Section 2320

Cured-In-Place Pipe Lining

PART 1: General

1.1 *Description* –

1.1.1 Provide all materials, equipment, labor and incidentals for the installation and testing of cured-in-place pipe lining (CIPPL) within the sewer main.

1.1.2 The sewer main CIPPL process shall consist of inserting a resin-impregnated flexible tube into an existing sewer, expanding the tube out against the sewer pipe, and curing the tube to form a pipe liner. Curing shall be accomplished by applying ultraviolet light or circulating heated water or steam to affect the desired cure throughout the tube extending full length from manhole to manhole.

1.1.3 The CIPPL shall cure into a hard, impermeable liner pipe of the specified thickness and form a structurally sound liner pipe with a uniformly smooth interior.

1.2 *References* – Standards referenced in this Section are listed below:

ASTM D543-06	Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents
ASTM D790-07	Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D2990-01	Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
ASTM D3567-97 (2006)	Standard Practice for Determining Dimensions of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
ASTM D5813-04	Standard Specification for Cured-In-Place Thermosetting Resin Sewer Pipe
ASTM D1216-07B	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube
ASTM F1743-96 (2003)	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP)
ASTM F2019-03	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Pulled in Place Installation of Glass Reinforced Plastic (GRP) Cured-in-Place Thermosetting Resin Pipe (CIPP)

1.3 *Qualifications* – The Contractor shall have a minimum of three years of continuous experience installing the product proposed for this project. Additionally, the Contractor shall have successfully completed projects using the proposed product on projects of the same size and installation conditions as this project. The Contractor shall provide experienced crews using the product proposed and installed under the same installation conditions as this project.

1.4 *Delivery, Storage, and Handling –*

1.4.1 Care shall be taken in shipping, handling and storage to avoid damaging the liner. Extra care shall be taken during warm weather construction. Any liner damaged in shipment shall be replaced as directed by the Owner at no additional cost to Owner.

1.4.2 While stored, the CIPPL shall be adequately supported and protected. CIPPL shall be stored in a manner as recommended by the Manufacturer and as approved by the Engineer.

1.5 *Quality Control –*

1.5.1 No change of material, design values, or procedures may be made during the course of the Work without the prior written approval of the Engineer.

1.5.2 All liner to be installed under this Work may be inspected at the Manufacturer plant(s) and wet-out facility for compliance with these Specifications by Owner or Engineer. The Contractor shall require the wet-out facility's cooperation in these inspections. The cost of inspection will be the responsibility of the Owner.

1.5.3 At the time of manufacture, inspect each lot of liner for defects. At the time of delivery, the liner shall be homogeneous throughout, uniform in color, free of cracks, holes, foreign materials, blisters, or deleterious faults.

1.5.4 Contractor shall have a Quality Control Plan or Procedure in place that will allow the Engineer to monitor the resin impregnation process.

1.5.5 All test results shall be provided by an independent, certified ISO 17025 testing facility

1.6 *Warranty* – All lining work shall be fully guaranteed by the Contractor for a period of 5 years from the date of Final Acceptance unless otherwise stipulated in writing by the Owner prior to the date of Conditional Acceptance. During this period, all defects discovered by the Owner or Engineer shall be addressed by the Contractor in a satisfactory manner at no cost to the Owner. The Owner may conduct independent inspections, at its own expense, of the lining Work at any time prior to the completion of the guarantee period.

1.7 *Submittals –*

1.7.1 *Cured-In-Place Pipe –*

1.7.1.1 Summary table of CIPP material properties, including short-term flexural modulus of elasticity, 50-year flexural modulus of elasticity, short-term flexural strength (bending stress), 50-year flexural strength (bending stress), chemical resistance, and hardness. Certified test reports shall be submitted verifying each value as described below

1.7.1.2 Independent third party certified laboratory test reports demonstrating that the exact resin/liner combination to be used for this project meets the requirements for initial structural properties (performed in accordance with ASTM F1216, ASTM F2019, and ASTM D790) and chemical resistance (performed in accordance with ASTM F1216-Appendix X2 or ASTM D5813). If the architecture of the CIPP is such that the physical properties vary depending on the direction of testing (i.e.,

axial versus circumferential), submit test data on both directions in accordance with the test methods listed above in this paragraph.

