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*Notification of this Addendum is transmitted via email to all current plan holders.  
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October 14, 2016

**ADDENDUM NO. 1**  
**TO CONTRACT DOCUMENTS FOR THE**  
**PACHECO CONDUIT REHABILITATION PROJECT**  
**Project No. 91214001**

**Contract No. C0621**

Notice is hereby given to Prospective Bidders that the Contract Documents are modified as hereinafter set forth.

**BID DOCUMENTS**

**NOTICE TO BIDDERS**

**Section 4. Contract Time**

**REPLACE** Paragraph D. in its entirety with:

“D. Milestone # 4 - All shutdown-related work required to restore Hollister Conduit to service. The Contractor shall complete Milestone #4 work before the expiration of 42 calendar days from the first day that the transmission system is taken out of service.”

**ADD** New Paragraph E.:

“E. Milestone # 5 - All shutdown-related work required to restore the transmission system to service. The Contractor shall complete Milestone #5 work before the expiration of 80 calendar days from the first day that the transmission system is taken out of service.”

**REPLACE** Paragraph E. and F. in their entirety with:

“F. Milestone # 6 - All non-shutdown-related work required to completely rehabilitate and upgrade all pipeline and tunnel appurtenances and vaults. The Contractor shall complete Milestone #6 work before the expiration of 20 calendar days from the first day that the transmission system is returned to service.”

G. Milestone # 7 (Project Completion) - All work required to complete the Project. The Contractor shall complete Milestone #7 work before the expiration of 20 calendar

days from the first day that the Contractor completes Milestone #6 the first day that the transmission system is returned to service.”

## **SPECIFICATIONS AND CONTRACT DOCUMENTS**

### SPECIAL PROVISIONS

#### **Article 12.01. Summary of Work**

**REPLACE** Paragraphs F.4. through F.6. in their entirety with:

- “4. The scope of work to be completed under **Milestone 4** - Hollister Conduit at BIF includes:
- a. All shutdown related work required to completely rehabilitate and upgrade all pipeline appurtenances on the Hollister Conduit at BIF.
    - (1) Remove 42” hydraulically operated BFV and install 42” electrically operated BFV.
    - (2) Install 42” Restrained FCA.
    - (3) Replace 42” BFV Support.
    - (4) Install 42” manually operated BFV.
    - (5) Install 42” BFV Support.
    - (6) Remove 12” hydraulically operated bypass BFV.
    - (7) Replace 12” bypass assembly.
    - (8) Install 12” electrically operated BFV.
    - (9) Install 12” bypass assembly supports.
    - (10) Replace 6” BFV and COMB ARV.
    - (11) Install (1) 4” flanged nozzle and BV.
    - (12) Install (2) 10” bypass pumping risers.
5. The scope of work to be completed under **Milestone 5** includes:
- a. All shutdown related work required to restore the Pacheco Conduit, the Santa Clara Conduit and the Santa Clara Tunnel to service.
    - (1) Pacheco Conduit, Santa Clara Conduit and Santa Clara Tunnel appurtenance work – The Contractor shall complete the work as depicted in the Drawings and as specified in the Pipeline Maintenance Tables on sheets G-5 through G-8 of the Drawings, except as noted.

- (2) Pacheco Conduit and Santa Clara Conduit manned internal visual and electromagnetic inspection work – The Contractor shall support and participate in all internal pipeline inspection activities. See Article 31.07 – ‘Support for Internal Pipeline Work’.
- (3) Pacheco Conduit and Santa Clara Conduit internal repair work – Based on results of the visual and electromagnetic inspections, the Contractor may be required to:
  - (a) Install internal Carbon Fiber Reinforcement in multiple deteriorated sections of the existing Prestressed Concrete Cylinder Pipe. See Article 42.03 – ‘Carbon Fiber Reinforcement’.
  - (b) Install internal weko-seals at multiple locations. See Article 31.05 – ‘Weko-Seal Installation’.
  - (c) Perform internal pipeline repairs and debris removal at multiple locations. See Article 31.08 – ‘Internal Pipeline Work & Debris Removal’
- (4) Santa Clara Tunnel Lining – The Contractor shall install a Polyurea lining from station 15+00 to 19+60.
  - (a) Based on the District and Contractor internal tunnel inspection and jointly developed internal tunnel repair scope of work, the Contractor shall:
    - i) Perform cement contact grouting. See Article 42.02 – Contact and Pressure Grouting.
    - ii) Perform water intrusion polyurethane injection concrete crack repair. See Article 42.01 –Polyurea Liner.
    - iii) Perform structural epoxy injection concrete crack repair. See Article 42.01 – Polyurea Liner.
    - iv) Perform concrete surface repair. See Article 42.01 – Polyurea Liner.
  - (b) The Contractor shall prepare the internal concrete surface of the tunnel as required for the installation of the Polyurea Lining and install the Polyurea Lining. See Article 42.01 – ‘Polyurea Liner’.

6. The scope of work to be completed under **Milestone 6** includes:

- a. All non-shutdown related work required to completely rehabilitate and upgrade all pipeline and tunnel appurtenances and vaults.
  - (1) Install all stairs, ladder and maintenance platforms at BIF.

- (2) Demo and remove the hydraulic system at BIF.
- (3) Reconstruct and/or repair all facility components that were adversely impacted by construction operations.
- (4) Prepare and paint all in-vault and exposed exterior pipeline, appurtenance and associated component surfaces at all work sites.
- (5) Complete final site cleanup”

**ADD** Milestone 7:

- “7. The scope of work to be completed under **Milestone 7 – Project Completion** includes:
- a. Participate in project walk-thru with District and applicable city and county representatives and assist with the development of a project punch list.
  - b. Complete project punch list items.
  - c. Complete all remaining project closeout work required under the Contract.”

**Article 12.03. Contract Time(s)**

**REPLACE** Paragraph C., items 4. through 6. in their entirety with:

- “4. The Contractor shall complete **Milestone 4** before the expiration of 42 Calendar Days from the first day that the raw water transmission system is taken out of service. See Article 12.01 – ‘Summary of Work’ for the Milestone 4 scope of work.
5. The Contractor shall complete **Milestone 5** before the expiration of 80 Calendar Days from the first day that the raw water transmission system is taken out of service. See Article 12.01 – ‘Summary of Work’ for the Milestone 5 scope of work.
  - a. Based on the findings of the internal visual and electromagnetic inspection and the extent of the resulting internal repairs as specified in Article 12.01 – ‘Summary of Work’, the allowable time for the completion of Milestone 5 may be reevaluated.
6. The Contractor shall complete **Milestone 6** before the expiration of 20 Calendar Days from the first day that the raw water transmission system is returned to service. See Article 12.01 – ‘Summary of Work’ for the Milestone 6 scope of work.”

**ADD** Paragraph C., item 7.:

- “7. The Contractor shall complete **Milestone 7** before the expiration of 20 Calendar Days from the first day that the Contractor completes Milestone 6. See Article 12.01 – ‘Summary of Work’ for the Milestone 7 scope of work.”

