

Specification for Carbon Fiber Reinforced Composite (FRP) System For Pipe & Conduit Repair & Rehabilitation

1.0 Scope

- 1.1** This specification covers the application, manufacturing, and installation of a carbon fiber reinforced composite system for structural and non-structural repair and rehabilitation of pipelines and other conduits.
- 1.2** This specification is intended to aid purchasers, contractors and users of carbon fiber repair composites in establishing acceptable criteria for the selection, application, and installation of a carbon fiber composite repair system.
- 1.3** The FRP renewal process utilizes carbon fibers and high strength epoxy resins. Hand applied to the internal or external surface the FRP system is for structural rehabilitation and strength enhancement of all types of conduit.
- 1.4** The FRP renewal process shall create a rehabilitated conduit with improved chemical resistance characteristics, improved flow coefficients, and, where required, structural enhancement for the host pipe.
- 1.5** The renewal system is intended for circular and non-circular gravity and pressure piping systems and shall be capable of being installed with little or no surface excavation. For internal repairs, a typical entry point into the system will be from a manhole or outfall. When completed, the FRP system shall extend over the contractually-specified renewal limits.

2.0 Referenced Documents

<i>ASTM D 3039:</i>	<i>Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials.</i>
<i>ASTM D 5379:</i>	<i>Standard Test Method for Shear Properties of Composite Materials by V-Notched Beam Method.</i>
<i>ASTM D 790:</i>	<i>Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Insulating Materials.</i>
<i>ASTM D 4541:</i>	<i>Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Testers.</i>
<i>ASME PCC-2</i>	<i>Article 4.1; Non-Metallic Composite Repair Systems for Piping & Pipework: High Risk Applications Article 4.2; Non-Metallic Composite Repair Systems for Piping & Pipework: Low Risk Applications.</i>
<i>ASTM E 831</i>	<i>Standard Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis.</i>
<i>ASTM D 2583</i>	<i>Standard Test Method for Indentation Hardness of Rigid Plastics by Means of Barcol Impressor.</i>
<i>ASTM G8</i>	<i>Standard Test Method for Cathodic Disbonding of Pipeline Coatings.</i>
<i>ASTM D3165</i>	<i>Standard Test Method for Strength Properties of Adhesives in Shear by Tension Loading of Single-Lap-Joint Laminated Assemblies.</i>

3.0 Composite Material

3.1 Definitions:

Primer: 100% solids, high build epoxy primer that provides excellent adhesion to a variety of substrates while allowing sag free application at high film builds.

Wet-Out: 100% solids, epoxy resin designed to thoroughly wet-out the carbon fiber forming a composite matrix with very high tensile and flexural properties.

Carbon Fiber: Strands of carbon fiber arranged in various unidirectional or bidirectional weaves providing high strength characteristics, excellent corrosion resistance and excellent fatigue properties.

Composite System: System consisting of epoxy primer, epoxy wet-out and carbon fiber.

3.2 Specifications: The carbon fiber repair system shall provide, as a minimum, the physical and chemical properties listed below:

Primer:

Working Life @ 68°F	15 minutes
Dry Time @ 68°F	4 hours
% Vol Solids (ASTM 2369)	100
Shore D Hardness (ASTM D2240)	80
Flash Point	>200°F

Wet-Out:

Working Life @ 68°F	15 minutes
Dry Time @ 68°F	4 hours
% Vol Solids (ASTM 2369)	100
Shore D Hardness (ASTM D2240)	85
Flash Point	>200°F

Carbon Fiber

	12k x 3k	3k x 3k
Warp raw material	12K Continuous Tow	3K Continuous Tow
Filling raw material	3K Continuous Tow	3K Continuous Tow
Weave Style	Plain	Plain
Fabric Areal Weight	300 gsm (approx.)	193 gsm (approx.)
Warp Ends/Inch	8.0 +/- 1.0	12.5 +/- 1.0
Pick/Inch	8.0 +/- 1.0	12.5 +/- 1.0
Nominal Thickness	.02 inches	.012 inches

Composite

	300C12	200C6
Tensile Strength (psi) (Hoop Direction)	104,000	44,100
Tensile Modulus (psi)	8,260,000	4,440,000
% Elongation	1.27	1.04
Flexural Strength (psi)	77,300	54,100
Flexural Modulus (psi)	3,800,000	2,360,000
Maximum Operating Temp (°F)	250	250
Coefficient of Expansion	5.6 x 10 ⁻⁶	

Adhesion:

Substrate	ASTM D4541 (psi)
Cold Rolled Steel	>2,000
Hot Rolled Steel	>2,000
Cast Iron	>2,000
304 Stainless Steel	>2,000
316 Stainless Steel	>2,000
Concrete	Concrete Failure

Chemical Resistance

ASTM D543 (30 day immersion)

Water	No effect
Sodium Hydroxide 5%	No effect
Ammonium Hydroxide 5%	No effect
Sodium Hypochlorite (bleach)	No effect
Ferric Chloride 1%	No effect
Sulfuric Acid 20%	No effect
Nitric Acid 1%	No effect
Detergent Solution	No effect
Gasoline	No effect
Toluene	No effect

3.3 Manufacturer:

The carbon fiber reinforced composite system shall be manufactured and supplied by **HydraTech Engineered Products LLC**, 10448 Chester Road, Cincinnati, Ohio 45215.

4.0 Submittals & Documentation

- 4.1** The owner, consulting engineer, contractor or any other party authorized by the owner, requesting repair of a pipe defect shall submit details regarding the pipe service, existing condition, operating parameters, type of defect and other pertinent information as outline in Attachment A “**Engineering Evaluation**”.
- 4.2** The composite manufacturer shall review the data furnished by the owner, or party representing the owner, and shall design composite repair system in accordance with applicable codes and specifications. The composite system supplier shall provide engineering data and calculations to verify recommended composite thickness to meet the requirements of the project.
- 4.3** The composite manufacturer shall provide all test information, including independent test data, with regards to the carbon fiber system being recommended.
- 4.4** When applicable, the composite manufacturer shall submit engineering drawings detailing the repair method to assist owners and/or the installation contractor with the installation of the carbon fiber repair method.

5.0 Pre-Installation & Site Preparation

5.1 Material Handling, Storage & Inspection

- 5.1.1 All materials shall be properly stored. Water contamination, temperatures below 32°F and above 100°F should be avoided.
- 5.1.2 Fabric boxes should not be stored on end, be in contact with moisture or left open in direct sunlight.
- 5.1.3 Materials should be visually checked for damage or defects that may affect performance or installation.
- 5.1.4 Inspect and certify that all required materials are available, identified by lot numbers, correctly labeled and have not reached their shelf life or use expiration date.
- 5.1.5 All required installation tools and equipment are on-site and in good working condition.
- 5.1.6 All testing equipment requiring calibration are verified as properly calibrated, functional and available for use.

5.2 Site Preparation

- 5.2.1 All work shall be performed in accordance with applicable OSHA standards and Owner specified safety regulations.
- 5.2.2 All debris and obstructions shall be removed from the host pipe and disposed of in accordance with the requirements of the contract, and local codes and ordinances.
- 5.2.3 Where required for internal repairs, the Contractor shall provide by-pass flow around the length of host pipe designated for repair.
- 5.2.4 By-passing shall consist of, but is not limited to, plugging the host pipe at an existing upstream access point (manhole) and pumping flow to an access point downstream of pipe area requiring repair.
- 5.2.5 By-pass flow shall be maintained until the repair and rehabilitation process is complete.
- 5.2.6 Contractor and Owner shall establish access points for internal pipe repairs or repairs requiring confined space entry.
- 5.2.7 Should temporary excavations be needed to access the host pipe, such work shall be coordinated with the Owner. Excavations shall be sloped or shored in accordance with all applicable safety regulations.
- 5.2.8 If required continuous forced air ventilation shall be established and is sufficient to maintain the confined space safe for entry.

6.0 Installation

6.1 Safety

- 6.1.1 All work shall be performed in accordance with applicable OSHA standards and Owner specified safety regulations.
- 6.1.2 Contractor shall provide all confined space apparatus and employees trained to work in confined space areas when internal pipe repairs are part of the scope.

6.2 Pre-Installation Inspection & Surface Preparation

- 6.2.1 The surface preparation method is dependent on the substrate and component(s) which the FRP System will be applied to and the engineering parameters being sought (e.g., strength, abrasion resistance, etc.). Generally the surface should be accessible to facilitate wrapping, clean, dry and free of extremely low or high areas. Specific details and requirements may be given on the manufacturer's Engineering Instructions for the

work being performed. Any deficiencies shall be documented and reviewed by the manufacturer prior to installation.