1.7.1.3 Independent third party certified laboratory test reports demonstrating that the exact resin and liner to be used for this project has been tested for long-term flexural modulus of elasticity and long-term flexural strength (i.e. 10,000 hour minimum creep testing performed in accordance with ASTM D2990 for design conditions applicable to this project). When filled resins are proposed, complementary data of the same data for unfilled resin shall also be provided. If the architecture of the CIPP is such that the physical properties vary depending on the direction of testing (i.e., axial versus circumferential), submit test data on both directions in accordance with the test methods listed above in this paragraph. If the data submitted in not for the exact materials to be used on this project, submit a detailed description of the physical properties of both the materials used in the test and the materials to be used for this project to demonstrate that the two sets of materials are comparable in terms of physical properties.

1.7.1.3.1 Test will be performed for a minimum of 10,000 hours under test conditions and loadings described below. The data points from 1,000 hours to 10,000 hours, or such other time period as determined by the Engineer based on the curve or slope of the plotted data, of the Long-term Flexural Modulus shall be extrapolated using a Microsoft Excel log-log scale linear regression analysis to determine the minimum service life performance of the materials.

1.7.1.3.2 Testing will be conducted at:

1.7.1.3.2.1 Temperature: 21-25°C

1.7.1.3.2.2 Relative humidity: 50 percent minimum

1.7.1.3.2.3 Load: Load shall be equivalent to a load that is 25 percent of the yield stress as measured by ASTM D790, or as approved by Engineer.

1.7.1.3.3 If non-round host pipes (ovality greater than 10 percent) are to be rehabilitated and if the architecture of the CIPP is such that the physical properties vary depending on the direction of testing (i.e., axial versus circumferential), only ASTM D2990 test results on a specimen prepared in accordance with ASTM D790 will be accepted; no other testing methodology for long-term creep will be accepted.

1.7.1.4 The name of the liner and resin Manufacturer, the location of the facility where each was manufactured, and a list of appurtenant materials and accessories to be furnished.

1.7.1.5 Structural design calculations and specification data sheets listing all parameters used in the liner design and thickness calculations based on Appendix X1 of ASTM F1216 for each pipe segment with less than 10 percent ovality.

1.7.1.6 The Quality Control report for the wet-out facility that ensures proper materials and amounts are used in the resin impregnation process and in liner shipping and storage. At a minimum, the Quality Control report should include, for each CIPP

segment, resin lot numbers, volumes of resin, catalyst, and enhancers, date of wet-out, and storage and transportation controls and quality assurance procedures. Include a checklist so that each critical step in the resin impregnation process is checked off and initialed.

1.7.1.7 Installation and quality control plan, including bypass pumping plans, mainline sewer cleaning plan and cleanliness requirements, liner shot plan and sequence, liner installation standard procedures (including, but not limited to, minimum and maximum allowable installation pressures and speeds, and minimum and maximum allowable curing temperatures, pressures, and curing durations and speeds, all certified by the resin and tube Manufacturers), intermediate manhole exposed liner restraining method, boiler sizing calculations, light train sizing, temperature monitoring plan, odor controls procedures, and plan to manage flow to/from laterals during lining.

1.7.1.8 Curing schedule for each shot, including heating, curing, and cool-down schedules.

1.7.1.9 Available standard written warranty from the Manufacturer of wet-out liner.

1.7.2 *Methods and Materials* – Material and method of installation for hydrophilic end seals, cured-in-place pipe end seals, and pre-liners.

1.7.3 *Contingency Planning* – Contingency Plan, including methods and equipment to be used to repair unacceptable liner defects and for removing failed liners, and for availability and accessibility of backup equipment such as air compressors and lateral reinstatement cutters.

1.7.4 *Inspection Documentation* – Documentation of Pre-Construction Inspection, Post-construction Inspection and Warranty Inspection.

1.7.5 *Data and Other Information* –

1.7.5.1 Curing log of CIPPL temperatures and pressures at the upstream and downstream manholes during the curing process to document that proper temperatures, pressures and cure times have been achieved. Curing log shall list as a minimum the temperature of the hot water, steam and/or interior of the liner, the temperature of external thermocouples, pressures, and rate of travel of the ultraviolet assembly (for UV-cured CIPPL) at least once every five minutes or as recommended by the resin and tube Manufacturers, whichever is more frequent.

