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ASME Post Construction SC-Repair & Testing
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PCC-2, REPAIR STANDARD

ARTICLE 4.2, NON-METALLIC COMPOSITE REPAIR SYSTEMS FOR PIPELINES AND PIPEWORK: LOW RISK APPLICATIONS

CONTENTS

Guide for Selection of Repair Technique

	General wall thinning	Local wall thinning	Pitting	Gouges	Blisters	Laminations	Circumferential cracks	Longitudinal cracks	Other
Non-Metallic Composite Repair Systems for Pipelines and Pipework	Y	Y	Y	R	Y	Y	Y	R	

Nomenclature:
Y = Generally appropriate.
S = Although may be acceptable, is not generally used for this condition.
R = May be used, but requires special cautions.
N = Not generally appropriate.

1. DESCRIPTION

1.1 Scope

This Article provides the requirements for the repair of low risk piping using a qualified Repair System.

The Repair System is defined as the combination of the following elements for which qualification testing has been completed: substrate (pipe), surface preparation, composite material (repair laminate), filler material, adhesive, application method, and curing protocol.

The composite materials allowed for the Repair System are fiber reinforcements in a resin matrix (e.g. polyester, polyurethane, phenolic, vinyl ester or epoxy).

1.2 Applicability

This Article addresses the repair of piping originally designed in accordance with a variety of pipe standards, including ASME B31.1 / B31.3 / B31.4, AWWA C200 / C300 / C301 C302 / C303 / C400, and ISO 15649 and 13623.

Low risk applications, for the purposes of this Article, are defined as those applications where all of the following apply:

- Non-hazardous fluids (e.g., aqueous fluids); and
- Piping systems not critical to the safety of workers (e.g., fire suppression systems); and
- Non-IDLH fluids; and
- Less than 150 psig (1 MN/m^2); and
- Less than 120^oF (50^oC); and
- Above 0^oF (-20^oC); and
- Less than 78 inch (2 m) piping diameter; and
- Te leaking defect size, *d*, and design pressure, P, satisfy the following relationship:
    - $P\sqrt{d} < 150$ psig $(\text{inch})^{0.5}$
    - $P\sqrt{d} < 0.5$ $MN/m^{1.5}$
    - The defect size shall be limited to $d \leq 0.25 \times D$

The following type of defects may be repaired:

- external corrosion;
- external damage;
- internal corrosion and / or erosion,;
- leaks;
- manufacturing or fabrication defects

1.3 Risk Assessment

A determination shall be made as to whether the repair is low risk, as defined in Paragraph 1.2. The Risk Assessment should define the acceptable life of the repair. An assessment of the risks associated with the defect and repair method should be completed in line with the relevant industry best practice.

- See Article 4.1 for guidance in Risk Assessment.

The information and data describing any hazards shall be included in the Risk Assessment to be used on site.

1.4 Repair Life

The repair life is the useful service period of the Repair System, which may be affected by external and environmental exposures, active internal corrosion/erosion, and external mechanical influences. The repair life shall be defined by the risk assessment.

2. LIMITATIONS

2.1 Section I of PCC-2

Section I of the Repair Standard contains additional requirements and limitations. This Article shall be used in conjunction with Section I.

2.2 Qualification

The use of this Article is limited to those Repair Systems for which the qualification testing described in Appendix II has been completed. Any change to any element of the Repair System, 1.1, constitutes a different and therefore new Repair System. This new Repair System shall require qualification as described in Appendix II. See also Section 3.2.

2.3 Installation

The installation procedures shall be those used in the Repair System qualification. If the installation procedures are not those used in the Repair System qualification then the repair is not in compliance with this Article.

2.4 Loading

If axial or other loads are significant, in addition to internal pressure, then Article 4.1 shall be used.

3. DESIGN

3.1 Symbols

These are the symbols used throughout this article.

d = leaking defect size (m) (inch)
d_f = design factor
D = external pipe diameter (m) (inch)
E_c = tensile modulus for the composite laminate in the circumferential direction determined by test according to Table 1 (N/m^2) (psi)
HDT = heat distortion temperature (^oC) (^oF)
L = total axial repair length (m) (inch)
L_{over} = overlap length (m) (inch)
L_{taper} = taper length (m) (inch)
n = number of wraps as determined by the relevant repair design case
n_A = minimum number of wraps for Type A repairs
n_B = minimum number of wraps for Type B repairs
n_C = minimum number of wraps for Type C repairs
n_D = minimum number of wraps for Type D repairs
P = repair design pressure (N/m^2) (psi)
S_w = Strength per ply per metre (per inch) in tension
t = wall thickness of substrate (m) (inch)
T_d = design temperature of Repair System (^oC) (^oF)
T_g = glass transition temperature (^oC) (^oF)

3.2 Repair System Qualification Data

Qualification of the Repair System shall be completed in accordance with Table 1 and Appendix II.

