CHALLENGE EVERYTHING

SPECIFICATION FOR ENGINEERED COMPOSITE REPAIR

Date	05/30/2018
Asset Owner, City	LM Promotora, - -
EAF Submitted by	Leonardo Paim, , LPaim@Neptuneresearch.Com
EAF Last Edited by	N/A
Line ID#	3/4" OD line
NRI Report #	E16217-
Design Engineer	Leonardo Paim,, LPaim@neptuneresearch.com
Product	Thermo-Wrap Inspectable
# of Layers	2
Repair Length	23622 in

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PREFACE

ECR System Definition & Responsible Parties:

This document preface provides the information on what constitutes an Engineered Composite Repair (ECR) System and how responsible party requirements and obligations are broken down according to industry standards and general practice. It is important that each responsible party know and understand their individual roles within the process of implementing ECR Systems.

Qualified Engineered Composite Repair System Definition

a. Qualified components list

This list is defined by ASME PCC-2-2015 Article 4.1, Section 1.1 (b) The Repair System is defined as a combination of the following elements for which qualification testing has been completed:

(1) substrate (component)

(2) surface preparation

(3) composite material (repair laminate)

(4) load transfer material (filler material)

(5) primer layer adhesive (an adhesive used in some repair systems, attaching the composite laminate to the substrate)

(6) application method

(7) curing protocol

(8) interlaminar adhesive for Repair Systems that utilize precurved plies”

b. Changing of components in a qualified repair system

i. Any change to any element of the Repair System (see para. 1.1 for scope) shall constitute a different and therefore new Repair System

ii. Changing of components within a qualified repair system may be allowed, but only if new qualification testing is completed on the new system with the changed component

1. Requirements for re-qualification based on component change are discussed in the ASME PCC-2 Article 4.1 Section 3.6 “Requalification,” and given in further detail in the Nonmandatory Appendix B “Recommended Retesting for a Modified Qualified Repair System”

2. Field technicians changing a component in the field represents a new system, and may no longer be compliant to the testing thereby potentially rendering it as “not qualified”

3. This should not be allowed without subsequent re-testing and re-qualification of the new system

Responsible Party Breakdown

a. The breakdown of responsibility for each representative party is outlined in the relevant industry standards which govern the use of ECR systems. It is critical for each party involved to understand the role in which they operate in the full process from start to finish

b. There are 3 primary responsible parties in the ECR process.

i. Material Manufacturer

ii. Installation Company

iii. End User / Asset Owner

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Requirements of Responsible Party

a. Manufacturer:

This party shall be primarily responsible for supplying the qualified repair system materials and documentation, and providing sufficient training and documentation for the installation technicians to install and perform quality checks on the materials.

i. ECR System (material) qualification documentation
ii. Qualified “system” definition
iii. Design of repair thickness documentation
iv. Installation guidance documentation
v. QA/QC procedure requirements
vi. Perform installer training & qualification

b. Installer:

This party shall be primarily responsible for all site specific requirements as they would relate to the installation, documentation, and completion of the repair.

i. Job site risk assessment
ii. Job site method statement
iii. Design & material information
iv. Repair application and QA documentation
v. Obtaining/Attending installer training course

c. End User / Asset Owner:

This party shall be responsible for the submission and verification of data with regard to how the ECR program is implemented within the facility, and for requiring all documentation to be presented prior to the approval of the repair installation.

i. Risk assessment of defect
ii. Design & operating conditions
iii. Contents of system
iv. Repair life
v. Approval of repair design
vi. Approval/verification of installation technicians

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Chapter 1: Data Supplied by Client

Type of Repair	Type-A Non-Leaking	
Location of Damage	External	
Installation Type	Refinery	
Geometry	Straight	
Nominal Wall Thickness of Pipe	0.113	inches
Design Temperature	158	°F
Operating Temperature	158	°F
Installation Temperature	158	°F
Priority Status	Standard	
Preferred Composite System	No Preference	
Service Contractor	LM Promotora	
City	- -	
Email	LPaim@neptuneresearch.com	

SMYS*Cf (Pipeline) or Allowable Stress (Refinery)	15000	psi
Diameter of Pipe	1.05	inches
Internal Design Pressure	100	psi
Minimum Remaining Thickness	0.107	Inches
Axial Length of Defect	1000	inches
Desired Length of Repair	23622	inches
NRI Distributor	LM Promotora	
Asset Owner	LM Promotora	
Line Id	3/4" OD line	
Date Added	05/30/2018	
Completed By	Leonardo Paim	

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Additional Comments

All information provided on the Engineering Assessment Form (including design conditions, chemical contents, etc.) has been reviewed for feasibility and the proposed solution in this document has been found to be acceptable and fit for service based on the information provided. Any change in the information supplied and shown in this chapter may require a change in the proposed solution. It is the responsibility of the user of this proposal to ensure the provided information is accurate and correct to ensure the proposed solution is designed correctly. NRI is not liable for any design for which inaccurate or incorrect information has been supplied for use in said design.

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Revision Notes:

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Chapter 2: Engineered Repair Design Justification

Project

NRI is pleased to provide the following analysis for the repair of a non-leaking 1.05" line undergoing external corrosion for LM Promotora. The analysis provided in this proposal shows that 2 layers of NRI's Thermo-Wrap Inspectable are necessary to withstand the specified design pressure and temperature.

Introduction and Background

The existing line has experienced external corrosion. The design pressure and temperature are 100psi and 158°F, respectively. A non-leaking analysis has been presented in this report and a minimum repair thickness is specified.

The line is to be reinforced via composite repair to meet or exceed its original design strength and extend the life of the line.