1.7.5.2 Name and credentials of testing laboratory.

1.7.5.3 Post-installation testing results.

PART 2: Products

2.1 *Design Requirements* –

2.1.1 *General* – The CIPPL lining shall be a resin-impregnated flexible tube which is inserted into the sewer to be rehabilitated and cured-in-place by an acceptable curing method. The tube may have a suitable polyurethane membrane coating for protection of the interior surface and to provide a uniform, smooth flow surface and may be removed after installation and curing is completed. The resin shall be a liquid thermosetting resin and shall be suitable for the design conditions as well as the curing process.

2.1.2 *50-Year Flexural Strength (ASTM D790, D2990)* - 2,500 psi minimum.

2.1.3 *50-Year Flexural Modulus (ASTM D790, D2990)* - 175,000 psi minimum with no greater than a 50 percent reduction from initial (hour 0) strength.

2.1.4 *CIPPL Thickness* –

2.1.4.1 The required structural CIPPL wall thickness shall be based, as a minimum:

2.1.4.1.1 In accordance with ASTM F1216, Appendix X1, Design Considerations for a fully deteriorated or partially deteriorated host pipe, for a circular host pipe with 10 percent ovality or less.

2.1.4.1.2 A safety factor of 2.

2.1.4.1.3 A minimum service life of 50 years under continuous service.

2.1.4.1.4 A modulus of soil reaction of 1000 psi.

2.1.4.1.5 A soil density of 115 lbs/ft^3.

2.1.4.1.6 A Poisson's ratio of 0.3.

2.1.4.1.7 An enhancement factor of 7.

2.1.4.1.8 A groundwater elevation shall be at grade for each pipe segment.

2.1.4.1.9 Ovality for each segment shall be considered 3 percent unless otherwise noted on the drawings.

2.1.4.1.10 Live loads for each segment shall be assumed to be HS-20 unless otherwise noted on the drawings.

2.1.4.1.11 Soil depth for each segment to be lined will be based on the max distance in feet measured between the crown of the pipe and the highest point of soil cover over the length of the pipe.

2.1.4.2 The flexural modulus and flexural strength used in the design shall be the values as rated for the specified service life and as submitted in Paragraph 1.7.1. When filled resins are proposed, complementary data of the same data for unfilled resin shall be provided.

2.1.5 The liner thickness of each pipe segment shall be determined by the Contractor and submitted per Paragraph 1.7 of this Section. Minimum CIPPL design thicknesses are listed in the table below for each pipe diameter in this project.

CIPPL Liner Thickness	
Pipe Segment Diameter	**Minimum CIPPL Design Thickness (felt/fiberglass)**
8-inch	6.0 mm / 3 mm
10-inch	6.0 mm / 3 mm
12-inch	7.5 mm / 5 mm
15-inch	7.5 mm / 5 mm
18-inch	9.0 mm / 7 mm
21-inch	10.5 mm / 7 mm
24-inch	12.0 mm / 7 mm
30-inch	15.0 mm / 9 mm
36-inch	16.5 mm / 11 mm
42-inch	19.5 mm / 11 mm
48-inch	22.5 mm / 13 mm

2.1.6 CIPPL installations that result in thicknesses that exceed the design thickness by 15 percent or more as certified by an independent testing laboratory in accordance with paragraph 3.7, may be considered non-compliant if, in the judgment of the Engineer, will impede O&M and future work.

2.1.7 When cured, the liner shall form a continuous, tight fitting, hard, impermeable liner that is chemically resistant to chemicals found in both domestic sewage and seawater.

2.1.8 The liner shall be fabricated to a size that when cured will tightly fit the sewer being rehabilitated. Allowance for longitudinal and circumferential expansion shall be taken into account when sizing and installing the liner. Field verify all dimensions prior to delivery of the liner. The contact tolerance for pipe with a conic section (i.e., oval or round, but not arch pipe) is 2.0 mm; in these cases where any space or gap between the outside surface of the liner and the inside surface of the existing pipe exceeds 2.0 mm, the liner fit will be deemed deficient and corrective action will be required. Where irregularities of the existing pipe exist such as offset joints, protrusions, bumps, and deformations, and the irregularities remain after the sewer has been prepared in accordance with the Contract Documents, exception to the contact tolerance will be allowed in the irregularity zone. The exception shall not present an obstruction to sewage flow.

2.1.9 The length of the liner shall be that deemed necessary by the Contractor to effectively carry out installation and seal the liner at the inlet and outlet of each manhole/structure as specified herein. Field verify all lengths prior to construction.