- 6.2.2 Remove all loose dirt, scale, and other debris from application areas in accordance with the manufacturer's Engineering & Installation Instructions at least 2 inches on each side of where fabric will be applied. The idea adhesion for the primer to the substrate is to provide a surface profile and near white metal surfaces. Grinding, wire brushing and water blasting are acceptable as long as a surface profile is present. Surface preparation in mandatory at each end of the wrap in the case of significant wall loss is anticipated.
- 6.2.3 Substrate preparation dictates the adhesion performance of any coatings system. A properly prepped surface will ensure maximum life and performance of the system. See the manufacturer's Engineering & Installation Instructions for recommended surface preparation. In general the following surface preparation will be recommended:
 - Concrete:** NACE No.6* / SSPC-SP 13*
 - Steel:** NACE No.2* / SSPC-SP 10*
 - NACE No.3 / SSPC-SP 6
 - NACE No.5 / SSPC-SP 12
- 6.2.4 Mark the locations on the prepared surface to clearly define the installation positions or locations.
- 6.2.5 All sharp edges and corners are rounded to a minimum ½ inch radius. This can also be accomplished by thickened epoxy resin build-up.
- 6.2.6 All high/low surface imperfections (including dirt, scale, and other debris) running axially through or part way through the installation surface must be removed.
- 6.2.7 Any joint gaps or deep imperfections must be properly filled with approved joint filler and rendered smooth.
- 6.2.8 Required repairs or patch work shall be completed and cured prior to application of primer or epoxy materials.
- 6.2.9 The locations of all lateral connections to the host pipe shall be noted and suitable preparation made to ensure the FRP connects into the lateral connections.
- 6.2.10 The Contractor shall perform a pre-installation video or photographic survey of the host pipe as required by the Owner.

6.3 Installation

- 6.3.1 The Contractor shall furnish all tools, equipment, materials and supplies and shall perform all labor required to complete installation of the fiber reinforced polymer (FRP) renewal process in full conformity with the Contract Documents
- 6.3.2 The FRP System shall be installed by experienced and qualified personnel. Personnel shall use proper PPE.
- 6.3.3 Temperature and humidity controls will be established in accordance with Engineering Instructions. If required these conditions will be documented and verified at the specified frequency and recorded.
- 6.3.4 All components shall be evenly and completely mixed at the proper ratios specified.
- 6.3.5 Surfaces shall be properly primed in accordance with the manufactures instructions.
- 6.3.6 The Primer acts as an adhesive and also a filler between the substrate and the fabric. Typically applying a 30-50 mil thick layer of primer evenly over the prepared substrate is required.
- 6.3.7 The primer should fully cover the prepared areas with a smooth surface filling voids and other surface irregularities.
- 6.3.8 All manual fabric wet-out saturation work shall be monitored by Supervision and performed by Qualified Installation personnel.
- 6.3.9 The combination of fabric and epoxy materials shall be applied to a prepared surface using methods that provide a uniform surface across the width of the fabric. Overlaps will be as designated on the Engineering Instructions and will be recorded on the Daily Installation Report.

- 6.3.10 Dry light-weight fabrics may be applied directly to wet primed surfaces and saturated in-situ using a paint roller, brush or trowel.
- 6.3.11 The finished exposed edges shall be covered by epoxy or trim cut for aesthetics.
- 6.3.12 Unilateral or multidirectional fibers shall be applied in accordance with the Engineering Instructions. The sequence and details shall be documented on the Daily Installation Report. See Attachment B.
- 6.3.13 The sequence and details of installation shall be documented. See Attachment B.
- 6.3.14 Any excess materials, application tools and containers shall be removed from site by Contractor.
- 6.3.15 If specified material testing coupons are required, they shall be prepared in the same manner and with the same materials use for the installation. A minimum of two (2) samples will be taken unless otherwise specified. A flat and smooth surface shall be covered with a non-stick material for the preparation of the samples in the same manner that the installation is being accomplished.
- 6.3.16 Batch numbers and/or lot numbers will be recorded each day for polymer liner materials that are used.
- 6.3.17 Application conditions shall be per the following.

Minimum Application Temperature	40°F (4.4°C)
Maximum Relative Humidity	85%
Substrate Temperature	5°F (3°C) above dew point
Thinning	Do not thin
Cleaning Fluid	Paint Thinner; MEK, or equal
	To aid application at low temperatures, both components should be warmed to 60-68°F (15.5-20°C) prior to mixing.