The following parameters are taken into account for a design solution:

Pipe Diameter	1.05	in
Wall Thickness	0.113	in
Design Pressure	100	psi
Design Temperature	158	°F
Axial Length of Defect	1000	in
Requested Repair Length	23622	in

Table 1 - Repair Parameters

Non-Leaking Analysis (Type-A)

The line is treated as a cylindrical pressure vessel under internal pressure. The repair of the corrosion defect will be addressed by ASME PCC-2-2015 repair of a non-leaking component eq (5). The minimum thickness of repair is determined by equation (5). Variable definition is provided below where as Table 2 shows the material properties of Thermo-Wrap Inspectable.

$$\epsilon_c = \frac{PD}{2E_c t_{repair}} - s\frac{t_s}{E_c t_{repair}} - \frac{P_{live} D}{2(E_c t_{repair} + E_s t_s)} \quad (5)$$

Where:

t_{repair}	is the minimum required repair thickness
$\epsilon_c, 0$	is the allowable long term circumferential strain per ASME PCC-2-2011 Table 3.
ϵ_c	is the de-rated long term strain based on a temperature de-rating factor f_T
E_c	is the design modulus of elasticity of NRI's Thermo-Wrap Inspectable
E_s	is the design modulus of elasticity of steel
P	is the design pressure
P_{live}	is the live pressure in the pipe during repair
D	is the outside diameter of the pipe to be repaired
s	is the specified minimum yield strength of the component de-rated by the appropriate construction code.
t_s	is the remaining wall thickness of the pipe.

The temperature derating factor (f_T) is defined in equation (2) of the ASME PCC-2-2015 and shown below in eq (2).

$$f_T = 2 \cdot 10^{-5}(T_m - T_d)^2 + 0.0006(T_m - T_d) + 0.7014 \quad (2)$$

$$f_T = 2 \cdot 10^{-5}(330 - 158)^2 + 0.0006(330 - 158) + 0.7014 = 1.3962$$

Per ASME PCC-2 Article 4.1, eq(2) cannot exceed a result of "1", anything exceeding this number will default to "1".

Where:

T_d	is the design temperature of the repair system
T_m	is the Upper temperature limit of composite system

The allowable circumferential strain is calculated based on equation 10(a) of the ASME PCC-2-2015 and is defined in equation (10a) below.

$$\epsilon_c = f_t \epsilon_{c0} - \Delta T(\alpha_s - \alpha_c) \quad (10a)$$

$$\epsilon_c = 1 \cdot 0.0025 - (158 - 158)(6.67 \cdot 10^{-6} - 5.72 \cdot 10^{-6}) = 0.0025$$

Where:

ΔT	is absolute temperature difference between design and installation
$\alpha_s = 6.67 \cdot 10^{-6}$	is steel's coefficient of thermal expansion
$\alpha_c = 5.72 \cdot 10^{-6}$	is Thermo-Wrap Inspectable's coefficient of thermal expansion in the circumferential direction

Based on equation (10a) the allowable strain is calculated to be 0.0025 = 0.25%.

Thermo-Wrap Inspectable Type A Repair		
Allowable Circumferential Strain - ϵ_c	0.0025	in/in
Design Pressure - P	100	psi
Diameter of Pipe - D	1.05	in
Circumferential Modulus - E_c	4290000	psi
Allowable Stress of Steel - s	15000	psi
Remaining Thickness of Steel - t_s	0.107	in
Live Pressure - P_{live}	0	psi
Modulus of Steel - E_s	29	Msi

Table 2 - Material Properties Of Thermo-Wrap Inspectable

Using the calculated and material property values of Thermo-Wrap Inspectable, the repair thickness for the line based on equation 6 is calculated as follows:

$$t_{repair} = \frac{1}{\epsilon_c E_c}\left(\frac{PD}{2} - st_s\right) \tag{6}$$

$$t_{repair} = \frac{1}{4290000 \cdot 0.0025}\left(\frac{100 \cdot 1.05}{2} - 15000 \cdot 0.107\right) = -0.1448$$

The above equation shows that for a design pressure of 100 psi, the remaining wall thickness is sufficient to prevent structural failure of the substrate. Per the ASME PCC-2 Article 4.1, Section 1.2.c.1, it states that for "external corrosion where the structural integrity is compromised. In this case it is probable the application of a Repair System will arrest further deterioration." In order to isolate the defect from the corrosive environment, NRI recommends the application of the Thermo-Wrap Inspectable as a corrosion and mechanical protection coating at a thickness of at least 2 layers.

Design of Repair Length

The overlap length of the repair is determined by equation (18) of the ASME PCC-2-2015 Article 4. Table 3 shows the values used in the calculation of the repair length of the line.

$$L_{over} = 2.5\sqrt{Dt/2} \tag{17}$$

$$L_{over} = 2.5\sqrt{1.05 \cdot 0.113/2} = 0.60\ ”$$

Thermo-Wrap Inspectable		
L over		
Diameter of Pipe - D	1.05"	in
Original Wall Thickness - t	0.113"	in
Thickness of Repair - t_{repair}	0.054	in
Axial Modulus - E_a	2290000	psi
Allowable Axial Strain - ϵ_a	0.001	in/in
Lap Shear Strength - τ	1268	psi

Table 3 - Input Data To Calculate Repair Length

The total axial length of repair is calculated according to equation (19) of the ASME PCC2-2015:

$$L = 2L_{over} + L_{defect} + 2L_{taper} \tag{19}$$

$$L = 2 \cdot 0.60 + 1000 + 2 \cdot 0.27 = 1001.740$$

The taper length is specified by PCC-2 to be not less than a 5:1 ratio length to repair thickness. The total axial length of the repair is shown in table 4 below.