**Article 12.03. Contract Time(s)**

**REPLACE** Table 12.03-1, Tentative Schedule of Work in its entirety with:

<b>Description</b>	<b>Duration (Calendar Days)</b>	<b>Start Date</b>	<b>End Date</b>
Milestone 1 Scope of Work – Site Preparation & Equipment Staging	31	Tuesday, December 13 2016	Friday, January 13, 2017
Pipeline Isolation, LOTO & Initial District Draining	3	Friday, January 13, 2017	Sunday, January 15, 2017
Milestone 2 Scope of Work – Pipeline Dewatering & Inspection Preparation	21	Monday, January 16, 2017	Sunday, February 5, 2017
Internal Santa Clara Tunnel Visual Inspection for Grouting & Surface Repair Scope of Work	1	Thursday, February 2, 2017	Thursday, February 2, 2017
Internal Pipeline Visual & EM Inspection	7	Monday, February 6, 2017	Sunday, February 12, 2017
Acoustic Fiber Optic (AFO) Monitoring Installation	28	Monday, February 13, 2017	Sunday, March 12, 2017
Milestone 3 Scope of Work – AFO Installation Support	14	Monday, February 13, 2017	Sunday, February 26, 2017
Milestone 4 Scope of Work – Shutdown Required Work	<u>42</u>	Friday, January 13, 2017	Friday, February 24, 2017
Milestone 5 Scope of Work – Shutdown Required Work	80	Friday, January 13, 2017	Sunday, April 2, 2017
Pre-Fill Appurtenance Inspection	3	Monday, April 3, 2017	Wednesday, April 5, 2017
Pipeline De-isolation, LOTO, Fill & Pressurization	2	Thursday, April 6, 2017	Friday, April 7, 2017
Pressurization Appurtenance Inspection	3	Monday, April 10, 2017	Wednesday, April 13, 2017
Milestone 6 Scope of Work – Non-Shutdown Required Work	20	Monday, April 10, 2017	Sunday, April 30, 2017
Milestone 7 Scope of Work – Project Completion	20	Monday, May 1, 2017	Sunday, May 21, 2017

## **Article 12.05. Liquidated Damages**

**REPLACE** Paragraph A. in its entirety with:

- “A. In accordance with Standard Provisions Article 5.07. Liquidated Damages, the District may assess as Liquidated Damages the following amounts:
1. \$3,500 per Day for failure to complete all Work of Milestone 1 within the time limit allowed.
  2. \$23,000 per Day for failure to complete all Work of Milestone 2 within the time limit allowed.
  3. \$7,500 per Day for failure to complete all Work of Milestone 3 within the time limit allowed.
  4. \$7,500 per Day for failure to complete all Work of Milestone 4 within the time limit allowed.
  5. \$7,500 per Day for failure to complete all Work of Milestone 5 within the time limit allowed.
  6. \$3,500 per Day for failure to complete all Work of Milestone 6 within the time limit allowed.
  7. \$3,500 per Day for failure to complete all Work of Milestone 7 within the time limit allowed.
  8. \$250 per Day for failure to submit the Preliminary Progress Schedules, any Progress Schedules, or master submittal list within the time limits allowed.”

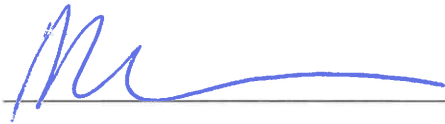
**ADD** Paragraph A., item 9.:

9. \$350 per Day for failure to submit each of the immediate submittals as listed within the time limits allowed.”

## **TECHNICAL PROVISIONS**

**ADD** Article 42.03 – INTERNAL CFRP LINER REPAIR OF DISTRESSED PCCP  
**(ATTACHMENT 1)**

THIS ADDENDUM NO.1, WHICH CONTAINS 7 PAGES AND 1 ATTACHMENT, IS ATTACHED TO AND IS A PART OF THE SPECIFICATIONS AND CONTRACT DOCUMENTS FOR THIS PROJECT.



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Date: 10/14/16

Debra Caldon  
Acting Deputy Operating Officer  
Water Utility Technical Support Division

Enclosure(s):

1. ATTACHMENT 1 – TECHNICAL PROVISIONS SECTION 42.03 – INTERNAL CFRP LINER REPAIR OF DISTRESSED PCCP

**PACHECO CONDUIT REHABILITATION PROJECT  
ADDENDUM NO. 1**

**ATTACHMENT 1:  
TECHNICAL PROVISIONS SECTION 42.03 – INTERNAL  
CFRP LINER REPAIR OF DISTRESSED PCCP**



**PART 1 GENERAL**

1.01 DEFINITIONS

**Carbon Fiber Reinforced Polymer (CFRP) Composite System:** A proprietary system consisting of all associated fiber reinforcement and polymer adhesives/resins and installation requirements. All components of the CFRP composite system, including primer, thickened epoxy, fiber reinforcement, impregnating resin, and topcoat resin, shall be compatible and provided by the same Manufacturer.

**Contractor's Inspector:** The Contractor's Inspector is an inspector who is a part of the Contractor's QC team and is responsible for performing all inspections specified herein and for initiating corrective action on any nonconformities or defects encountered in the storage and handling of material, surface preparation, saturation of fabric, installation, and curing.

**Installer:** The contractor that installs the CFRP composite system on the PCCP in accordance with all drawings and specifications issued by the Engineer and performs all corrective actions specified by the Engineer and Inspector.

**Manufacturer:** The Manufacturer supplies all components of the CFRP composite system and provides all material data required in this scope of service / specification and instructions for delivery, storage, handling, and application of all materials.

**PCCP:** Pre-stressed concrete cylinder pipe manufactured in accordance with AWWA C301.

**Services:** All labor to be furnished by the Contractor for design, installation, inspection and testing of the CFRP composite repairs.

**Testing Agency:** A qualified testing laboratory that is independent from the Installer and Manufacturer, capable of performing tests according to the ASTM standards specified herein. The Testing Agency is retained by the District, Engineer, or Inspector to perform tension tests on the CFRP witness panels prepared by the Installer during construction. The Testing Agency reports results to the Engineer.

## 1.02 SUMMARY

- A. Contractor shall perform all Work in accordance with the Drawings and these Specifications. Work includes furnishing all materials, equipment, services, training and supervision for installation, inspection and testing of CFRP composite repairs of PCCP in accordance with the Drawings and this Specification, and Federal and State safety requirements.
- B. Contractor shall provide the Installer that supplies the specified CFRP material and labor to install CFRP in 120 in. diameter PCCP, including:
  - 1. Preparation of the internal concrete surface as required by the Engineer's CFRP installation Drawings and these Specifications.
  - 2. Installation of the CFRP laminates in accordance with the Engineer's CFRP Drawings and installation specifications using the wet lay-up technique to the inside surface of the PCCP. Access for all equipment, materials, and crew will be through existing manholes identified by the District.
  - 3. Curing all installed CFRP according to the requirements of these Specifications.
- C. Contractor will mobilize and demobilize all required labor, equipment and materials to and from the Work site.
- D. Contractor will provide all necessary equipment and personnel to complete the work in a timely manner and in accordance with applicable safety, engineering, and schedule requirements.

## 1.03 RELATED REQUIREMENTS

The following references are incorporated into these Specifications. The ACI and ICRI references are not developed for concrete pipe and are applicable only to the extent referenced. These written Specifications take precedence over incorporated references. The Installer shall be familiar with the contents of the latest version of the following references.