7.0 Post Inspection & Site Restoration

- 7.1 When required by contract, Contractor shall perform post-inspection video or a photographic survey.
- 7.2 The renewed conduit shall be subject to a final inspection, and no such work shall be scheduled or started without having made prior arrangements with the Owner to provide for the required inspections. Not less than 24 hours notice shall be provided to the Owner for scheduling such inspections.
- 7.3 Any defects in the FRP lining must be recorded and repaired by an approved method.
- 7.4 At points where temporary excavation was required for access to the host pipe or lateral connections, appropriate encasement shall be provided for the exposed pipes. Encasement materials may consist of concrete, sand slurry, or other suitable materials as approved by the Owner.

8.0 Quality Assurance

- 8.1 Work shall be performed by a Contractor who has a proven record of performance for similar installations. Contractor shall submit resumes for superintendents, foremen, and other applicable lead personnel for field installation crews demonstrating competency and experience to perform the work scope as defined in this specification and all other applicable contract documents.
- 8.2 The Contractor shall be licensed by the FRP material manufacturer.
- 8.3 Documents of qualification by the FRP manufacturer certifying the fitness of their products for use in the lining system and conformance to the requirements of this specification and all other

applicable contract requirements. Certification shall also provide the history of successful application of the product.

- 8.4** During installation, a quality record providing the physical properties of the applied liner. Properties to be measured from test coupons prepared on site if required by contract documents.
- 8.5** During installation, a quality record of the applied material thickness, if required by contract documents.
- 8.6** Within 2 weeks of final acceptance of the work the Contractor shall submit a post-installation video or photographic survey of the renewed conduit to the Owner, when feasible and deemed necessary:

9.0 Acceptance

- 9.1** Owner shall acknowledge acceptance of repair and rehabilitation work by providing Contractor with signed acceptance form (attachment C).

ATTACHMENT "A"

ENGINEERING EVALUATION ASSESSMENT #

CONTACT INFORMATION	
Client Name	
Contact	
Address	
Phone	
Email	

INSTALLER INFORMATION	
Installer Name	
Contact	
Address	
Phone	
Email	

PROBLEM DESCRIPTION
Description:

PIPELINE INSTALLATION	
Pipeline Identification	
Outer Diameter	
Material/Grade	
Nominal Thickness	
Material/Grade	
Design Temperature	
Operating Temperature	
Design Pressure	
Operating Pressure	
MAWP (Max Allowable Working Pressure)	

PIPELINE INSTALLATION	
Line Chemistry	
Flow Rate	
Pipe Coatings	

PIPE LOCATION: Above Ground Below Ground Distance: _____

Soil Type: N/A Sand/Gravel Clay Silt Stone

Live Loading: N/A H-20 Railroad Airport

DEFECT INFORMATION:

Defect Cause: Erosion Corrosion Mechanical

Attached Details: Drawings/Photos Thickness Readings
 Inspection Reports Other _____

Defect Location: Straight Elbow Tee/Wye

Defect Size: Length _____ Width _____ Depth _____

REPAIR INFORMATION:

Repair Type: Internal External Allowable Duration _____

Line Pressurized During Installation? Yes No Pressure _____

Ambient Temp: Minimum _____ Maximum _____ Humidity _____

PIPELINE LIMITATIONS	
Surface Preparation Limitations	
Pipe Access Limitations	
Humidity	
Ambient Temperature	

NOTES
Description:

Attachment "B"

Job No. _____
 Date: _____

Project Manager: _____
 Qualified Applicator(s) _____

ENVIRONMENTAL CONDITIONS

Time	Temp °F	Relative Humidity	Substrate Temp	Dew Point

General Weather Conditions _____

APPLICATION SYSTEM

Surface Preparation: None Hand Clean Mechanical Jet wash/vac
 Special (below)

Application: Weld Straight Spiral Elbow Tee Other

Fabric Type: Unidirectional Multidirectional

Wraps: 1-Ply 2-Ply 3-Ply 4-Ply Other _____

Epoxy: Standard High temp Acid Resist

Primer: Spray Roller Brush

DAILY INSTALLATION TOTALS

Product /Service (Description & Lot number)	Pipe Diameter/Installed Length/Joint Total (Complete new line for each different service, product, pipe size or phase)

LOCATION

LOCATION						
Direction of Wrap						
Number of Wraps						
Overlap of Fabric						

Project Manager: _____

Date: _____

Attachment "C"

Client Name: _____ Job # _____

Client Address: _____

Project Location: _____

Description of Project: _____

Products Installed: _____

Completion of Work:

Client signature confirms that the full scope of the original contract and all associated addendums, punchlist items, and additional work orders have been completed:

Client Representative:

Date