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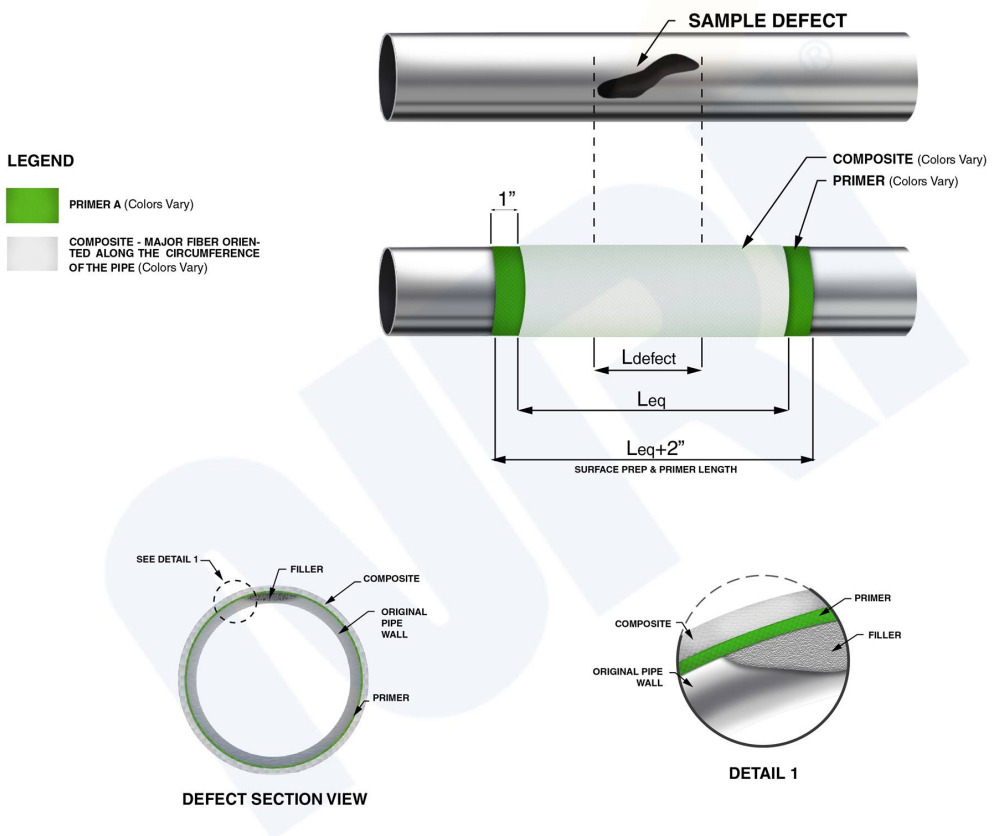
Thermo-Wrap Inspectable		
Repair Length Results		
Final Thickness of Repair - t_{min}	0.054	in
Length of Defect - L_{defect}	1000	in
Overlap Length - L_{over}	0.60	in
Taper Length - L_{taper}	0.27	in
Total Repair Length - L	1001.740	in

Table 4 - Total Axial Length Calculations



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Interpretation of Results

NRI has performed a leaking defect analysis per ASME-PCC-2-2015 3.4.3.2 for a 1.05" line with external corrosion. The results show that the minimum required repair thickness corresponds to 2 layers of Thermo-Wrap Inspectable.

The overlap length should be at least 0.87’’ past each edge of the defect. The total repair length required is 1001.740’’ considering a 1000’’ defect as described.

NRI’s surface preparation guidelines are required to be followed to ensure an adequate bond to the substrate.

The parameters required to calculate the material quantity to perform this installation include:

- 2 layers of Thermo-Wrap Inspectable for a 1.05" straight line.
- 1001.740" minimum repair length
- 23622" requested repair length

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Material Estimate:

Material estimate is based on the requested repair length, or required repair length, whichever is greater.

Additional length may be wrapped at owner's discretion and does not require an update to this Specification for ECR document

The parameters required to calculate the material quantity to perform this installation include:

- 2 layers of Thermo-Wrap Inspectable
- 23622 inches repair length

System Component	Amount Estimated	Units	Formula
Filler	2.474	Fluid Ounces	$D \cdot \frac{\pi}{2} \cdot (t - t_r) \cdot l_{defect} \cdot 0.25$
Composite	1082.239	Square Feet	$D \cdot \frac{\pi}{144 sq.in./sq.ft.} \cdot l_{total} \cdot layers$
Compression Film	2164.478	Square Feet	$D \cdot \frac{\pi}{144 sq.in./sq.ft.} \cdot l_{total} \cdot 4_{layers}$

Notes

- Additional material will be required for odd geometries.
- Protective top coat is required for all repairs.
- If OD is greater than 14in, or wrap length is greater than 100ft, please contact NRI-U for installation consultation (nriudept@neptuneresearch.com).

Chapter 3: Surface Preparation Requirements

This chapter will define the required surface preparation necessary for successful and compliant ECR system installations. Surface preparation requirements are the same for all of NRI's ECR systems. Variations and/or alterations in specified methods may be accepted based on a case by case basis, provided full details are supplied to the NRI Engineering Department during the design phase to ensure proper calculations are made to account for this.

3.1. Qualified Surface Preparation Standards

NRI has tested and qualified various methods and standards of surface preparation. The below standards outline each of these options in detail. For the full standard description and detail, these may be purchased from the organizations named.

a. **NACE (National Association of Corrosion Engineers)**

i. NACE 2 – Near-White Blast Cleaning (equivalent to SSPC-SP10)

b. **SSPC (Society for Protective Coatings)**

i. SSPC-SP1 – Solvent Cleaning

ii. SSPC-SP10 – Near-White Blast Cleaning (equivalent to NACE 2)

iii. SSPC-SP11 – Power Tool Cleaning to Bare Metal

3.2. Surface Preparation Procedures

The following procedures will describe the order of steps to successfully complete the full surface preparation regimen before beginning the ECR system installation process.

a. **Solvent Cleaning of Pipe**

i. The first step is to clean the entire pipe surface with an approved solvent. No oil-based solvents should be used. Denatured alcohol, Isopropanol alcohol, or Acetone are all approved for use as a solvent with NRI's ECR systems.

b. **Surface Preparation**

i. Surface preparation may be performed after the first solvent clean is completed. **Surface preparation may be done by grit blasting or by power tool provided that the specific tools are of the two which have been tested and qualified by NRI.** The following are surface preparation options and typical results which may be achieved with each.

