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Third edition
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Oil and gas industries including lower carbon energy — Composite repairs for piping — Qualification and design, installation, testing and integrity management

Industries du petrole et du gaz, y compris les énergies à faible teneur en carbone — Reparations en materiau composite pour tuyauterie — Conformite aux exigences de performance et conception, installation, essai et gestion de l'intégrité

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Foreword

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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 document 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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This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, Subcommittee SC 6, *Process equipment, piping, systems, and related safety,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 12, *Oil and gas industries including lower carbon energy,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 24817:2017), which has been technically revised.

The main changes are as follows:

— Clause 7 has been split into three separate Clauses: 7 (Qualification), 8 (Repair feasibility assessment) and 9 (Design methodology) to enable clear referencing;

— in Clause 9, the individual design stages have been reorganised so that they are now presented in the sequence they are used to make it easier to follow and review;

— where multiple options for design are presented, clarification has been added to guide on when each should be selected;

— design lifetimes of up to 50 years can now be considered and the guidance on managing them in service has been reinforced;

— requirements for considering temperature effects have been clarified;

— assessment of cyclic loading has been updated to maintain equivalence with guidance in ISO 14692;

— Poisson’s effects have been reviewed and updated;

— Type A design formulae have been re-arranged so that they can be calculated rather than some requiring iteration;

— considerations of installing repairs on live lines (under pressure) have been revised;

— guidance on using composite materials to reinforce defects such as crack-like-flaws has been added;

— the test method for determining the value of design strain specified in Annex E has been revised to remove the influence of the substrate in testing;

— units for variables has been standardised throughout. The main change is for the value of energy release rate, γ_{LCL}, which will now be in N mm rather than J m^{-2};

— Annex I has been added to provide guidance on how to assess requirements for applying repairs to Type B defects.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The objective of this document is to ensure that piping, pipelines, tanks and vessels repaired using composite systems that are qualified, designed, installed and managed using this document meet the specified performance requirements. The main users of this document are plant and equipment owners, design contractors, suppliers contracted to provide the repair system, certifying authorities, installation, maintenance and inspection contractors.

Oil and gas industries including lower carbon energy — Composite repairs for piping — Qualification and design, installation, testing and integrity management

1 Scope

This document specifies requirements and gives recommendations for the qualification and design, installation, testing and integrity management for the external application of composite repair systems to corroded or damaged piping and pipelines, tanks and vessels.

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 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics*

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 8501 (all parts), *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness*

ISO 10952, *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 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 D638, *Standard Test Method for Tensile Properties of Plastics*

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*

EN 59, *Glass reinforced plastics — Determination of indentation hardness by means of a Barcol hardness tester*

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 terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
Barcol hardness
measure of surface hardness using a surface impresser

3.2
blister
air void between *layers* (3.23) within the *laminate* (3.4) visible on the surface as a raised area

3.3
composite
thermoset resin system (3.49) that is reinforced by fibres

3.4
composite laminate
laminate
repair laminate
part of a *repair system* (3.39) that is the *composite* (3.3)

Note 1 to entry: Most composites considered in this document are composed of discrete lamina or *layers* (3.23) which are wrapped or stacked, one on top of the other. This stacked construction is the laminate.

3.5
crack
split in the *composite laminate* (3.4) extending perpendicular to the surface such that there is actual separation with opposite surfaces

3.6
cure
setting of a *thermoset resin system* (3.49), such as polyester or epoxy, by an irreversible chemical reaction

3.7
cure schedule
time-temperature profile qualified to generate a specified *glass transition temperature* (3.17), T_g, or *heat distortion temperature (HDT)* (3.19)

3.8
delamination
area of separation between *layers* (3.23) in the *composite laminate* (3.4)

3.9
design lifetime
period of time used in the design calculations that is typically the maximum period for which the repair is expected to be required

Note 1 to entry: The design lifetime shall not be interpreted as the achievable *service life* (3.44) of the repaired system.

3.10
design temperature
maximum temperature for which the repair is designed (the highest temperature the component to be repaired is expected to experience in service)

3.11
differential scanning calorimetry
DSC
method of determining the *glass transition temperature* (3.17) of a thermosetting resin

3.12
disbond
interfacial delamination
area between the *composite laminate* (3.4) and the *substrate* (3.46) which should be bonded but where no bond exists

3.13
exposed fibre
area of fibre not impregnated with resin that projects from the body of the repair

3.14
filler material
material used to repair external surface imperfections prior to the application of the *composite laminate* (3.4)

3.15
foreign matter
any substance other than the reinforcing fibre or other materials that form part of the *repair system* (3.39)

3.16
finishing materials
final layer of material to help compact the *composite laminate* (3.4), 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.

