PCC-2, REPAIR STANDARD

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

CONTENTS

1. Description
2. Limitations
3. Design
4. Fabrication
5. Examination
6. Testing
7. References
Appendix I – Repair Data Sheet
Appendix II – Qualification Data
Appendix III – Measurement of $\gamma$ for Leaking Pipe Calculation
Appendix IV – Installer Qualifications
Appendix V – Installation
Appendix VI – Glossary of Terms and Acronyms

Guide for Selection of Repair Technique

<table>
<thead>
<tr>
<th>Non-Metallic Composite Repair Systems for Pipelines and Pipework</th>
<th>General wall thinning</th>
<th>Local wall thinning</th>
<th>Pitting</th>
<th>Pitting</th>
<th>Blister</th>
<th>Lamination</th>
<th>Circumferential cracks</th>
<th>Longitudinal cracks</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>R</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>R</td>
<td>N</td>
<td></td>
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</table>

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/m²); and
- Less than 120°F (50°C); and
- Above 0°F (-20°C); and
- Less than 78 inch (2 m) piping diameter; and
- The leaking defect size, \( d \), and design pressure, \( P \), satisfy the following relationship:
  - \( P \sqrt{d} < 150 \text{ psig (inch)}^{0.5} \)
  - \( P \sqrt{d} < 0.5 \text{ MN/m}^{1.5} \)
  - 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)
\[ d_t \] = 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/m²) (psi)
\[ HDT \] = heat distortion temperature (°C) (°F)
\[ L \] = total axial repair length (m) (inch)
\[ L_{overlap} \] = 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/m²) (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 (°C) (°F)
\[ T_g \] = glass transition temperature (°C) (°F)

3.2 Repair System Qualification Data

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

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

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:

$$n_A = \frac{PD}{2d_f S_w}$$  \hspace{1cm} (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 $L_{over}$:

$$L_{over} = 2\sqrt{Dt}$$  \hspace{1cm} (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,

$$L = 2L_{over} + L_{defect} + 2L_{taper}$$  \hspace{1cm} (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.

<table>
<thead>
<tr>
<th>Hold Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials Preparation</td>
</tr>
<tr>
<td>– reinforcement</td>
</tr>
<tr>
<td>– resin</td>
</tr>
<tr>
<td>Surface Preparation</td>
</tr>
<tr>
<td>– inspection</td>
</tr>
<tr>
<td>Filler Profile</td>
</tr>
<tr>
<td>Stage Check on Reinforcement Lay-up</td>
</tr>
<tr>
<td>Inspection of Repair Laminate</td>
</tr>
<tr>
<td>– cure (hardness)</td>
</tr>
<tr>
<td>– number of wraps (thickness)</td>
</tr>
<tr>
<td>– dimensions &amp; position</td>
</tr>
<tr>
<td>– external inspection (see Table 3)</td>
</tr>
<tr>
<td>Pressure Test</td>
</tr>
</tbody>
</table>

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 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**

<table>
<thead>
<tr>
<th>Standard or Specification</th>
<th>Title</th>
<th>Revision Date or Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI/API RP 579</td>
<td>Fitness-For-Service (Recommended Practice)</td>
<td>2000</td>
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<tr>
<td>ASME PCC-2</td>
<td>Repair of Pressure Equipment and Piping</td>
<td>latest edition</td>
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<td>ASME B31.1</td>
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<td>1998</td>
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<td>ASTM D1599</td>
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<td>1999</td>
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<td>1995</td>
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<td>BS EN 59</td>
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<td>1977</td>
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<td>BS EN 1465</td>
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<td>Guide on methods for assessing the acceptability of flaws in metallic structures</td>
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<td>ISO 75</td>
<td>Plastics - Determination of temperature of deflection under load.</td>
<td>1993</td>
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<td>Plastics - Determination of flexural properties.</td>
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<td>1993</td>
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<tr>
<td>ISO 868</td>
<td>Plastics and ebonite - Determination of indentation hardness by means of a durometer (Shore hardness)</td>
<td>2003</td>
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<tr>
<td>ISO 8501</td>
<td>Preparation of steel substrates before application of paints and related products</td>
<td>1988</td>
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<tr>
<td>ISO 8502</td>
<td>Tests for the assessment of steel cleanliness</td>
<td>1992</td>
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<td>ISO</td>
<td>Description</td>
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<td>ISO 8503</td>
<td>Surface roughness characteristics of blast cleaned steel substrates</td>
<td>1988</td>
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<td>ISO 8504</td>
<td>Surface preparation methods</td>
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<td>ISO 10952</td>
<td>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</td>
<td>1999</td>
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<td>Plastics -- Thermomechanical analysis (TMA) -- Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature</td>
<td>1999</td>
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<td>ISO 13623</td>
<td>Petroleum and natural gas industries -- Pipeline transportation systems</td>
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<td>Petroleum and natural gas industries -- Piping</td>
<td>2001</td>
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