1. **Safety Tool "Rough Boy" Cold Grinder:**

a. Typical results (as published by the manufacturer) obtained yield 1.5 – 3.0 mil (40 – 75 microns) on carbon steel with the Rough Boy files which are typically used for preparing pipe.

2. **MBX Bristle Blaster:**

a. Typical results (as published by the manufacturer) obtained yield 2.5 – 3.3 mil (63.5 – 83.8 microns) on carbon steel provided the belt is in good, working condition. Belts should be changed as needed to ensure minimum results are being generated.

3. **Grit Blasting:**

a. Results can vary greatly with this method based on the type and size of grit being used, ranging from 1.5 mil (40 microns) up to 5 mil (127 microns). Common media types include garnet, silica (be aware of potential safety concerns), and wet slurry.

c. **Solvent Cleaning of Pipe**

i. The final step is to do a final solvent clean to remove any residual dust, grease, or other surface contaminates which remain after the surface preparation. The same solvents as given above may be used for this step as well. No oil-based solvents are allowed for use.

3.3. Surface Preparation Measurement

a. The final surface profile shall be measured to ensure that surface preparation was completed and meets the minimum requirements as set forth by NRI based on testing and qualification. ***Minimum surface profile shall be not less than 1 mil (0.025mm, 25 micron)***to be considered in compliance with qualification. Surface profile may be measured by various means using standard industry tools available for this purpose.

Chapter 4: Method Statement & Critical Hold Points

This chapter will provide the general method statement and **critical hold points** for ECR systems. For specific installation procedures and steps, consult the product-specific Detailed Installation Guide which can be provided by NRI. Critical hold points are defined as steps which if not completed according to the installation procedure or not passing QC criteria, may grant the installer, and/or supervisor and/or asset owner the authority to stop work. These are identified in each section by **bold red text**.

4.1. Review of repair project documentation

a. **All documentation shall be reviewed by the installation technician prior to beginning the project work** to ensure accuracy in material requirements and verification of project scope/location within the facility.

b. This should include, but may not be limited to:

i. All design and operating conditions used for repair design calculations.

ii. Pipe specifications.

iii. Defect specifications and analysis.

iv. Temperatures (design, operating, environmental, pipe skin temperature, etc.).

v. Design calculations and requirements for product identification, total required thickness (i.e., number of layers), and total repair length.

vi. Any special considerations noted as would affect working conditions of the repair system or installation needs.

4.2. Review of repair materials on site

a. All repair materials shall be inspected to ensure they are within their usable shelf life.

b. **All lot/batch numbers shall be recorded on documentation**.

c. Any product packaging or noticeable damages which are out of specification for the product shall be recorded and product not used until verified that performance will be acceptable per design.

d. **All product names must match product design data used within the repair design calculation** (i.e., the qualified “system” must be what is used, no replacing components with other different components on site).

i. Example: Changing a filler which is qualified in the design means that the “system” is no longer the qualified and compliant system which was used in the repair design.

e. Verify product quantities are sufficient to satisfy the design requirements of the repair project.

4.3. Defect identification and location

a. Confirm the location and pipe specification matches with the information provided in this document for the repair location.

b. Identify and verify the defect location.

c. **Ensure the defect is within the limits as stated in the design criteria submitted which was used in the repair design calculations**.

4.4. Surface preparation

a. For full details, see Chapter 3 of this document, and relevant section of specific product Detailed Installation Guide which can be provided by NRI.

b. Ensure preparation has been completed to required minimums or greater as stated in the qualification documentation for the ECR system being utilized.

c. Ensure surface preparation has been completed to the required length as stated in this document.

d. **Measure and record surface profile on QC documentation**.

4.5. Marking of repair area & temperature measurements

a. Ensure the length required beyond the defect is identified and confirmed once surface preparation has been completed.

b. Mark each edge of the repair area so that the boundaries are clear during the application to ensure material is not wasted by going beyond the repair area.

i. Wrapping a longer distance is certainly acceptable; the need for marking is due to the fact that the material supplied may be for that length only and going beyond will mean material will not be sufficient to achieve the total thickness required within the calculated repair length.

c. **Note the environmental temperature and the skin temperature of the pipe and record on QC documentation** to ensure it does not exceed the recommended upper and/or lower limits for the ECR system being installed.

4.6. Installation of filler material

a. Filler material is required for external defects and is used for the “reshaping” of the defect area to bring them back to the original pipe geometry (i.e., filling of corrosion pits, dents, etc.).

b. Filler material may also be used to assist in smoothing transitional areas such as over large weld seams or over leak sealing clamps/devices.

i. Note: There are cases where filler material may not be required, such as with internal corrosion issues where the external of the pipe is in good condition.

c. **Ensure that filler material is mixed according to correct mix ratios** .

d. **Ensure that filler material is fully mixed until uniform in color with no streaking or marbling present** .

e. Ensure that mixed filler material is applied into the defect or over transition area creating a smooth and geometrically correct final structure.

i. If applying into corrosion pit or dent, result should be to closely resemble the original pipe geometry.

ii. If applying as a transitional media, ensure that the transition is smooth with no sharp edges and an approximately 5:1 height to length ratio.

f. If filler is allowed to set to solid state, ensure that no rough edges or sharp transitions are there by sanding down smooth.

g. **Record each step as required on the QC documentation**.

4.7. Installation of primer material

a. Primer is typically used as a means to promote adhesion between the host pipe and the composite repair material and can vary greatly in type and make-up.

b. Application of a primer system promotes bonding, acts as a corrosion coating, and in some cases may also act as an electrically insulating layer between the host pipe and the composite repair.

c. **Ensure that the primer material is mixed according to correct mix ratios**.

d. **Ensure that the primer material is fully mixed until uniform in color**.

e. The primer shall be applied around the full circumference of the pipe and over the entire length of repair area with at least one (1) inch extending beyond the repair area limit on either end of the repair.

f. **If a specific thickness range of primer is given by the manufacturer, the final thickness shall be measured with a wet film thickness gauge and recorded on QC documentation**.