2.1.10 Approved products

2.1.10.1 Insituform

2.1.10.2 Inliner CIPP

2.1.10.3 Masterliner

2.1.10.4 National Liner

2.2 *Flexible Tube* –

2.2.1 The tube shall consist of one or more layers of absorbent non-woven felt fabric that meets the requirements of ASTM F1216 or fiberglass laminate tube that meets the requirements of ASTM F2019.

2.2.2 The tube shall be homogeneous across the entire wall thickness containing no intermediate or encapsulated elastomeric layers. No material shall be included in the tube that may cause delamination in the CIPPL. No dry or unsaturated layers shall be evident.

2.2.3 The felt content of the liner shall be determined by the Contractor, but shall not exceed 25 percent of the total impregnated liner volume.

2.2.4 The wall color of the interior pipe surface of CIPPL after installation shall be a light reflective color so that a clear detailed examination with closed circuit television inspection equipment may be made.

2.3 *Resin* –

2.3.1 The liquid thermosetting resin shall saturate the tube and produce a properly cured liner which is resistant to abrasion due to solids, grit, and sand.

2.3.2 Polyester, vinyl ester, or epoxy resin and catalyst system shall comply with the following requirements and that when properly cured meets the requirements of ASTM F1216. Resins created from recycled materials are not allowed.

2.3.3 Resin enhancers are allowed and may be used by the Contractor. The maximum amount of enhancer allowed is 30 pounds enhancer per 100 pounds resin. Submit data verifying amount of enhancer and certify the limit of enhancer has not been exceeded.

2.3.4 Resin enhancers shall utilize a suitable bond enhancing compound to increase the bond between resins and other materials. Submit certification that bond enhancing compound is suitable for use in aqueous environments.

2.4 *Hydrophilic Seals* – The hydrophilic waterstop end seals shall be bands that are 20 mm wide and 5 mm high and installed at every entrance to a manhole.

Approved Manufacturers	
Manufacturer	**Model/Style**
Hydrotite	RS-0520-3.51
Adeka Ultra Seal	MC-2005T
Or equal as approved by ECUA in writing	

2.5 *Cured-In-Place Pipe End Seal* –

2.5.1 Provide cured-in-place pipe (CIPPL) end seals where directed by the Owner or as shown on the Drawings to seal watertight the end of the CIPP where it enters the manhole.

2.5.2 Provide 316 stainless steels bands for securing end seal to CIPPL and the original host pipe.

2.5.3 CIPPL end seal shall match the diameter of the existing CIPPs where it will be installed.

2.5.4 Product and Manufacturer: Provide CIPPL End Seal as manufactured by NPC, Inc. of Milford, NH or approved equal.

2.6 *Pre-Liners* – Pre-liners shall be 10 mil thick PVC or polyethylene tubes sized to nominal host pipe inside diameter.

PART 3: Execution

3.1 *Preparation* –

3.1.1 Review Owner's television inspection logs and/or conduct additional inspection of the pipes as deemed necessary by Contractor to plan rehabilitation work. Determine the location of all active service connections prior to lining. Dye test to verify all active service connections, if necessary, or otherwise required by the Contract Documents. Do not reopen taps that are not active.

3.1.2 Clean pipes prior to Pre-Construction Inspection, such that the pipes are free of roots, grease, sand, rocks, sludge, tuberculation (to a tolerance of 0.25 inches projection) and other debris.

3.1.3 Remove intruding taps and seal material prior to Pre-Construction Inspection.

3.1.4 Submit and obtain Engineer's approval of Pre-Construction Inspection prior to wetting out liner. Inspect and confirm the inside diameter, alignment and condition of each segment to be lined. Use the data and information collected from this inspection to verify the size of the liner and refine the installation techniques. If unknown physical conditions in the work area are uncovered during the investigation that materially differ from those ordinarily encountered, notify the Engineer.

3.1.5 As required, provide for continuous flow around the section of pipe that is to be lined. The pump and bypass lines shall be of adequate capacity and size to handle the flow of the sewers. The proposed bypassing system shall be reviewed in advance by the Engineer. The review of the bypassing system by the Engineer shall in no way relieve the Contractor of his responsibility and liability.

3.1.6 Clear the line of obstructions such as solids or broken pipe that will prevent the insertion of the liner. If inspection reveals an obstruction that cannot be removed by the conventional cleaning equipment, make an excavation and repair the obstruction. Excavation work shall be approved by the Engineer prior to commencement of the work and shall be paid under a Change Order.