- A. ACI 440.3R – Guide Test Methods For Fiber-Reinforced Polymers (Fraps) For Reinforcing or Strengthening Concrete Structures.
- B. ACI 546R – Concrete Repair Guide.
- C. ASTM A240 – Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.
- D. ASTM D570 – Standard Test Method for Water Absorption of Plastics.

- E. ASTM D638 – Standard Test Method for Tensile Properties of Plastics.
- F. ASTM D695 – Standard Test Method for Compressive Properties of Rigid Plastics.
- G. ASTM D696 – Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics between -30 Degree C and 30 Degree C with a Vitreous Silica Dilatometer.
- H. ASTM D790 – Standard Test Method for Flexural Properties of Unreinforced and
- I. Reinforced Plastics and Insulating Materials.
- J. ASTM D792 – Density and Specific Gravity (Relative Density) of Plastics by Displacement.
- K. ASTM D1141 – Standard Practice for the Preparation of Substitute Ocean Water.
- L. ASTM D2240 – Standard Test Method for Rubber Property Durometer Hardness.
- M. ASTM D2247 – Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity.
- N. ASTM D2583 – Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barco Impresser.
- O. ASTM D3039 – Test Method for Tensile Properties of Polymer Matrix Composite
- P. Materials.
- Q. ASTM D3045 – Standard Practice for Heat Aging of Plastics without Load.
- R. ASTM D6641 – Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading.
- S. ASTM D4065 – Standard Practice for Plastics: Dynamic Mechanical Properties: Determination and Report of Procedures.
- T. ASTM D4473 – Standard Test Method for Plastics: Dynamic Mechanical Properties: Cure Behavior.

- U. ASTM D4541 – Standard Test Method for Pull-off Strength of Coatings Using Portable Adhesion Tester.
- V. ASTM D7290 – Standard Practice for Evaluating Material Property Characteristic
- W. Values for Polymeric Composites for Civil Engineering Structural Applications.
- X. ASTM D7616 - Standard Test Method for Determining Apparent Overlap Splice Shear Strength Properties of Wet Lay-Up Fiber-Reinforced Polymer Matrix Composites Used for Strengthening Civil Structures.
- Y. ASTM E104 – Standard Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions.
- Z. ASTM E2160 – Standard Test Method for Heat of Reaction of Thermally Reactive Materials by Differential Scanning Calorimetry.
- AA. ICC-ES – Acceptance Criteria for Inspection and Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber-Reinforced Polymer (FRP) Composite Systems (AC125),” International Code Council Evaluation Service, Inc.
- BB. ICRI Guideline No. 03732 – Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays.
- CC. NSF/ANSI 61 – Drinking Water System Components – Health Effects.

#### 1.04 SUBMITTALS

##### 1.04.1 SUBMITTALS REQUIRED AT TIME OF BID

All items listed in this section shall be submitted with bid.

##### A. Manufacturer Submittals:

1. Documents indicating conformance of the Manufacturer to the experience requirements in these Specifications.
2. Product data sheets for all materials to be used in the CFRP and GFRP systems.
3. All material data required as specified in these Specifications.
4. Material Safety Data Sheets for all materials to be used.
5. Documentation of previous satisfactory applications or thermal test results indicating satisfactory curing performance of the epoxy under the curing schedule recommended by the Manufacturer.

6. Letter from the Manufacturer indicating the allowable time windows between application of primer and thickened epoxy for each layer of the CFRP system, and between completion of the CFRP layers and application of the topcoat considering the likely temperatures in the pipeline during construction.
7. Warranty as required in these Specifications.
8. Delivery, storage, handling, and application instructions and general recommendations for each material to be used.

**B. Installer Submittals:**

1. Documents indicating conformance of the Installer to the experience requirements in these Specifications.
2. Documents indicating compliance of the Installer's Safety Program with the OSHA mining and tunneling division.
3. Detailed work schedule, step-by-step installation procedure, details of curing schedule, and equipment to be used.
4. Working drawings detailing the type, locations, dimensions, number of layers, and orientations of all CFRP materials to be installed.
5. Document indicating agreement of the Installer to have at least two field QC inspectors throughout the project execution as required in these Specification.

**1.04.2 SUBMITTALS REQUIRED AFTER AWARD OF CONTRACT PRIOR TO CONSTRUCTION**

- A. Documents indicating the details of the proposed quality control program and compliance of the field QC inspectors with the experience and training required.
- B. Plan and details of proposed noise abatement measures.

**1.04.3 SUBMITTALS REQUIRED AFTER CONSTRUCTION**

- A. All quality control forms completed throughout the construction, including post-installation corrective actions, if any.
- B. As-built repair drawings indicating all CFRP liner details and end terminations installed.

**1.04.4 CONTRACTOR PROJECT MANAGEMENT/SUPERVISION**

1. Contractor shall submit resumes for key personnel that are going to be involved with the CFRP repair project (Project Manager, Field Superintendents, and Safety Manager).
2. Key personnel changes must be approved by the District.
3. Contractor on-site PM/Superintendent must complete a documented daily report and provide a copy to the Engineer.

**1.05 QUALIFICATIONS****1.05.01 PREQUALIFICATION OF CFRP SYSTEM MANUFACTURER****A. Experience**

1. The Manufacturer shall be specialized in the manufacturing of the products specified herein with documented experience.
2. The CFRP system shall have documented in-service history of over 10 years and a minimum of one hundred field installations in civil structural applications.
3. The CFRP system shall have documented in-service history of over 5 years and a minimum of fifty PCCP segments of 48 in. diameter and above in five or more repair and strengthening projects.

**B. Material Data for Submission and Qualification**

1. The Contractor shall provide the Engineer with Manufacturer's product data sheets indicating physical, mechanical, and chemical characteristics of all materials used in the CFRP system. As a minimum, the Engineer shall be provided with the mechanical properties of the CFRP laminate listed in Table 1, durability of the CFRP laminate based on the environmental conditions in Table 2, and the physical properties of the resin listed in Table 3. Reported properties shall be based on the listed standards and the number of tests required in these tables. Reporting of strength and modulus properties of CFRP laminate shall comply with provision of these Specifications.

**Table 1 – Mechanical Property Tests Required for CFRP Laminate**

Material Property	ASTM Test Method	Min. No. of Tests
Longitudinal tensile strength and modulus	D3039	50
Longitudinal compressive strength and modulus	D6641	10
Longitudinal flexural strength and modulus	D790	10
Overlap splice shear strength	D7616	10
Shear bond strength between CFRP and steel	D7616	10

**Table 2 – Minimum Environmental Durability Requirements for CFRP Laminate**

Environmental Durability Test	ASTM Test Method	Test Condition	Test Duration (hrs)	Required % Retention of Tensile Properties per ASTM D3039
Water Resistance	D2247 E104	100% RH, 100±2°F	1,000	90
			3,000	85
			10,000	80
Salt Water Resistance	D1141	Immersion at 73±2°F	1,000	90
			3,000	85
			10,000	80
Alkali Resistance	C581	Immersion in Ca(CO <sub>3</sub> ) at pH=9.5 and 73±3°F	1,000	90
			3,000	85
Temperature Resistance	D3045	140±5°F	1,000	90
			3,000	85

**Table 3 – Physical Property Tests Required for Resin**

Material Property	ASTM Test Method	Min. No. of Tests
Glass transition temperature	D4065	20
Water absorption	D570, Sec. 7.4	5
Longitudinal coefficient of thermal expansion	D696	5
Transverse coefficient of thermal expansion	D696	5
Shore D hardness	D2240	10
Volatile organic compound (VOC)	D2369	2

- The test reports shall indicate clearly the commercial names of the products used, batch ID, sample dimensions, number of samples tested, number of fabric layers used, load and strain measurement techniques, failure modes, and obtained strength, modulus, and ultimate elongation for each sample tested. Any deviation from the specified ASTM standards shall be clearly reported.