4.8. Installation of composite wrap material

a. The composite wrap material shall be applied in the manner as specified in the Detailed Installation Guide for the specific system being installed.

b. There are multiple product type options and each will have a specific need for installation of the composite wrap material depending on its make-up.

i. Pre-impregnated MCU composite wraps. If a moisture-cured urethane based composite wrap is being used (Syntho-Glass® XT or Viper Skin™), then the following procedures shall be taken.

1. **Do not open the pouch which contains the pre-impregnated roll of fiber until ready for installation.**

a. Opening before ready for use will cause the activation process to begin from the moisture in the atmosphere and the material will begin to harden.

2. Begin the wrapping process one inch from the edge of the primer previously applied.

3. Wrap one full straight wrap around the pipe to ensure 100% coverage.

4. Begin spiral wrapping down the length of the repair area with a 50% overlap, which will apply 2 layers per pass.

5. When the other end of the repair is reached, stop spiral wrapping and wrap one full straight wrap around the pipe being sure to leave one inch of primer on that edge.

6. **Spray the entire repair area length with water to begin activating the MCU resin** .

7. Reverse direction and continue spiral wrapping with a 50% overlap back toward the beginning edge while spraying the wrap with water as you are applying it now.

8. Repeat this process and **ensure that the total number of layers have been applied as per the design calculations**.

ii. Field-saturated Epoxy composite wraps. If an epoxy-based, field-saturated composite wrap is being used (Thermo-Wrap™ Inspectable, Thermo-Wrap™ CF, or Acid-Shield™), then the following procedures shall be taken.

1. These system types are supplied with dry fiber rolls and epoxy kits which are mixed and used to saturate the dry fiber rolls.

2. **Ensure that the epoxy material is mixed according to correct mix ratios** .

3. **Ensure that the epoxy material is fully mixed until uniform in color** .

4. Once mixed, the dry fibers are then saturated with the fully mixed epoxy material either by use of a Resinator tool or by manual method.

5. Consult the product Detailed Installation Guide for specific instructions on each saturation method option.

6. **Ensure that the fiber is fully saturated with no dry spots, but also not overly saturated causing excess dripping from the fibers**.

7. Once dry fiber has been saturated, begin the wrapping process one inch from the edge of the primer previously applied.

8. Wrap one full straight wrap around the pipe to ensure 100% coverage.

9. Begin spiral wrapping down the length of the repair area with a 50% overlap, which will apply 2 layers per pass.

10. When the other end of the repair is reached, stop spiral wrapping and wrap one full straight wrap around the pipe being sure to leave one inch of primer on that edge.

11. Reverse direction and continue spiral wrapping with a 50% overlap back toward the beginning edge.

12. Repeat this process and **ensure that the total number of layers have been applied as per the design calculations**.

4.9. Installation of compression film wrap

a. The compression film material shall be applied in the manner as specified in the Detailed Installation Guide for the specific system being installed.

b. Compression film is applied to both system types (MCU and Epoxy), but have differing requirements for each.

i. Pre-impregnated MCU composite wraps. If a moisture-cured urethane based composite wrap is being used (Syntho-Glass® XT or Viper Skin™), then the following procedures shall be taken.

1. **The completed composite repair shall be overwrapped by four (4) layers of compression film and perforated using the perforator tool**.

2. Begin the Compression Film application on the outside of the primer layer to fully wrap 100% overlap on the pipe itself.

3. Overwrap the entire length of the repair using a 50% overlapping spiral method going beyond the other end to fully encapsulate the repair area with the compression film.

4. Reverse direction and return to the beginning location of the compression film, which will result in a total of 4 layers being applied.

5. **Apply enough tension to the compression film that you see the film begin to stretch and get narrower as it is applied**.

6. **Once four (4) layers have been applied (two [2] passes with 50% overlap), perforate to allow the release of the CO2 gas byproduct and excess water and resin**.

7. **The compression film shall be removed when the composite repair system has reached its cure time requirements prior to taking Shore D hardness measurements**.

ii. Field-saturated Epoxy composite wraps. If an epoxy-based, field-saturated composite wrap is being used (Thermo-Wrap™ Inspectable, Thermo-Wrap™ CF, or Acid-Shield™), then the following procedures shall be taken.

1. **The completed composite repair shall be overwrapped by four (4) layers of compression film** .

2. Begin the Compression Film application on the outside of the primer layer to fully wrap 100% overlap on the pipe itself.

3. Overwrap the entire length of the repair using a 50% overlapping spiral method going beyond the other end to fully encapsulate the repair area with the compression film.

4. Reverse direction and return to the beginning location of the compression film, which will result in a total of 4 layers being applied.

5. **Apply enough tension to the compression film that you see the film begin to stretch and get narrower as it is applied**.

6. **The compression film shall be removed when the composite repair system has reached its cure time requirements prior to taking Shore D hardness.**

4.10. Final inspection of completed repair

a. Final inspection of the installed and cured composite repair system shall be completed to verify operational fitness for service.

b. The following items shall be measured and recorded on relevant Quality Documentation for the repair being installed per this document.

i. Shore D Hardness.

1. **Hardness shall be measured using a Durometer Type D to verify the composite repair is cured as required to a value that is 90% of the full cure value as measured in qualification testing.**

2. Values required for the specific repair system being used may be found on relevant quality documentation from the manufacturer.

ii. Total Repair Length.

1. **The total repair length shall be at least the required length as calculated in the design found within this document.**

2. It is acceptable to have a repair length longer than what is stated, but not acceptable to be shorter than what is stated.

iii. Total Repair Thickness.

1. **The total repair thickness shall be at least the required thickness (total layers) as calculated in the design found within this document**.

2. It is acceptable to have a repair thickness greater than what is stated, but not acceptable to be less than what is stated.

3. Specific means of determining the repair thickness may be found on relevant quality documentation from the manufacturer.

iv. Visual Inspections.

