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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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

This first edition cancels and replaces ISO/TS 24817:2006, which has been technically revised.

Introduction

The objective of this International Standard is to ensure that pipework, pipelines, tanks, and vessels repaired using composite systems that are qualified, designed, installed, and inspected using this International Standard 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 International Standard 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.

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

1 Scope

This International Standard 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, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 impresser)*

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.

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 International Standard 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, 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, 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

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
p_{after}	internal pressure after repair system is applied
p_e	external design pressure
p_{eq}	equivalent design pressure

$p_{ext,soil}$	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: $R_c = \frac{p_{min}}{p_{max}}$
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
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 International Standard 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 International Standard 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 International Standard is not a defect assessment standard. Within this International Standard, no statements are made regarding whether a specific defect is acceptable or unacceptable for repair. The standard assumes that a defect assessment has already been performed to, for example ASME B31G or API RP 579. The starting point for this International Standard 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 wall thickness is used as input for the repair design. This International Standard is concerned with the subsequent activities of repair qualification, design, installation, and inspection.

Repair systems are applied to restore structural integrity. The following repair situations are addressed:

— external corrosion, where the defect is or is not through-wall. In this case, the application of a repair system will usually arrest further deterioration;