3.1.7 Remove pockets of water from the pipe.

3.1.8 In presence of Engineer, perform a pre-lining CCTV inspection immediately prior to CIPPL lining to demonstrate that the pipe is clean and free of roots, grease, sand, rocks, sludge, PACP Runners or Gushers, pockets of water, or structural impediments that would affect long-term viability of the pipe liner. Obtain Engineer's verbal approval of the acceptability of the existing pipe condition prior to installation of the CIPPL.

3.2 *Bypass Pumping* –

3.2.1 Maintain commercial and residential sewer service during the installation process. If necessary to properly complete the work, the Contractor may interrupt flow from services if such interruption is first coordinated with and allowed by the property Owner(s). Contact the property Owners and notify them of any service interruptions. Upon completion of the work, immediately reinstate all services and notify the property Owner(s) that service is again available. The Contractor assumes all responsibility for notifying property Owners of service interruptions. The Contractor also assumes all responsibility for blockages, back-ups or damages caused to public or private property as a result of the interruption of service, whether caused by the Contractor's or property Owner's actions.

3.2.2 Bypass pump sewage from individual laterals, if needed.

3.3 *CIPPL Installation Procedures* –

3.3.1 *Lateral Cutters* – Maintain two working lateral reinstatement cutters at the job site at all times. Lining work shall not commence if the Contractor does not have the required number of working cutters on site. No additional time or compensation shall be awarded to the Contractor in the event that work is stopped due to the Contractor's failure to comply with this requirement.

3.3.2 *Resin Impregnation (Wet Out)* – Designate a location where the flexible tube will be impregnated with resin. Thoroughly saturate flexible tube prior to installation. For tubes with exposed resin faces, add five percent excess resin to account for resin migration in pipe defects and joints and resin loss through the ends of the liner. Adjust roller gap setting so that the excess resin is uniformly distributed throughout the length of the liner. Wet-out logs shall provide proper documentation that excess resin was added. Tubes that have a coating between the inside surface of the host pipe and the exterior surface of the tube do not require excess resin. A catalyst system, or additive compatible with the resin and flexible tube, may be used as recommended by the Manufacturer and with approval of the Engineer. Handle the resin-impregnated flexible tube to retard or prevent resin setting until it is ready for insertion.

3.3.3 *Insertion* – Insert flexible tube through an existing access way. The liner material shall be inserted through a manhole by means and method required by the Manufacturer, and shall be fully extended to the lower manhole. Where practical, insert the tube such that the seam of the liner is positioned at the 6 o'clock position. Use only lubricants approved by the tube Manufacturer. Follow the Manufacturer's standards during the elevated curing temperature so as not to over stress the flexible tube and cause damage or failure of the liner prior to cure. Make allowance for circumferential stretching during inversion. Make allowances for longitudinal stretching during pull-in or inversion. Do not utilize overlapped layers of felt in longitudinal seams that cause lumps in the final product. Extend head end (A-side) and tail end (B-side) of the liner for taking samples as required in Paragraph 3.8. If recirculation hoses are used during the curing process, extend the end of such hoses and liner beyond the end of the host pipe and into the downstream manhole.

3.3.4 *Restraint Sleeves* – CIPPL restraint sleeves shall be approved for use at the insertion and receiving manholes only. Ensure that the sleeve system does not enter the host pipe. Sleeve restraint systems will not be allowed in intermediate manholes. Cover exposed CIPPL in intermediate manholes with cut PVC pipe and sandbags to prevent overstretching of the liner or insufficient curing.

3.3.5 *Waterstops* – Insert continuous or properly trimmed hydrophilic waterstops at each manhole opening, centered within the intersection of the host pipe and the manhole wall. Trimmed waterstop edges shall be butted up against each other at the crown of the pipe using a 45-degree miter cut. Waterstops with any gap between the ends will not be accepted. For manholes with outside drops, install two hydrophilic waterstops, one approximately one inch inside the manhole wall and another approximately nine inches upstream of the outside drop and reinstate the drop opening through the CIPPL. If defects in the host pipe near the manhole are such that the end seal will not form a watertight seal between the liner and host pipe, apply hydraulic cement to the defects in the host pipe to provide a smooth surface to receive the end seal.