3. The proposed CFRP lining system shall have an approved and valid International Code Council (ICC) Evaluation Service Report. Products that do not have an ESR number shall provide all durability tests defined in ICC AC125 to validate the durability of the proposed lining.
4. The environmental durability data provided by the Manufacturer shall be based on tests conducted on samples made with the same fabric and impregnating resin, and similar fiber content as the laminate to be used during the upgrade work.
5. The Contractor shall provide the Engineer with the Manufacturer's results of creep rupture tests on a similar laminate constructed by the proprietary method of the Contractor. A minimum of eighteen specimens shall be tested at the maximum operating temperature defined by the District by subjecting them to different stress levels less than the short-term tensile strength until failure, and the time to failure shall be recorded. The stress is then plotted against the time to failure in a log-log plot and the strength is extrapolated to 50 yrs.
6. The Contractor shall provide Manufacturer's test data indicating percent completion of cure (ASTM E2160) versus temperature and duration, and percent completion of cure versus Shore D (ASTM D2240) hardness. (Completion of cure is characterized by flattening of the exothermic portion of the thermogram obtained by differential scanning calorimetry.)
7. The Contractor shall provide Manufacturer's documents indicating that all materials meet OSHA, EPA, and local ordinances for health and safety including VOC compliance.
8. Manufacturer's Safety Data Sheets (SDS) for all materials to be used.
9. Application instructions, delivery, storage and handling instructions, and general recommendations regarding each material to be used.

### C. Warranty

1. This section provides the technical requirements of the warranty. The length of the warranty shall be specified in a resulting commercial contract.
2. The Contractor shall provide a warranty for the CFRP system used for strengthening of the pipe. The CFRP system strengthening warranty shall include, but not be limited to interfacial peel-off of CFRP layers and debonding from concrete substrate unless it was specifically stated in the design documents by the Company's Engineer that debonding could be expected and tolerated without compromising the design capacity.



#### D. Training Support

1. The Manufacturer shall support a training program to instruct the Installer in the installation of their CFRP composite system presented to meet this Specification.

#### E. Evaluation and Conditions of Acceptance by the Engineer

1. Submission of the documents required in these Specifications is needed for qualification of Contractor's Subcontractor (the Manufacturer).
2. The submitted test data required in Table 1 will be evaluated statistically by the Engineer to determine the characteristic values. (The characteristic value of a strength or modulus property corresponds to the 5th percentile value with 80% confidence. It is determined from a sample size of ten or more according to ASTM D7290.)
  - a. For each property, outliers will be removed from each data set. Any remaining data set with fewer than five samples will be discarded.
  - b. Statistical tests will be performed to determine whether the remaining data sets can be combined. If all data sets cannot be combined, several combined data sets will be formed with the maximum possible number of samples, but not fewer than ten. If no combined data sets can be formed with ten or more samples, data will be rejected. In the case of more than one combined set with a comparable number of samples, the smallest characteristic value will be selected as the overall characteristic value of the material property.
3. The CFRP upgrade design is based on the characteristic values of strength and modulus of the CFRP laminate properties. While conformance with these properties qualifies the materials for the design shown on the drawings, nonconformance does not necessarily disqualify the materials. In the case of nonconformance on strength and modulus, a greater number of CFRP layers than shown on the drawings may be required and may need to be provided by the Contractor.
4. The laminate shall retain its tensile strength and modulus according to Table 2 where percent retained strength or modulus is the ratio of the value obtained for conditioned specimens to the characteristic value for that property obtained for unconditioned specimens.
5. The extrapolated tensile strength at 50 yrs based on creep-rupture tests on a log-log plot of stress versus time to failure shall be greater than 55% of the characteristic short-term tensile strength.
6. The average glass-transition temperature shall be at least 40°F greater than the maximum operating temperature of 135°F, with a coefficient of variation less than 10%.

7. The long-term water absorption shall be less than 2% with a coefficient of variation less than 10%.
8. The resin shall retain its glass-transition temperature according to the water resistance test and the corresponding retention values in Table 2.

#### 1.05.02 PREQUALIFICATION OF CONTRACTOR

##### A. Experience and Certification

1. The Contractor shall have successful installation of Internal CFRP composite systems for pipe upgrade similar to those described in these Specifications and shown on the included Drawings, using the wet lay-up technique, on a minimum of twenty pressurized PCCP segments from a minimum of five separate projects, within the last 3 years, documented with client contact information and a summary of work performed in each project.
2. The Contractor's crews for each area of work, including pipe surface preparation, mixing of materials, impregnation of fabrics, and installation of impregnated fabrics, shall include at least one crew member per crew (crew supervisor) with a minimum of 3 years experience and a minimum of five projects in internal CFRP upgrade of PCCP. The Contractor shall provide a list of reference projects for all crew members.
3. All crew members shall have received training from the Manufacturer.
4. The Contractor shall have a quality control program and shall agree to have at least two field QC inspectors (referred to herein as Contractor's Inspectors) on site throughout the project execution (one at the material preparation site above ground, and one at the application site inside the pipe). Contractor's Inspectors shall be qualified according these Specifications.
5. The Contractor shall have a confined space entry procedure, calibrated gas meters in the pipeline for all phases of work at all times, and a health and safety plan. The confined space entry procedure and health and safety plan shall meet the District's requirements specified in the contractual terms and conditions.
6. The Contractor shall have a noise abatement plan for equipment needed to support ventilation and dehumidification of the pipeline throughout the CFRP installation and curing. The Contractor shall comply with jurisdictional requirements for acceptable decibel levels within specified distances from occupied dwellings.

**1.05.03 PREQUALIFICATION OF CONTRACTOR'S INSPECTORS**

- A. Contractor's Inspectors shall have completed the training program supported by the Manufacturer on the installation of bonded CFRP systems and shall have experience on at least five projects involving CFRP application in confined spaces.
- B. Any change of Contractor's Inspectors is subject to the same qualifications.

**1.06 MEASUREMENT AND PAYMENT**

- A. Payment will be made on a contract unit price for Bid Item Number 59, "Carbon Fiber Reinforcement for PCCP – SUPPLEMENTAL WORK," which price will include all labor, materials, equipment, and incidentals to conduct the efforts necessary to complete the required work according to the Drawings and these Specifications.
- B. Refer to Article 20.1 – Schedule of Bid Items

**PART 2 PRODUCTS****2.01 DESIGN REQUIREMENTS**

- A. Design Approach
  - 1. The CFRP liner shown on the upgrade drawings accompanying this specification was designed to satisfy all limit states related to at least one of the following two systems
    - a. CFRP liner acting as a stand-alone buried flexible pipe (i.e., CFRP separated from the inner core with the outer concrete core cracked)
    - b. CFRP liner and inner core concrete acting as a composite system.
  - 2. No contribution from the steel cylinder or prestressing wires was considered.
  - 3. The design includes load factors, resistance factors, material adjustment factors, and time-effect factors selected for long-term loads, short-term loads, and buckling.
  - 4. End Termination: CFRP shall be terminated with end details that prevent water from getting behind the CFRP liner.