3.17
glass transition temperature
temperature at which a resin undergoes a marked change in physical properties

3.18
hardener
component added to a thermosetting resin to effect *cure* (3.6)

3.19
heat distortion temperature
HDT
temperature at which a standard test bar deflects by a specified amount under a given load

3.20
inspection authority
entity responsible for verifying the repair complies with the requirements

3.21
installer
person who is qualified to apply a *repair system* (3.39)

3.22
installation temperature
expected *substrate* (3.46) (component) surface temperature at the time of repair installation

3.23
layer
single, individual lamina of the *composite laminate* (3.4)

3.24
leak
perforation in the *substrate* (3.46) with loss of containment

3.25
material group
substrate family
class of metallurgical alloys or materials whose members have similar chemical compositions

EXAMPLE Cast irons, carbon steels, austenitic stainless steels, glass reinforced epoxy resin (GRE), glass reinforced vinyl ester (GRVE) and glass reinforced unsaturated polyester (GRuP).

3.26
maximum initial service life
minimum of the *design lifetime* (3.9) or 20 years

Note 1 to entry: See Table 5.

3.27
maximum design lifetime
maximum value that may be selected for the *design lifetime* (3.9)

Note 1 to entry: See Table 5.

3.28
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.

3.29
operating temperature
temperature at which the repair is expected to operate

3.30
owner
organization that owns or operates the component to be repaired

3.31
pin hole
pin-prick hole in the resin rich surface, not extending into the *laminate* (3.4)

3.32
pipeline
pipe with components subject to the same design conditions used to transport fluids between plants

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

3.33
piping
piping system
pipework
assemblies of components used to convey fluids within a plant

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

3.34
pit
depression in the surface of the *composite laminate* (3.4)

3.35
post cure
additional elevated-temperature *cure* (3.6) applied after resin has hardened to ensure the required *glass transition temperature* (3.17) is achieved

3.36
qualified application procedure
application procedure used for the qualification tests and subsequently used to install repairs

3.37
qualification test temperature
temperature at which qualification testing of the *repair system* (3.39) is performed

3.38
reinforcement
fibre embedded in the *resin system* (3.42)

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* (3.46), *composite laminate* (3.4), *filler material* (3.14), adhesive and including surface preparation and installation methods

3.40
repair system installer
company that installs the *repair system* (3.39)

3.41
repair system supplier
company that designs and supplies the *repair system* (3.39)

3.42
resin system
all of the components that make up the matrix portion of a *composite* (3.3)

Note 1 to entry: Often this includes a resin, filler(s), pigment, mechanical property modifiers and catalyst or *hardener* (3.18).

3.43
risk
event encompassing what can happen (scenario), its likelihood (probability) and its level or degree of damage (consequences)

3.44
service life
defined lifetime
period of time for which the repair is intended to be retained in service by the *owner* (3.30)

Note 1 to entry: This shall not exceed the *design lifetime* (3.9). An appropriate maintenance strategy shall be specified and implemented to realize the required service life, see 11.5.

3.45
stop gap
temporary solutions applied to stop live *leaks* (3.24) and so enable a *composite* (3.3) repair to be installed

Note 1 to entry: Stop gaps do not restore the integrity of the component and have expected service lives in the order of days to weeks.

3.46
substrate
surface to which a repair is applied

3.47
supervisor
experienced *installer* (3.21) who is qualified by successfully completing a relevant training course

3.48
Shore hardness
measure of surface hardness using a surface impresser or durometer

3.49
thermoset resin system
resin system (3.42) that cannot be melted or remoulded following polymerization

3.50
Type A defect
defect within the *substrate* (3.46) where, at the end of *design lifetime* (3.9), the remaining wall thickness will be ≥ 1 mm

Note 1 to entry: See 6.4.2.

3.51
Type B defect
through-wall defect or defect within the *substrate* (3.46) where, at the end of *design lifetime* (3.9), the remaining wall thickness will be < 1 mm

Note 1 to entry: See 6.4.2.

3.52
un-impregnated fibre
area of fibre not impregnated with resin, with bare, *exposed fibre* (3.13) visible

3.53
wrinkle
wavy surface or distinct ridge in the composite *laminate* (3.4) where the reinforcing fabric has creased during application

4 Symbols and abbreviated terms

4.1 Symbols

A	pressurised cross-sectional area as specified in Formula (9)	mm^2
α_s	thermal expansion coefficient of substrate	°C^{-1}
α_a	thermal expansion coefficient of the composite laminate in the axial direction	°C^{-1}
α_c	thermal expansion coefficient of the composite laminate in the circumferential direction	°C^{-1}
B	dimensionless regression gradient in G.3	-
D	original external diameter	mm
D_b	original external branch or nozzle diameter	mm
d	defect diameter (or diameter of the equivalent circle)	mm
d_{peak}	peak wall loss due to corrosion in pipeline defect, equal to $t - t_s$	mm
$\Delta\alpha$	the difference in thermal coefficients of the substrate and repair as specified in Formula (40)	°C^{-1}
$\Delta\varepsilon_{th}$	differential thermal strain as specified in Formula (39)	-
ΔT	difference between design and installation temperatures (T-$T_{install}$)	°C
E_c	tensile modulus of the composite laminate in the circumferential direction	MPa
E_a	tensile modulus of the composite laminate in the axial direction	MPa
E_{ac}	combined tensile modulus $\sqrt{E_a E_c}$	MPa
E_s	tensile modulus of the substrate	MPa
ε_c	design circumferential strain	-
ε_{c0}	default allowable circumferential strain, as specified in Table 7	-
ε_a	design axial strain	-