1. **Visual inspection of the final repair shall be conducted according to the following items to ensure the composite repair is fit for service.**

a. Delamination in any area of the repair but especially at the ends of the repair area.

i. A tap test may be used to verify there is no disbondment within the repair system.

b. Cracks within the resin or through the repair system.

c. Foreign matter trapped within the composite repair.

d. Wrinkles within the laminate.

e. Pinholes.

f. Uniform coloring of the resin.

g. Dry spots.

2. Any inspection points which are noted as “out of norm” shall be recorded and the manufacturer consulted to determine if allowable limits have been exceeded.

3. It is highly recommended photo documentation is made during this time for future reference should the repair be left in service for extended periods of time so that a new inspection report may be compared to the original more effectively.

4.11. Completion of ECR System documentation

a. **Final repair documentation shall be provided to the Asset Owner / End User by the repair Contractor / Installation Company to include the following as a final package:**

i. ECR design package, including operational and design data provided in assessment phase and detailed calculations for the specific data provided.

ii. Completed quality control documentation as recorded during the installation of the composite repair system.

iii. Completed final composite repair inspection documentation.

b. An ECR system installation is only considered fully compliant if all steps outlined have been taken throughout the entire process and final documentation is approved and signed off by the Asset Owner / End User.

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Chapter 5: Critical Contacts

NRI General Contact	Phones: +1-561-683-6992 | +1-800-328-0090
NRI Engineering • Specifications and design procedures • Regulatory compliant design proposals • Composite engineering consultation	Email: techservice@neptuneresearch.com Web: neptuneresearch.com/engineering/
NRI University • Contractor training services • Onsite quality control • Assessment of potential applications	Email: nriudept@neptuneresearch.com Web: neptuneresearch.com/nriu/
NRI Customer Service • Customer support • RFQs & quotes • Order processing	Email: customerservice@neptuneresearch.com
Safety Data Sheets	http://www.neptuneresearch.com/sds

Appendix A: ECR Quality Control

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This ECR Quality Control document is intended to provide the means of recording the relevant information from the installation of an ECR System to ensure all critical hold points are identified and the installation process is properly executed resulting in an acceptable and successful composite repair installation. Any deviation from the specified installation steps or in the design/site conditions for a specified ECR System should be noted and a work-stop issued until the client can accept and sign off on any change in process or scope. This document shall not be considered complete or valid unless signed by both the installation technician/supervisor and the asset owner/operator. Each of the following identified sections must be completed:

1. Design Verification
2. Material Verification
3. Site Conditions
4. Installation Controls
5. Curing Protocols
6. Final Repair Inspection

	Design Verification	Data / Values	Initials
1	Calculation ID#		
2	ECR System Name Specified		
3	Diameter of Pipe		
4	Pipe Grade & Schedule		
5	Line ID (if given)		
6	Repair Location Geometry		
7	Design Repair Type		
8	Defect Type & Size		
9	Total # Layers		
10	Total Repair Length		

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	Material Verification	Data / Values		Initials
11	Material Quantities	Material quantities on hand meet minimum values estimated for full job scope completion (volume of polymers and square footage of composite wrap)		
		Lot #(s)	Expiration Date(s)	
12	Filler (as required**) *Must be the filler qualified with the ECR System*			
13	Primer *Must be the Primer qualified with the ECR System*			
14	Saturant (as required**) *Must be the Saturant qualified with the ECR System*			
15	Composite Wrap *Must be the Composite Wrap qualified with the ECR System*			
	*Record all individual Lot #'s and Expiration Dates separately. If multiple items have same Lot #, they only need to be recorded once. **If no filler (such as for internal corrosion) or no saturant (such as in pre-impregnated material) is required, leave these sections blank. *If additional room is required, use additional sheets to record all data.*			

	Site Conditions	Data / Values	Initials
16	Environmental Temperature[1]		
	[1]*If tent/enclosure required on site for environmental protection, then record temperature in enclosed area*		
17	Pipe Surface Temperature	Pipe surface temperature must be 5°F (-15°C) above dew point. Pipe Surface Temperature: _____	
18	Weather Conditions (rain, snow, etc.)		
19	Humidity	Relative humidity during installation of epoxy-based systems should be 85% or less. Measured Humidity Level: _____	
20	Defect is within design limits as calculated and specified	Defect type & size used in design: _____ Defect type & size confirmed at site: _____	

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21	If Type B defect, no active leak is present and zero (0) pressure in pipe	No pressure or vacuum is present in the event the leak is not sealed by some other means prior to wrapping. If pipe shut down or blocked, ensure no pressure leak is present in block valve; and ensure that no head pressure exists from remaining fluid in pipe even if section is not pressurized by the system.	
22	Repair Length specified is within limits and available on site	Repair Length specified in design: _____ Repair Length available at site: _____	
23	Surface Preparation Length	Length of prepared surface is at least two (2) inches (50mm) longer than the calculated and specified Repair Length to allow for primer to extend beyond the Repair Length by one (1) inch (25mm) on each end of the repair area.	
24	Surface Preparation	Reference industry standards for acceptable means of performing surface preparation: **SSPC-SP-10 / NACE 2** "Near White Metal Blast" or**SSPC-SP-11** "Power Tool Cleaning" at minimum *Method/Tool Used for Surface Prep:* _____ *If grit blast used, provide media type:* _____	
25	Surface Profile Measurement	Minimum profile of 1 mil (25.4 microns) required. Record data below and to right.	