## 2.02 CFRP SYSTEM

A. The CFRP system shall consist of epoxy primer, thickened epoxy (i.e., putty), tack coat (i.e., epoxy specially formulated for overhead applications) if required by the Manufacturer, unidirectional carbon fabric, impregnating epoxy resin, and topcoat of thickened epoxy. Resin types other than epoxy (e.g., polyester, vinyl ester) shall not be used as any of these components.

### B. Primer

1. The concrete substrate shall be primed with an epoxy material, which shall penetrate the pore structure of the substrate. The primer shall be 100% solids, epoxy resin.
2. The glass-transition temperature requirements of these Specifications and the water absorption requirement of these Specifications also apply to the primer.

### C. Thickened Epoxy

1. Thickened epoxy shall have a high enough viscosity to fill all voids in the concrete substrate and provide a smooth base for the subsequent CFRP laminates.
2. Thickened epoxy shall either be pre-formulated and brought to site in pre-proportioned containers, or prepared on site by mixing the impregnating resin with Cab-O-Sil TS-720 treated fumed silica to achieve the required viscosity. If prepared on site with Cab-O-Sil, the Contractor shall obtain the Contractor's Inspectors' and District's Inspector's approval prior to any use.
3. The glass-transition temperature requirements of these Specifications and the water absorption requirement of these Specifications also apply to the thickened epoxy.

### D. Tack Coat

1. Tack coat, if recommended by the Manufacturer, shall be a high-viscosity epoxy that is specially formulated for overhead applications.
2. The glass-transition temperature requirements of these Specifications and the water absorption requirement of these Specifications also apply to the tack coat.

### E. Impregnating Resin

1. All fabrics shall be impregnated with 100% solids, low-viscosity epoxy resin.
2. The impregnating resin shall meet the glass-transition temperature requirements and the water absorption requirement of these Specifications.

## F. Unidirectional Carbon Fiber-Epoxy Laminates

The following CFRP Laminate materials have been determined by the Engineer to meet the requirements of these Specifications. The Contractor shall not use other CFRP Laminate materials, or different batches of the approved material, unless documentation demonstrating compliance is submitted for District review and approval 14 calendar days prior to bid opening, and Engineer approves their usage.

1. 0.08 in. V-Wrap C400H (38 oz/sq yd), Batches 23692, 24072
2. 0.08 in. Tyfo SCH-41-2x (40 oz/sq yd)

Required Properties of Unidirectional Carbon Fiber-Epoxy Laminates:

1. The unidirectional carbon fiber-epoxy laminate shall meet the requirements of these Specifications and as shown on the Drawings.
2. The tensile properties of the CFRP lamina to be used in design shall be determined according to ASTM D3039 and statistically analyzed according to ASTM D7290 to determine the characteristic values.
3. The CFRP designs shown on the drawings accompanying this Specification are based on the characteristic properties for one layer of CFRP. CFRP systems other than those shown on the drawings shall be approved by the Engineer, and used to calculate the required number of layers.
4. The characteristic values for multi-layer laminates shall be based on the reduction in strength due to the strength variability and redistribution of stresses of a failed lamina among other layers using strain compatibility.

## 2.03 GFRP (GLASS FIBER-REINFORCED POLYMER) LAYER

1. The laminate shall include a GFRP system used as insulator between the steel substrate and the CFRP layer and may include a second system for watertightness.
2. The GFRP composite systems shall be a proprietary system consisting of all associated fiber reinforcement and polymer adhesives/resins. All components of the GFRP composite systems shall be provided by the same Manufacturer of CFRP system.
3. The GFRP composite layer shall be used as insulator between any steel components and CFRP to avoid possible galvanic corrosion, and shall have a total nominal thickness of a single GFRP lamina of not be less than 0.034 in. (V-Wrap EG50-B bidirectional GFRP and Tyfo Web were included in the Drawings for use as dielectric barrier between any steel components and CFRP; other GFRP composite systems shall have equivalent satisfactory performance and shall be approved by the Engineer.)

4. The GFRP system used for watertightness shall be successfully tested with the design laminate or a laminate that is part of the design laminate.

#### 2.04 PROTECTIVE COATING (TOP COAT)

The Contractor shall ensure the following:

1. The CFRP system shall be top-coated with a coating recommended by the CFRP system Manufacturer and in conformance with the following:
  - a. The topcoat shall consist of the same thickened epoxy used between the CFRP layers or potable water coating, if needed.
  - b. Seams in fabric and edges shall be smoothed with thickened epoxy prior to application of the topcoat.
  - c. The topcoat material shall have been used successfully as a finished assembly on a minimum of five past documented PCCP pipe strengthening projects.
2. Topcoat shall be installed in accordance with the Manufacturer's published installation instructions. The duration elapsed between the application of the last CFRP layer and the topcoat shall not exceed the time specified by the Manufacturer.

#### 2.05 OTHER MATERIALS

##### A. Epoxy Mortar

1. The Contractor shall ensure that epoxy mortar consists of five parts epoxy resin mixed with one part sand or equivalent demonstrated to have the ability to bond to concrete, steel, and CFRP in overhead and all other positions. The Contractor shall obtain the Contractor's Inspectors' and District's Inspector's approval on the consistency of the epoxy mortar prior to any use.

##### B. Bond Breaker

1. Where indicated on the drawings accompanying this specification, the Contractor shall provide a bond-breaker material consisting of one of the following:
  - a. 100% acrylic elastomeric coating.
  - b. Paraffin wax.
  - c. Approved equivalent of the above.

### C. Steel Expansion Ring

1. WEKO-Seal stainless steel expansion ring, or approved equivalent with a 1/4 in. rubber strip using the equipment and jacking pressures recommended by the manufacturer. All expansion rings, wedges, and shims shall be 316 stainless steel and shall conform to ASTM A240. The installer of the expansion rings shall be trained and certified by the Contractor.

## 2.06 DELIVERY, STORAGE, AND HANDLING OF ALL MATERIALS

The Contractor shall ensure the following:

### A. Delivery

1. The products shall be delivered in original, unopened containers. Containers shall be clearly marked with legible and intact labels listing the Manufacturer's name, brand name, product identification, batch number, storage conditions, mixing ratios, and shelf life.

### B. Storage

1. All Contractor materials and equipment shall be stored in areas designated by the District and using access locations designated by the District.
2. Contractor shall ensure that materials are stored at temperatures that conform to Manufacturer's written recommendations and instructions.
3. Stored fiber reinforcement and resins shall be protected from dust, moisture, and chemical exposure.
4. Resin components shall be stored separately and in tightly closed containers, away from direct sunlight, flame sources, or other hazards.
5. In the event that the work is to be completed during winter or in temperatures below freezing, the fiber reinforcement and resins shall not be exposed to freezing temperatures during transport, storage, preparation, installation, or curing. To achieve protection against freezing temperatures, the Contractor shall provide temporary portable heat sources reviewed and approved by the District prior to use.

