

Second edition
2017-08

Corrected version
2018-01

**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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Reference number
ISO 24817:2017(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).

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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 24817:2015), which has been technically revised.

This corrected version of ISO 24817:2017 incorporates the following correction:

- in [7.5.7, Formula \(15\)](#), “D4” has been replaced by “D⁴”.

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*

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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*

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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

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4 Symbols and abbreviated terms

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4.1 Symbols

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α_s	thermal expansion coefficient of substrate
α_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
ΔT	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
ε_c	circumferential design strain
ε_{c0}	allowable circumferential strain

ε_a	axial design strain
ε_{a0}	allowable axial strain
σ_{lt}	lower confidence limit of the long-term strain determined by performance testing
ε_t	thermal strain
ε_{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
ϕ	angle subtended by axial slot
G	shear modulus of the composite laminate γ toughness parameter (energy release rate) for the composite laminate, steel interface
γ_{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

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p_{after}	internal pressure after repair system is applied
p_e	external design pressure
p_{eq}	equivalent design pressure
$p_{\text{ext,soil}}$	external soil pressure
p_{live}	internal pressure within the substrate during application of the repair
p_{min}	minimum (internal pressure) load (or stress) of the load cycle
p_{max}	maximum (internal pressure) load (or stress) of the load cycle
p_{mthp}	medium-term hydrostatic test pressure
p_s	maximum allowable working pressure (MAWP)
p_{sthp}	short-term hydrostatic test pressure
p_0	initial test pressure
p_1	fixed linear increase in test pressure
q	tensile stress
R_c	cyclic loading severity, defined as: $R_c = \frac{p_{\text{min}}}{p_{\text{max}}}$
s	allowable stress of the substrate material
s_a	measured yield stress of substrate or mill certification yield stress
T_d	required design temperature
T_g	glass transition temperature
T_m	maximum operating temperature of repair system
T_{amb}	ambient (qualification) test temperature
T_{test}	qualification test temperature
t	original wall thickness of substrate
t_{lifetime}	repair design lifetime
t_{layer}	thickness of an individual wrap or layer of repair laminate
t_b	wall thickness of branch, tee
t_f	wall thickness of flange
t_{design}	design thickness of repair laminate
t_{min}	minimum thickness of repair laminate
t_s	minimum remaining substrate wall thickness

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τ	lap shear strength
ν	Poisson's ratio for the repair laminate
w	(axial) width of circumferential slot defect

4.2 Abbreviated terms

ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
API	American Petroleum Institute
AWWA	American Water Works Association
BS (BSI)	British Standards Institute
CFRP	carbon fibre-reinforced plastic
COSHH	regulations for control of substances hazardous to health
CSWIP	certification scheme for welding inspection personnel
DSC	differential scanning calorimetry
FRP	fibre-reinforced plastic
GRP	glass-reinforced plastic
HDT	heat distortion temperature
MAWP	maximum allowable working pressure
MSDS	materials safety data sheets
NDT	non-destructive testing
OSHA	Occupational Safety and Health Act
PCC	Post-Construction Committee
SMYS	specified minimum yield strength

5 Applications

The qualification and design, installation, testing and inspection procedures for composite repair systems in this document cover situations involving the repair of damage commonly encountered in oil, gas, utility pipework systems and vessels. The procedures are also applicable to the repair of pipelines, caissons and storage tanks with appropriate consideration.

Procedures in this document cover the repair of metallic and GRP pipework, pipework components, pipelines originally designed in accordance with a variety of standards, including ISO 15649, ISO 13623, ISO 14692, ASME B31.1, ASME B31.3, ASME B31.4, ASME B31.8 and BS 8010.

This document is not a defect assessment standard. Within this document, no statements are made regarding whether a specific defect is acceptable or unacceptable for repair. The document assumes that a defect assessment has already been performed to, for example ASME B31G or API RP 579. The starting point for this document is that a decision has been taken to repair a given defect with a composite repair system and the output from the defect assessment, e.g. MAWP or minimum remaining