	Material Property	International Test Method	ASTM Test Method
Mechanical properties	Tensile properties (S_w)	ISO 527	ASTM D3039
	Glass transition temperature of resin (T_g)	ISO 11357-2	ASTM D6604 or ASTM E1640 or ASTM E831
	Heat Distortion Temperature (HDT)	ISO 75-1Ae or ISO 75-1Be	ASTM D648
	Barcol or Shore hardness	BS EN 59 ISO 868	ASTM D2583
Adhesion strength	Lap shear Leak sealing performance (optional)	BS EN 1465 Appendix III	ASTM D3165

Table 1: Repair System required material and performance properties

Equivalent national or international published test methods are also acceptable.

Materials performance and test data shall be measured by a certified or nationally accredited test facility, or certified by a registered Professional Engineer (or international equivalent).

The Repair System supplier shall specify:

- pipe material restrictions
- surface preparation
- repair laminate (polymer matrix and fiber reinforcement)
- filler material (dimensional restoration), if used
- adhesive / primer, if used
- application method.

Any change to the Repair System shall constitute a new Repair System and require qualification.

3.3 Additional Required Data

The following data should be provided for each repair:

- Lifetime requirements / expectation of the repair service life.
- Required design and operating pressures / temperatures.
- Expected future service conditions.
- Piping line identity.
- Description of the piping, including material specification and pipe wall thickness.

The data used in the design shall be recorded. Appendix I may be utilized.

3.4 Calculations

The design of the repair laminate shall be carried out using the requirements in the following sections. There are four design cases:

- Type A Design Case: For pipes that are not leaking (requiring structural reinforcement only). This shall be calculated for all repairs.

- Type B Design Case: This shall be calculated for pipes that are leaking.

- Type C Design Case: This shall be calculated for pipe tees that are not leaking.

- Type D Design Case: This shall be calculated for pipe tees that are leaking.

A pipe shall be considered to be leaking if the wall thickness at any point of the affected area is expected to be less than 1 mm (0.04-in) at the end of the repair life. This should take account of active internal corrosion where applicable.

For elbows, bends, reducers, and flanges the repair thickness calculated in Sections 3.4.1 and 3.4.2 shall be used.

3.4.1 Type A Design Case

For hoop stresses due to internal pressure the minimum number of wraps, n_A, is given by:

$$n_A = \frac{PD}{2d_f S_w} \tag{2}$$

where d_f is set at 0.2 and S_w is taken from Table 1.

3.4.2 Type B Design Case

The number of wraps, n_B, applied shall be that qualified in Appendix III.

3.4.3 Type C Design Case

For tees, the number of layers, n_C, shall be $2n_A$. For pipe tee joints the diameter of the larger pipe shall be used in the calculation.

3.4.4 Type D Design Case

For tees that are leaking, the number of layers, n_D, shall be the greater of n_C and n_B.

3.4.5 Axial length of repair

The design thickness of the repair laminate shall extend beyond the damaged region in the pipe by L_{over};

$$L_{over} = 2\sqrt{Dt} \tag{3}$$

L_{over} shall be at least 0.05m (2”).

The ends of the repair may be tapered. A minimum taper length, L_{taper}, of approximately 5:1 (horizontal:vertical) is recommended.

The total axial length of the repair is given by,

$$L = 2L_{over} + L_{defect} + 2L_{taper} \tag{4}$$

The repair shall be centered over the defect.

3.4.6 Environmental Compatibility

The suitability of the Repair System for use in the service environment specified by the owner shall be determined.

3.4.7 Design Output

The outputs of the design calculations of the repair laminate are the following:

- The number of wraps, *n*, shall be determined by the appropriate Design Case above (*n* shall not be less than 2)
- Total axial repair length, *L*

The Repair System Installer shall be provided with the following information:

- Details of laminate lay-up, including number of wraps, repair area to be covered, and orientation of individual layers of reinforcement (this may be presented as a written description or a drawing incorporating standard details such as overlap and taper).
- Details of surface preparation procedure, including method of application, equipment to be used and inspection method.
- Details of in-fill required to achieve a smooth outer profile prior to the application of the repair laminate.
- Details of cure protocol.