### C. Handling

1. The fabric reinforcement shall not be handled roughly. Care shall be taken not to damage the fibers.
2. Fabric reinforcement may be stored either in rolls of 3 inch diameter or greater or stacked after cutting.

Consult the Manufacturer's MSDS for specific handling hazards of resin components.

**PART 3 EXECUTION****3.01 GENERAL PROCEDURES**

- A. Work only in areas permitted by District-approved schedule.
- B. Remove all tools, buckets, and materials from work areas and store neatly at a designated location daily at the end of work.
- C. Protect adjacent areas from damage, stains, and spillage during delivery of material to upgrade areas. Repair all damage as a result of the work of this Specification to its condition at the start of work, or if such cannot be determined, to its original condition. Clean all stains by means approved by the Engineer.
- D. Protect the work from damage such as impact, marring of the surfaces, and other damage.
- E. Materials may be skin irritants or sensitizers. Accordingly, advise system installer to avoid contact with eyes and skin, inhalation of vapors, and ingestion. Use protective and safety equipment on site. Heed all label warnings by manufacturers. Make application in accordance with applicable safety laws.
- F. The Contractor, his Subcontractor(s), suppliers, consultants, and workers shall maintain a safety program that is at a minimum compliant with the safe work practices prescribed by the District and with OSHA and other safety laws and regulations.
- G. Prevent hazardous accumulations of dusts, fumes, mists, vapors, or gases in areas occupied during construction. Provide local exhaust ventilation to prevent harmful dispersal of hazardous substances into atmosphere of occupied areas. Dispose in a manner that will not result in harmful exposure to persons. Ventilate storage spaces containing hazardous or volatile materials. Provide dust and fume control, including, but not limited to, temporary protection and confinement barriers, ventilation equipment and procedures, and air-quality-monitoring equipment and procedures. Monitor air quality in the work area, and inside the pipeline. Comply with the requirements of all local governing regulatory agencies.
- H. Ventilation inside the pipeline shall be per all OSHA and District requirements, including, but not limited to, OSHA and District confined space entry and underground construction requirements.



**3.02 INSPECTION OF HOST PCCP**

- A. The Contractor's Inspectors shall examine the existing conditions to verify dimensions/geometry shown on drawings, assess quality of concrete substrate, document any cracks, ovality, or surface irregularities in the pipe, identify any leaks near upgrade areas and evaluate water retention plans (as necessary) of the Contractor, and evaluate risk of exposure of CFRP to water prior to cure. The concrete shall be sound and without standing water.
- B. The Contractor's Inspectors shall also examine the aboveground conditions under which materials will be stored, mixed, and transported into the pipe and specify corrective actions as necessary.
- C. The District's Inspector will report the observed pipe condition to the Engineer prior to commencement of upgrades.
- D. The Contractor shall correct all unsatisfactory conditions and obtain the Contractor's Inspectors' and District's Inspector's approval prior to commencement of upgrades.

**3.03 PREPARATION**

- A. The Contractor's Inspectors shall examine the existing conditions to verify dimensions/geometry shown on drawings, assess quality of concrete substrate, document any cracks, ovality, or surface irregularities in the pipe, identify any leaks near upgrade areas and evaluate water retention plans (as necessary) of the Contractor, and evaluate risk of exposure of CFRP to water prior to cure. The concrete shall be sound and without standing water.
- B. The Contractor's Inspectors shall also examine the above ground conditions under which materials will be stored, mixed, and transported into the pipe and specify corrective actions as necessary.
- C. The District's Inspector will report the observed pipe condition to the Engineer prior to commencement of upgrades.
- D. The Contractor shall correct all unsatisfactory conditions and obtain the Contractor's Inspectors' and District's Inspector's approval prior to commencement of upgrades.

### 3.04 PREPARATION

The Contractor shall ensure the following:

#### A. Environmental Conditions

1. Do not install CFRP when the ambient temperature is outside the range required by the Manufacturer, the relative humidity is outside the range required by the Manufacturer, and the concrete surface temperature is less than 5°F above the dew point. In cold conditions, auxiliary heat may be applied to raise the ambient temperature to a suitable level. If heating is used, direct-fired gas or kerosene salamander-type heaters shall not be permitted. Only electric or indirect-fired heaters shall be permitted, to avoid contaminating the substrate with carbonation.
2. The presence of water inhibits the adhesion of epoxy to the substrate. Do not install CFRP when surface moisture is present. Use dehumidifiers to keep the relative humidity within the range required by the Manufacturer. There shall be no standing water in the pipe.
3. If water leakage exists through cracks or joints, water flow shall be stopped prior to CFRP installation.

#### B. Site Conditions

1. The Contractor shall comply with the District's Confined Space entry procedure.
2. The Contractor shall maintain control of concrete chips, dust, and debris due to mortar lining upgrade or surface preparation in each area of work. The contractor shall clean up and remove such material at the completion of work each day.

### 3.05 INSTALLATION

The Contractor shall ensure the following:

#### A. Substrate Upgrade

1. All problems associated with the condition of the original concrete and the concrete substrate that can compromise the integrity of the CFRP system shall be addressed before surface preparation begins. ACI 546R and ICRI Guideline No. 310.2 detail methods for the upgrade and surface preparation of concrete. The Contractor shall ensure adherence to Manufacturer's requirements regarding compatibility of the CFRP system with materials used for upgrading the substrate. The Contractor shall provide supporting information regarding compatibility to the District for review and approval prior to proceeding with substrate upgrade.

2. Voids in the substrate shall be filled. Small voids no more than 0.50 in. in depth shall be filled with a thickened epoxy and larger voids with epoxy mortar.

#### B. Surface Preparation for Concrete and Steel Substrates

1. The Contractor shall first prepare a representative sample area. The sample area shall be prepared in accordance with the requirements of this Specification and the Manufacturer's written instructions, and shall be used as a reference standard depicting a satisfactorily prepared substrate. The concrete surface shall be profiled using hydro surface profiling or other abrasive blasting to remove all contaminants (laitance, surface lubricants, broken mortar pieces, etc.) and to achieve a minimum profile of ICRI CSP 3 (refer to ICRI Guideline No. 310.2 and molded replicas of surface textures that can be obtained from ICRI).
2. The concrete or upgraded surfaces to which the CFRP system is to be applied shall be freshly exposed and free of loose or unsound materials, and shall be allowed to dry prior to CFRP installation.
3. Localized out-of-plane variations, such as form lines, sharp edges, and protrusions, shall not exceed 0.25 inches. Such out-of-plane variations can be removed by grinding or abrasive blasting, or can be smoothed over using thickened epoxy if variations are very small.
4. All debris and dust generated during surface preparation shall be removed by air blasting or other approved means to achieve a dust-free concrete surface.
5. At areas where the GFRP systems will be adhered directly to the steel, such as spigot and bell ends, prepare the surface for length specified to SP10 near-white surface with a minimum surface profile of 2 mils prior to installing the CFRP system.

