

**3.26**

**leak**

condition of a substrate wall that can allow the contents to make contact with and act directly upon the (composite) repair laminate

Note 1 to entry: This does not refer to a fluid leaking through a hole or breach in the substrate.

**3.27**

**occasional load**

load that occurs rarely and during a short time

Note 1 to entry: Occasional loads typically occur less than 10 times in the life of the component and each load duration is less than 30 min.

**3.28**

**owner**

organization that owns or operates the substrate to be repaired

**3.29**

**pin hole**

pin-prick hole in the resin rich surface, not extending into the laminate

**3.30**

**pipeline**

pipe with components subject to the same design conditions used to transport fluids between plants

Note 1 to entry: Components include bends, flanges and valves.

**3.31****pipework**

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

**3.32****piping****piping system**

assemblies of piping components used to convey fluids within a plant

Note 1 to entry: Components include pipe, fittings, flanges, gaskets, bolting and valves. A piping system is often above ground but sometimes buried.

**3.33****pit**

depression in the surface of the laminate

**3.34****ply**

single wrap or layer (lamina) of a repair laminate

**3.35****post cure**

additional elevated-temperature cure applied after resin has hardened to ensure the required glass transition temperature is achieved

**3.36****qualification application procedure**

application procedure used to apply the repair system for the qualification tests

**3.37****qualification test temperature**

test temperature at which qualification testing of the repair system is performed

**3.38****reinforcement**

fibre embedded in the resin system

Note 1 to entry: Possible fibre materials include aramid, carbon, glass, polyester, or similar materials. Reinforcement results in mechanical properties superior to those of the base resin.

**3.39****repair system**

system comprised of the substrate, composite material (repair laminate), filler material, adhesive and including surface preparation and installation methods, used for repair of pipework

**3.40****repair system installer**

company that installs the repair system

**3.41****repair system supplier**

company that designs and supplies the repair system

**3.42****resin system**

all of the components that make up the matrix portion of a composite

Note 1 to entry: Often this includes a resin, filler(s), pigment, mechanical property modifiers and catalyst or hardener.

**3.43**

**risk**

event encompassing what can happen (scenario), its likelihood (probability) and its level or degree of damage (consequences)

**3.44**

**substrate**

surface on which a repair is carried out

Note 1 to entry: The surface may belong to original pipework, pipework component, pipeline, tank, or vessel.

**3.45**

**supervisor**

experienced installer who is qualified by successfully completing the supervisor training course

**3.46**

**Shore hardness**

measure of surface hardness using a surface impresser or durometer

**3.47**

**thermoset resin system**

resin system that cannot be melted or remoulded following polymerization

**3.48**

**wrinkle**

wavy surface or distinct ridge in the laminate where the reinforcing fabric has creased during application

**4 Symbols and abbreviated terms**

**4.1 Symbols**

$\alpha_s$	thermal expansion coefficient of substrate
$\alpha_c$	thermal expansion coefficient of the repair laminate for either the axial or circumferential directions
$c$	crack length
$D$	original external diameter
$D_b$	original external branch, tee, nozzle diameter
$d$	diameter (or diameter of the equivalent circle) of the through-wall defect
$\Delta T$	difference between operation and installation temperatures
$E_c$	tensile modulus of the composite laminate in the circumferential direction
$E_a$	tensile modulus of the composite laminate in axial direction
$E_{ac}$	combined tensile modulus $\sqrt{E_a E_c}$
$E_s$	tensile modulus of substrate
$\epsilon_c$	circumferential design strain
$\epsilon_{c0}$	allowable circumferential strain

$\varepsilon_a$	axial design strain
$\varepsilon_{a0}$	allowable axial strain
$\sigma_{lt}$	lower confidence limit of the long-term strain determined by performance testing
$\varepsilon_t$	thermal strain
$\varepsilon_{short}$	short-term failure strain of the composite laminate
$F_{ax}$	applied axial load
$F_{eq}$	equivalent axial load
$F_{sh}$	applied shear load
$f_c$	service factor for cyclic fatigue
$f_D$	degradation factor for the long-term performance of repairs to through-wall defects
$f_{leak}$	service factor for repairs to through-wall defects
$f_{perf}$	service factor for performance data
$f_{th,overlay}$	repair thickness increase factor for reduced available overlap length
$f_{th,stress}$	repair thickness increase factor for piping system or vessel component
$f_{T1}$	temperature de-rating factor for composite laminate allowable strains
$f_{T2}$	temperature de-rating factor for through-wall defect repair design
$\phi$	angle subtended by axial slot
$G$	shear modulus of the composite laminate $\gamma$ toughness parameter (energy release rate) for the composite laminate, steel interface
$\gamma_{soilg}$	specific weight of soil
$h$	burial depth
$I$	second moment of area
$l$	total axial length of repair
$l_{available}$	available landing area (axial extent) of undamaged substrate
$l_{over}$	axial extent of design thickness of repair
$l_{defect}$	axial length of defect
$l_{taper}$	axial length of taper
$N$	number of cycles
$M_{ax}$	applied axial moment
$M_{to}$	applied torsional moment
$n$	number of wraps or layers or repair laminate
$p$	required design internal pressure