3.5 Approval

Designs of repairs according to this Article shall be undertaken by a technically competent person acceptable to the Owner.

3.6 Re-qualification

Where there has been a change to Repair System, then the relevant testing specified in the Section 3.2 shall be completed.

4. FABRICATION (INSTALLATION)

4.1 Storage Conditions

Storage of material should comply with the Supplier's instructions. The MSDS should be retained for reference. It should be noted that the materials used will need to be stored and controlled according to national safety regulations (e.g. OSHA or COSHH).

4.2 Installer Qualifications

Personnel involved in the installation of a Repair System shall be trained and qualified for that Repair System according to Appendix IV.

4.3 Installation Guidance

Repair System Suppliers shall provide installation instructions. These instructions shall include (where appropriate):

- Acceptable environmental conditions of site at time of repair
- Material storage
- Surface preparation
- Resin mixing
- Laminate lay-up
- Laminate consolidation
- Cure
- Key hold points

Further details of these requirements can be found in Appendix V.

The key hold points that may be observed during a repair are summarized in Table 2.

Hold Point
Materials Preparation – reinforcement – resin
Surface Preparation – inspection
Filler Profile
Stage Check on Reinforcement Lay-up
Inspection of Repair Laminate – cure (hardness) – number of wraps (thickness) – dimensions & position – external inspection (see Table 3)
Pressure Test

Table 2. Hold points during installation

The results from the Inspection of the Repair Laminate shall meet the acceptance criteria of the Design Output.

4.4 Live Repairs

Repairs to non-leaking, live piping systems are possible, provided that the associated hazards are fully considered in the risk assessment for the operation. This should include any hazards to and from surrounding equipment in addition to the pipe being repaired.

5. EXAMINATION

5.1 Introduction

This section provides guidance on the post-installation / operational issues of Repair Systems. The installation of a Repair System will not adversely affect any internal inspections that may be carried out.

The inspection of the Repair System may include:

- cure (hardness)
- number of wraps (thickness)
- dimensions & position
- examination for defects (see Table 3)

The basic structure of a composite repair in this context is illustrated in Figure 1.

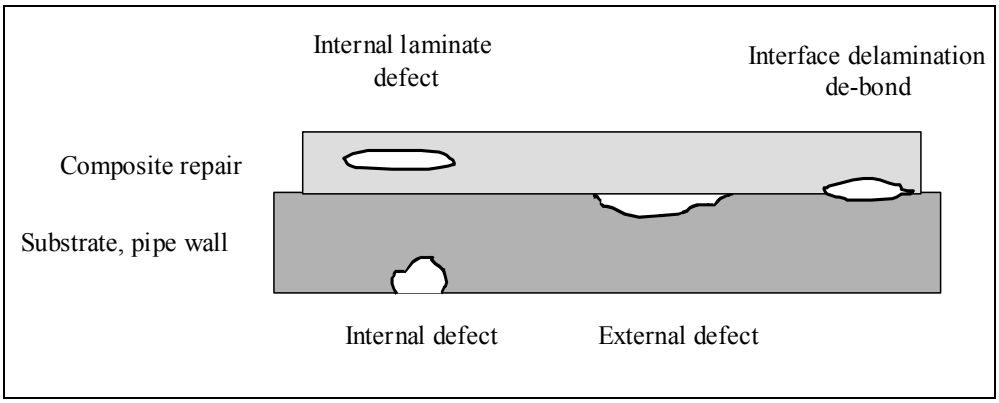

Figure 1: Schematic of a Repair System and location of defects.

5.2 Defects within the Repair System

The Repair System supplier shall provide post-installation visual examination criteria. Guidance on defects and allowable limits that are likely to be of importance are given in Table 3. The installer shall take care to ensure that these defects are not formed during application of the Repair System.