When using Testex or similar replica tape tool for surface profile measuring, reference:
NACE RP0287 *"Field Measurement of Surface Profile of Abrasive Blast-Cleaned Steel Surfaces Using a Replica Tape"*
SSPC-PA 17 *"Procedure for determining conformance to steel profile/surface roughness/peak count requirements"*

(Affix Press-O-Film tape here)	(Affix Press-O-Film tape here)	(Affix Press-O-Film tape here)	(Affix Press-O-Film tape here)
(Affix Press-O-Film tape here)	(Affix Press-O-Film tape here)	(Affix Press-O-Film tape here)	(Affix Press-O-Film tape here)
(Affix Press-O-Film tape here)	(Affix Press-O-Film tape here)	(Affix Press-O-Film tape here)	(Affix Press-O-Film tape here)
(Affix Press-O-Film tape here)	(Affix Press-O-Film tape here)	(Affix Press-O-Film tape here)	(Affix Press-O-Film tape here)

Surface Profile Average:
_____

If additional room is required, use additional sheets to record all data

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	Installations Controls	Data / Values	Initials
26	Filler Material Installation	Filler material mixed in correct ratios as specified on product packaging and fully mixed with no streaking or marbling visible, and in a manner which limits air pockets being “whipped” into the mixture. Filler Name: _____	
27		Mixed filler material installed fully into defect, or over transitional areas, as required with proper fairing to reduce sharp angles and no air pockets left within.	
	Does ECR System require base fiberglass layer as part of Primer? **Yes** = Complete Primer Checks 28-30 and skip Primer Checks 31-32. **No** = Complete Primer Checks 31-32 and skip Primer Checks 28-30. *Refer to specified ECR System Detailed Installation Guide for information on specific requirements of Primer to be used, and complete only the relevant checks for the Primer type as defined below.*		
28	Fiberglass Primer Material Installation	Primer material mixed in correct ratios as specified on product packaging and fully mixed with no streaking or marbling visible. Primer Name: _____	
29		100% of the fiberglass saturated using the mixed Primer polymer to ensure no dry spots remain. Use of NRI’s Resinator™ tool is highly recommended for saturating fibers on site.	
30		Saturated Fiberglass Primer material installed at a two (2) layer thickness as specified to completely cover the specified Repair Length plus two (2) inches (50mm), ensuring coverage over entire repair area. # layers achieved during installation: _____	
31	Primer Material Installation	Primer material mixed in correct ratios as specified on product packaging and fully mixed with no streaking or marbling visible, and in a manner which limits air pockets being “whipped” into the mixture. Primer Name: _____	
32		Mixed primer material installed 360° around the circumference of the pipe at a thickness specified in installation guide to completely cover the specified Repair Length plus two (2) inches (50mm), ensuring coverage over entire repair area. Thickness specified for ECR System Primer: _____ Thickness achieved during installation: _____	

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	What is the specific type of ECR System being installed? Refer to specified ECR System Detailed Installation Guide for information on specific requirements of the composite wrap, and complete only the relevant checks for the composite wrap type as defined below. Contact NRI (customerservice@neptuneresearch.com) to obtain necessary documents if needed. **Pre-Impregnated Moisture Cured Urethane (MCU)** = Complete MCU Checks 33-36. **Field Saturated Epoxy (FSE)** = Complete FSE Checks 37-41. **Pre-Impregnated Heat Cured Epoxy (PI-HCE)** = Complete PI-HCE Checks 42-44.		
33	MCU Composite Wrap Installation • *Syntho-Glass® XT* • *Viper-Skin®* • *Steel-Wrap® MCU*	100% of the wrap was activated with clean water during the wrapping of the material.	
34		The wrapping start point was one (1) inch (25mm) from the edge of the Primer material and end point was one (1) inch (25mm) from the end of the Primer material.	
35	MCU Composite Wrap Installation • *Syntho-Glass® XT* • *Viper-Skin®* • *Steel-Wrap® MCU*	Total number of layers installed is at least the required as stated in the calculation/design documentation (more layers is acceptable, less is not). Total # MCU Layers Installed = _____	
36		4 layers of compression film was installed over the entire repair area landing on the outside area beyond the composite wrap, and fully perforated within 5 minutes of completing the composite wrapping.	
37	FSE Composite Wrap Installation • *Thermo-Wrap™* • *Thermo-Wrap™ Inspectable* • *Thermo-Wrap™ CF* • *Acid-Shield™* • *Steel-Wrap® E*	Saturant polymer mixed per specified mix ratio, and fully mixed/agitated until uniform in color with no streaking/marbling visible.	
38		100% of the composite wrap dry fabric saturated using the mixed saturant polymer to ensure no dry spots remain but was not over-saturated which could cause potential sagging. Use of NRI's Resinator™ tool is required for saturating fibers on site and ensuring the proper resin to fiber ratio is achieved.	
39		The wrapping start point was one (1) inch (25mm) from the edge of the Primer material and end point was one (1) inch (25mm) from the end of the Primer material.	
40		Total number of layers installed is at least the required as stated in the calculation/design documentation (more layers is acceptable, less is not). Total # FSE Layers Installed = _____	
41		4 layers of compression film was installed over the entire repair area landing on the outside area beyond the composite wrap within 5 minutes of completing the composite wrapping.	

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42	PI-HCE Composite Wrap Installation • *Thermo-Wrap™ 500*	The wrapping start point was one (1) inch (25mm) from the edge of the Primer material and end point was one (1) inch (25mm) from the end of the Primer material.	
43		Total number of layers installed is at least the required as stated in the calculation/design documentation (more layers is acceptable, less is not). Total # PI-HCE Layers Installed = _____	
44		4 layers of heat resistant, compression film was installed over the entire repair area landing on the outside area beyond the composite wrap to prepare for heat curing process.	