#### C. Mixing of Resins

1. The resin and its catalyst shall be kept in tightly closed containers at all times except for the time of mixing to prevent absorption of carbon dioxide and moisture, which could lead to amine blush. The mixing technique shall not cause air entrainment in the resin system.
2. All resins shall be mixed according to the Manufacturer's instructions. All resin components shall be at a proper temperature and mixed from pre-proportioned and pre-packaged containers until there is a uniform and complete mixing of components. On-site proportioning of resin components is not allowed. Resins shall be mixed for the Manufacturer's prescribed mixing time and visually inspected for uniformity of color.
3. Mixed resin that exceeds the pot life specified by the Manufacturer shall not be used.

#### D. Application of CFRP System

1. The application of the CFRP system shall be performed in accordance with the Manufacturer's published installation instructions.
2. The CFRP system primer shall be applied to all areas on the existing concrete surface where the CFRP system is to be placed. The primer shall be placed uniformly on the prepared surface at the Manufacturer's specified rate of coverage. Subsequent materials shall be applied within the time window specified by the Manufacturer.
3. Following the primer, all voids in the substrate shall be filled to achieve a smooth surface.
4. All fabrics shall be impregnated using an impregnation machine that does not cause fast setting of the resin and require frequent clean up. Manual impregnation is not allowed.
5. The impregnated fabric shall be pressed onto the concrete surface to achieve intimate contact. Entrapped air between layers shall be released or rolled out before the resin sets.
6. A thin layer of thickened epoxy shall be applied between all consecutive CFRP layers, over the entire surface.
7. For areas requiring that the CFRP system that is not adhered to the substrate, apply the selected bond breaker material prior to commencing with the installation of CFRP layers. For these areas the application of primer and thickened epoxy, described in Items 2 and 3 above, is not required. If the elastomeric coating is used as bond breaker material, follow the Manufacturer's recommendations for installation procedure and curing time before installing the CFRP systems.

#### E. Project Sequencing

1. All components of the lining system, including the primer, thickened epoxy, tack coat (if used), CFRP and GFRP layers, and topcoat, shall be applied within the allowable time windows recommended by the Manufacturer. If a project delay causes violation of the recommended allowable time windows, the surface of the previously applied layer shall be prepared according to the Manufacturer's recommendations, and as a minimum scuff-sanded, all dust shall be removed by compressed air and/or vacuum, and the surface shall be wiped clean with a manufacturer-recommended cleaning agent before resuming work with application of the subsequent materials and layers.

#### F. Preparation of Test Samples and Areas

1. The standard of workmanship shall be measured prior to construction through pull-off (bond) testing on representative mockup areas, and after construction through tension tests performed on samples cut from witness panels.

2. Representative Mockups for Pull-off (Bond) Testing Prior to Construction
  - a. The Contractor shall install two layers of CFRP in at least 2 ft by 2 ft areas in at least two different representative locations as specified in the included Drawings to be used as mockups of the installed CFRP system. The locations shall be representative and selected by the Engineer. The locations may be on adjacent pipes that are not within the scope of upgrades provided that surface preparation is the same as that to be used for the pipe upgrade. Mockups shall be prepared on each type of concrete substrate or for each surface preparation technique used if variations in such conditions exist.
  - b. The Contractor shall perform at least three pull-off tests in the presence of the District's Inspector in each mockup area according to ASTM D7234 and using testers with documented calibration.
  - c. The minimum value of pull-off strength is 300 psi. The Contractor's Inspectors shall evaluate the results as follows:
    - i. Failure within CFRP or at the CFRP-concrete interface with pull-off strength greater than 300 psi: Acceptable.
    - ii. Failure within concrete (through aggregate) with pull-off strength less than 300 psi: The CFRP liner is rejected except for CFRP liners designed as a standalone system, at which point it is accepted at the discretion of the Engineer.
    - iii. Failure at the concrete surface (not through aggregate) with pull-off strength less than 300 psi: Rejected. The Contractor shall improve the surface preparation and prepare and test new mockup areas.
    - iv. Failure within CFRP with pull-off strength less than 300 psi: Rejected. The Contractor shall improve the quality of construction and prepare and test new mockup areas.
    - v. Do not start work until the Contractor's Inspectors and District's Inspector (with Engineer's approval if necessary) have approved the mockups unless the District allows by written agreement to Contractor commencement of work prior to testing of mockups.
3. Witness Panels for Tension Testing in Accordance with these Specifications after Construction
  - i. The Contractor shall prepare at least one CFRP panel per day per work shift, minimum 24 in. wide and 14 in. long, made of one layer of CFRP using the same material and techniques used in the actual field installation. The preparation of the witness panels shall be witnessed by the Contractor's Inspectors and District's Inspector.

- ii. Place a plastic sheet on a smooth flat horizontal surface (a plastic plate on plywood). Cover the plastic plate with a thin polyethylene film as a release agent. The fabric shall be resin coated on the plastic surface using the same amount of resin per unit area as would be applied in the actual installation. Eliminate trapped air in the CFRP laminate using the same tools (e.g., putty knives) used during pipe upgrades, as needed. The samples shall be stored on a rigid level surface in the pipeline or in an area representative of the temperature and humidity conditions in the CFRP upgrade areas during the curing period or the end of the upgrade work.
- iii. Cured witness plates shall be obtained from the job site and handled only by the Testing Agency retained by the District.

#### G. Curing

1. All CFRP areas shall be cured using the curing schedule recommended by the Manufacturer in writing and approved by the Engineer prior to construction.
2. The Contractor's work schedule shall allow sufficient time between completion of upgrades and refilling of the pipeline so that all CFRP completes at least 85% cure before being exposed to water based on the cure temperature versus time relationship provided by the Manufacturer, or laboratory testing of epoxy samples collected from the surface of the installed CFRP liner according to ASTM E2160.
3. The Contractor shall not demobilize until Engineer verifies that the specified degree of cure has been achieved.
4. The Contractor's Inspectors shall perform a preliminary check of the cure progress by performing hardness tests on the CFRP system and based on the percent completion versus Shore D hardness relationship provided by the Manufacturer, and inform the District's Inspector of any nonconformance. This does not constitute verification of cure, as such verification shall be provided by the Engineer based on laboratory testing.
5. The District's Inspector, with Engineer's approval, may specify a revised curing schedule during construction, if needed, based on the cure progress.
6. Perform curing in a dry environment. If heating is used, direct-fired gas or kerosene salamander-type heaters shall not be permitted. Only electric or indirect-fired heaters shall be permitted.
7. Perform curing at elevated temperatures to reduce the required curing time and to increase the glass transition temperature of the epoxy. Satisfactory performance of the curing schedules used shall be proven by the Manufacturer with documentation of previous satisfactory applications or thermal test results indicating the curing behavior of the epoxy.
8. Exhaust fumes from vehicles or equipment shall be kept away from CFRP-applied areas during curing.

#### H. Installation of Joint Seals

1. Install steel expansion rings in joints at each end of CFRP upgrade at least 24 hrs after CFRP installation. Select jacking pressure for expansion ring in strict accordance with to the manufacturer's recommended procedures.