Repair section	Defect	Allowable Limits
Repair materials and substrate pipe prior to repair application	Check that the materials are those specified by the Design Output.	
	Changes in geometry	Repair area to be free of sharp changes in geometry (all radii <5 mm (0.2 inch)), or sharp geometry to be smoothed. (Filler/contour material)
	Surface Preparation	In accordance with Repair System specification
		Axial extent to be in accordance with design
	Surface Temperature	In accordance with repair design
	Defect	Dimensions do not exceed those for which the repair has been designed
		Defect nature to be that for which the repair has been designed
	Location of repair	Axial extent and positioning to be in accordance with design
Interface	Delamination	Tap test may indicate presence of de-bonding
		None exist at ends of repair
Resin rich layer	Cracks	None (check adhesive fillets)
	Foreign matter, blisters and pits	Maximum 10 mm (0.5 inches) in width, 2.5 mm (0.1 inch) in height
	Wrinkles	No step changes in thickness greater than 2.5 mm (0.1 inch) in height
	Pin holes	None deeper than resin rich layer
	Resin color	Uniform
	Dry spots	None
Composite laminate	Fiber orientation	As specified in design
	Un-impregnated/dry fiber	None
	Exposed cut edges/ fibers	None
	Foreign matter	None
	Axial extent and positioning of the repair	As specified in the design
		Does not extend beyond prepared surface

Table 3: Defect type and allowable limits for the composite wrap

5.3 Repair of Defects within the Repair System

Corrective actions shall be as specified by the Repair System supplier to address the defects identified in Table 3.

Repairs containing defects that exceed the limits in Table 3 should be removed and reapplied. However, on agreement with the Owner, local removal of the damaged

area and re-application of the Repair System materials to this area are allowable if the Repair System supplier can demonstrate that this will restore the full performance of the repair.

6. SYSTEM PRESSURE TESTING

System pressure testing, if required, shall be specified by the Owner. A service test of the operating pressure is recommended. Any signs of leakage or indication of repair laminate failure shall be cause for rejection of the repair.

All repairs shall be cured in accordance with the Repair System supplier instructions before pressure testing.

If the test pressure exceeds the pressure for which the Repair System has been designed, then the repair shall be re-designed for this higher pressure.

7. REFERENCES

Standard or Specification	Title	Revision Date or Indicator
ANSI/API RP 579	Fitness-For-Service (Recommended Practice)	2000
ASME PCC-2	Repair of Pressure Equipment and Piping	latest edition
ASME B31.1	Power Piping	2004
ASME B31.3	Process Piping.	2002
ASME B31.4	Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids	1998
ASME B31G	Manual: Determining Remaining Strength of Corroded Pipelines: Supplement To B31 Code-Pressure Piping	1991
ASTM D648	Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position	2004
ASTM D1599	Test method for short time hydraulic failure pressure of plastic pipe, tubing and fittings.	1999
ASTM D2583	Standard test method for indentation hardness of rigid plastics by means of a Barcol impressor	1995
ASTM D3039	Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials	2000
ASTM D3165	Standard Test Method for Strength Properties of Adhesives in Shear by Tension Loading of Single-Lap-Joint Laminated Assemblies	2000
ASTM D3681	Standard Test Method for Chemical Resistance of Fiberglass (Glass-Fiber-Reinforced Thermosetting Resin) Pipe in a Deflected Condition	2001
ASTM D5379	Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method	1998
ASTM D6604	Standard Practice for glass transition temperatures of Hydrocarbon Resins by Differential Scanning Calorimetry	2000
ASTM E831	Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis	2003
ASTM E1640	Standard Test Method for Assignment of the glass transition temperature By Dynamic Mechanical Analysis	1999
BS EN 59	Measurement of hardness by means of a Barcol impressor.	1977
BS EN 1465	Determination of tensile lap shear strength of rigid to rigid bonded assemblies.	1995
BS 7910	Guide on methods for assessing the acceptability of flaws in metallic structures	1999
ISO 75	Plastics - Determination of temperature of deflection under load.	1993
ISO 178	Plastics - Determination of flexural properties.	2001
ISO 527	Plastics - Determination of tensile properties.	1993
ISO 868	Plastics and ebonite - Determination of indentation hardness by means of a durometer (Shore hardness)	2003
ISO 8501	Preparation of steel substrates before application of paints and related products	1988
ISO 8502	Tests for the assessment of steel cleanliness	1992

ISO 8503	Surface roughness characteristics of blast cleaned steel substrates	1988
ISO 8504	Surface preparation methods	2000
ISO 10952	Plastics piping systems -- Glass-reinforced thermosetting plastics (GRP) pipes and fittings -- Determination of the resistance to chemical attack from the inside of a section in a deflected condition	1999
ISO 11357-2	Plastics - Differential scanning calorimetry (DSC) – Part 2: Determination of glass transition temperature	1999
ISO 11359-2	Plastics -- Thermomechanical analysis (TMA) -- Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature	1999
ISO 13623	Petroleum and natural gas industries -- Pipeline transportation systems	2000
ISO 15649	Petroleum and natural gas industries -- Piping	2001