	Curing Protocol	**Data / Values**	**Initials**
45	Curing Temperature & Time Frame	Acceptable cure temperatures and time frames vary significantly for ECR Systems and must be measured and met in order to ensure an installation will perform as designed and desired. Consult Detailed Installation Guide or Technical Data Sheets to confirm curing specifications of the ECR System being utilized. Temperature of system during cure: _____ Time of cure at given temperature above: _____ Provide verification of temperature maintained either by time vs. temperature charts or by monitoring via thermocouples depending on site capacities and availability. *Example: If curing was completed overnight, it is important to know that the temperature of the repair was maintained and did not drop to a much lower temperature than when installed, as this will slow the curing profile based on the lower temperature experienced during the curing.*	
46	Post and/or Force Curing Notes	Provide any deviation information on curing of the ECR System should it be required (such as if the installation is made on elevated temperature piping that cures the ECR System faster than typical ambient conditions, or heat added due to cold environment, etc.). Leave this section blank if typical cure schedule is met. Notes:	

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	Final Repair Inspection	Data / Values / Requirements	Site Readings / Sign-off
	Hardness requirements must meet minimum requirements of the technical data. The ECR System's components should meet the minimum requirement of 90% of the ultimate hardness value typically published in the product's TDS to be considered ready for use as required by the ASME PCC-2 Article 4.1 and ISO-24817 standards. When using a Durometer of Type D for measuring hardness of cured composite, reference: ***ASTM D2240*** *"Standard Test Method for Rubber Property – Durometer Hardness"* • *Testing should be performed by placing the pin on the highest point of the composite repair to insure a proper reading is taken* • *The test point shall be placed directly on a fiber and not the valley where the fibers cross as this could result in a false low reading* • *A minimum of 10 test readings shall be taken to get the average value* • *The readings shall be taken at random points along the repair to represent all areas (top of pipe, sides of pipe, bottom of pipe, etc.)* • *For fillers which may be covered by the repair system installation, place a sample of the material used on site to the side for curing in the same conditions to be hardness tested with the system* Minimum values required for each of NRI's ECR Systems shown below (place check next to system being used and inspected by this form). Note that Compression Film ***MUST*** be removed to complete all following final inspection steps.		
47	Shore D Hardness: Filler Material	☐ Syntho-Glass XT = **74** ☐ Viper-Skin = **74** ☐ Thermo-Wrap = **78** ☐ Thermo-Wrap CF = **81** ☐ Acid-Shield = **78** ☐ Thermo-Wrap 500 = **82** ☐ Steel-Wrap E = **75**	Shored D Hardness Reading Average: _____
48	Shore D Hardness: Primer Material *(as applicable; not required if polymer in composite wrap is the same as primer)*	☐ Syntho-Subsea LV = **74**	Shored D Hardness Reading Average: _____
49	Shore D Hardness: Composite Wrap	☐ Syntho-Glass XT = **74** ☐ Viper-Skin = **74** ☐ Thermo-Wrap = **78** ☐ Thermo-Wrap CF = **81** ☐ Acid-Shield = **78** ☐ Thermo-Wrap 500 = **82** ☐ Steel-Wrap E = **75**	Shored D Hardness Reading Average: _____
50	Final Repair Length	Final, overall repair length must be at least the required Repair Length as specified in the design calculations. Repair Length specified in design: _____	Final Repair Length: _____

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51	Repair Location	Final repair is correctly located on piping section of concern with defect located within repair length providing sufficient length wrapped beyond the defect in each direction. A longer repair length than calculated is acceptable.	
52	Final Repair Thicknes	Final repair thickness must be at least the required # layers as specified in the design calculations. May be found by measuring final circumference and calculating by: C = π x OD *Where: C = Circumference of pipe; OD = Outside diameter* CCP = π [OD + Primer + (2 x "#Layers" x "Thickness per Layer")] *Where: CCP = Circumference of pipe & composite* *Final thickness = (CCP – C)/2* # layers & repair thickness specified in design: _____	Repair Thickness: _____ # Layers: _____
	The following inspection steps shall be completed in accordance with "allowable limits" criteria as defined by the ASME PCC-2 Article 4.1 (Table 6) and ISO-24817 (Table 16) standards. Indicate either "Accepted" or "Not Accepted" based on visual inspection and stated Allowable Limits.		

	Defect Type	**Allowable Limits**	
53	Delamination	Tap test near ends of Repair Length. No delamination/disbonding allowed at ends of repair.	☐ Accepted ☐ Rejected
54	Cracks in Surface	None allowed.	☐ Accepted ☐ Rejected
55	Foreign Matter, Blisters, and Pits	Maximum of 0.4" (10mm) in width, and 0.1" (2.5mm) in height.	☐ Accepted ☐ Rejected
56	Wrinkles	No step changes in thickness greater than 0.1" (2.5mm) in height.	☐ Accepted ☐ Rejected
57	Pinholes/Wormholes	None deeper than outer surface, polymer-rich layer.	☐ Accepted ☐ Rejected
58	Polymer Color	Should be uniform in color within same polymer system. (Different polymers used such as filler/primer/saturant may be different colors, but colors within same polymer should be uniform)	☐ Accepted ☐ Rejected
59	Dry Spots and Exposed Fibers	None allowed in composite wrap.	☐ Accepted ☐ Rejected

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**** Provide photos before, during and after installation for the quality records and future inspection reference ****

Installer Technician/Supervisor Sign-off:

Name:_____NRI Training ID #:_____

Signature:_____Date:_____

By signing the above, the installation technician/supervisor is confirming that he/she has completed the mandatory qualification training for the ECR System installed, that each step of the defined ECR process was completed per the specific detailed installation guide for the product utilized, and that all values are accurate and correct as recorded. Any deviation from the specified process was recorded and approved by the asset owner prior to proceeding with the repair.

Additional Techs: *Provide name and Training ID# for all trained techs on site for requalification records.*

Name:_____NRI Training ID #:_____

Name:_____NRI Training ID #:_____

Name:_____NRI Training ID #:_____

Name:_____NRI Training ID #:_____

Asset Owner/Operator Sign-off*:

Name:_____NRI CIC ID#:_____

Signature:_____Date:_____

By signing the above, the asset owner is confirming that the pipe specifications, operational and installation parameters, repair design parameters are correct and match the design proposal for the intended repair, that the installation process was followed, and the final repair was inspected according to established standards and found to be acceptable based on requirements of the ECR System utilized.

**It is highly recommended that the representative from the asset owner have previously completed the NRI Composite Inspection Course (CIC) to fully understand the requirements of commissioning a completed ECR.*