#### 3.06 INSPECTION DURING INSTALLATION

- A. The Contractor shall monitor and document all phases of the construction, including material preparation, impregnation of all fabrics, application of all CFRP and GFRP layers, end termination details, curing, and the environmental conditions under which materials were stored and applied. Such inspections shall be performed during all shifts of work.
- B. The Contractor's Inspectors shall inspect the fabric impregnation procedure periodically and perform a weight test at the beginning of each shift where CFRP installation takes place, as requested by the District's Inspector, following any substantial break in CFRP installation (e.g., lunch breaks where no CFRP material saturation is taking place), and at random intervals during all shifts of work. A weight test consists of weighing an approximately 1 ft x 1 ft piece of fabric before and after impregnation in the impregnation machine, and ensuring that the fabric-to-resin weight ratio is within the range recommended by the Manufacturer. The Contractor shall adjust the impregnation machine as necessary if specified by the Contractor's Inspectors or the District's Inspector.
- C. The Contractor's Inspectors shall witness preparation of all witness panels by the Contractor and monitor the conditions under which they are stored. The District's Inspector will also witness this task.
- D. The Contractor's Inspectors shall enforce the curing schedule specified by the Engineer.
- E. The Contractor's Inspectors shall specify corrective actions as necessary, and reinspect all items to be corrected.
- F. The Contractor's Inspectors shall inform the District's Inspector, who in turn reports to the Engineer, the results of all inspections required in this specification with traceable records, notes, measurements, and photographs. Reported results of bond tests performed on mockup areas shall indicate the location of test samples, pull-off test equipment used, and failure mode and test result for each sample tested.

### 3.07 POST-INSTALLATION INSPECTION AND REPAIR OF DAMAGED OR DEFECTIVE AREAS

#### A. Inspection for Voids and Delaminations

1. The Inspector shall inspect each upgrade pipe after the CFRP liner has become tack free to identify imperfections such as voids, delaminations, wrinkles, and raised fabric edges, and to specify corrective actions to be taken by the Contractor as necessary. Voids and delaminations shall be identified by dragging a coin or small piece of metal across the CFRP surface and tapping at areas for change in sound, or automated methods approved by the Engineer.
2. Voids requiring corrective action shall be marked and upgraded in accordance with these Specifications, and as shown on Drawings.
3. The Inspector shall also inspect all joints filled with epoxy mortar where CFRP is terminated and check for any sagging or hollow-sounding areas. If needed, the corrective action for hollow-sounding epoxy mortar shall be removal and replacement.

#### B. Repair of Delaminated Areas of Installed CFRP Reinforcement

1. Small delaminations less than 2 sq in. each do not require corrective action, as long as the total delaminated area is less than 5% of the total laminate area and there are no more than ten such delaminations per 10 sq ft. If there are more than the allowed amount of voids of this size, contact Engineer for corrective action.
2. Moderate delaminations between 2 sq in. and 25 sq in. shall be repaired by filling the delamination by low-pressure injection of the epoxy, followed by application of a GFRP patch, as detailed in the included Drawings.
3. For large delaminations, contact Engineer for corrective actions. Such cases will be addressed on a case by case basis.
4. Repair procedures for conditions that are not specifically addressed in this Specification shall be submitted for approval by the Engineer prior to the repair work.
5. All areas of corrective actions shall be re-inspected and approved by the Inspector and District's Inspector.

#### C. Inspection Report

1. The inspection report submitted by the Inspector to the District's Inspector at the end of the construction shall include the location and extent of all defects found during the post-installation inspection and the corrective actions taken.



### 3.08 TESTING OF CFRP WITNESS PANELS

#### A. Testing

1. After the construction, tension tests shall be performed by a Testing Agency retained by the District on coupons cut by the Contractor from the witness panels prepared during construction in conformance with these Specifications.
2. Witness plates shall be cured for the manufacturer-recommended duration as a minimum before tensile testing. The test coupons shall not be preconditioned prior to testing.
3. Sample preparation and testing shall comply with ASTM D3039 except that the thickness of the panel shall be taken as the nominal value and not the actual thickness. Coupons shall be tested with or without end tabs as long as failure at the grips is avoided.
4. At least ten specimens shall be tested from each witness panel. If the CFRP installation duration is longer than one week, the number of test specimens per panel may be reduced to five by Engineer. All test specimens shall be properly instrumented to determine the tensile modulus and tensile elongation.

#### B. Testing Report

1. The Testing Agency shall submit a detailed test report to the Engineer indicating the witness panel ID, sample dimensions, number of samples tested, number of fabric layers, load and strain measurement techniques, failure modes, and obtained strength, modulus, and ultimate elongation for each sample tested. Any deviation from the recommended ASTM D3039 practices shall be clearly reported.

#### C. Evaluation of Test Results

1. The Engineer will identify all valid tests, analyze the test results statistically, and calculate the average strength and modulus for each witness panel.
2. Pooling of all test results into a combined data set shall be allowed only if justified by statistical pooling methods.
3. The average strength and modulus shall be greater than the characteristic values calculated based on the test data provided by the Manufacturer prior to construction and used in design. Otherwise, the Engineer will check the design with the average test values, and recalculate the factors safety for each limit state. If the revised factors of safety are still above those required by the design, the CFRP witness panels will be approved. If not, the Contractor shall propose a method to supplement the CFRP liner to address the deficiency in its material properties.

### 3.09 QUALITY CONTROL AND QUALITY ASSURANCE

#### A. Prequalification of Contractor, Contractor's Manufacturer, and Inspectors

1. The Contractor, Contractor's Subcontractor (the Manufacturer), and Inspectors shall be prequalified in accordance with these Specifications.

#### B. Pre-Installation Conference

1. A preinstallation conference will be held with the representatives of the District, Engineer, Inspector, Contractor, Contractor's field supervisor, Contractor's Inspectors, and all other parties involved to discuss the conduct of the work in this Specification.

#### C. Quality Control Prior to, During, and After Installation

The Contractor shall ensure the following:

1. All materials shall be inspected prior to execution to ensure conformity with contract requirements, and that all materials are new and undamaged.
2. Procedures shall be established for executing the work prior to the start of work by a review and approval process established between the Contractor and the District.
3. The qualifications of installers shall be verified prior to construction according to these Specifications.
4. All phases of the upgrade work shall be inspected by the Contractor's Inspectors and will be verified by the District's Inspector to ensure that work is done in accordance with project drawings and specifications, established procedures, Manufacturer's instructions, specific instructions by the Engineer, if given, or recommended practices as given in the references of these Specifications.
5. All completed work shall be inspected according to these Specifications and defective work, if any, shall be corrected as specified therein.
6. CFRP witness panels prepared by the Contractor during construction shall be tested by a Testing Agency retained by the District after construction according to these Specifications, and the results shall be evaluated by the Engineer as specified therein.

### 3.10 SAFETY REQUIREMENTS

- A. Materials may be skin irritants or sensitizers. Accordingly, advise system installer to avoid contact with eyes and skin, inhalation of vapors, and ingestion. Use protective and safety equipment on site. Heed all label warnings by manufacturers. Make application in accordance with applicable safety laws.

- B. The Contractor, his Subcontractor(s), suppliers, consultants, and workers shall maintain a safety program that is at a minimum compliant with the safe work practices prescribed by the District and with OSHA and other safety laws and regulations.
- C. All contractor personnel shall successfully complete the OSHA 10 hr course and all contractor supervisors/safety oversight personnel shall successfully complete the OSHA 30 hr course prior to starting work on site.
- D. Contractor shall conduct documented daily Pre-Job/Safety Briefs for the duration of the project.