3.3.6 Pressure Head – The pressure head used during the installation process shall be sufficient to hold the liner tight to the pipe wall, produce dimples at all service connections and the two access manholes, and prevent wrinkles in the cured liner. The same head shall be great enough to prevent infiltration from entering the pipeline during the curing process. Pressure head shall be maintained sufficiently long enough to allow pockets of water to exfiltrate through the host pipe and prevent lifts in the liner and resin washout.

3.3.7 *Curing* –

3.3.7.1 Follow submitted cure schedule in curing of liner.

3.3.7.2 After insertion is completed, for non-light cured products, apply a suitable recirculation system capable of delivering air, steam, or water at various temperatures, and as required by the liner system Manufacturer, uniformly throughout the section to achieve a consistent cure of the resin while allowing any moisture to migrate from the liner. Maximum temperature increase rate between ambient to 140°F shall be 1°F per minute. Maintain the curing temperature or exposure times as recommended by the liner system Manufacturer. Prevent excessive temperatures that could scald or bubble the liner. Scalded or blistered liner will be rejected if, in the opinion of the Engineer, the performance of the liner is compromised.

3.3.7.3 Fit suitable monitors to any heat source to gauge the temperature of incoming and outgoing water or steam supply or UV lamps, where appropriate.

3.3.7.4 Monitor temperatures through two thermocouples placed between the CIPPL and the invert of the host pipe at each manhole. Record temperature measurement every 5 minutes. Record temperature in Fahrenheit.

3.3.7.5 Continue uninterrupted curing until the desired product is achieved.

3.3.7.6 Provide for vapor tight connections in the downstream manhole such that no vapors enter downstream pipes. Alternatively and at no additional cost to the Owner, provide styrene odor reducing agents, venting, and downstream plugs sufficient to prevent steam, styrene, or other odors from entering downstream buildings.

3.3.8 *Cool Down* – Initiate a controlled cool-down to cool the hardened liner to a temperature below 110°F, in accordance with the cure schedule. For pipe liners less than 21 mm thick, maximum cool down rate shall be 0.5°F per minute. For pipe liners greater than 21 mm thick, maximum cool down rate shall be 0.3°F per minute. Take care in release of the

pressure column so that a vacuum will not develop that could damage the newly installed liner. Cooling/Curing water shall only be discharged into ECUA's sanitary sewer. Discharging of cooling/curing water to the ground or storm water system is not permitted. Do not discharge water in excess of 100°F into the sewer system.

3.3.9 *Finished Pipe* – Provide a finished CIPPL that is continuous and free as commercially practicable from visual defects such as foreign inclusions, dry spots, pinholes, delamination, and wrinkles at any location totaling more than 5 percent of host pipe inside diameter.

3.3.10 *Reopening Services* – Reopen all of the existing active service connections in each length of sewer immediately following installation of the liner. Reopen active service connections from inside the sewer by means of a remote controlled, CCTV assisted cutting device appropriate for the liner material and the rehabilitated sewer pipe. Each active service connection shall be cut completely open and shall have smooth edges with no protruding material capable of hindering flow or catching and holding solids contained in the flow stream. If the service connection cannot be fully reopened due to time constraints, open each service connection to a minimum of 75 percent before the end of each working day. Partially opened service connections must be entirely opened by no later than the next working day.

Do not reopen capped or inactive lateral connections. Confirm the locations of all capped or inactive laterals during pre-construction CCTV inspections.

3.4 *Trimming At Manholes* –

3.4.1 Delay final trimming and sealing of the liner at manholes according to Manufacturer's guidelines.

3.4.2 Neatly and smoothly trim the finished ends of the liner to within two inches of host pipe end. Do not leave any rough edges that may catch debris. Do not leave any portion of CIPPL within the manhole channel unless directed by the Owner to remain.

3.4.3 Provide a smooth transition between the existing manhole channel invert and the effluent liner using cementitious or other approved material to prevent settling of sediments or debris from catching on the liner.

3.5 *CIPPL End Seal Installation* –

3.5.1 Field measure existing CIPP inside diameter prior to ordering CIPP end seal units.

3.5.2 Cut out, remove and dispose of a portion of the existing CIPP to expose a minimum of 1.5 inches of the host pipe. Remove the minimum amount of CIPP necessary to properly install the CIPP end seal.

3.5.3 Clean the CIPP and original host pipe so they are free of debris and grease.

3.5.4 Install CIPP end seal units in accordance to the Manufacturer's recommended procedure. Position the stainless steel expansion band closest to the manhole so it is located within the outer wall of the manhole.

3.5.5 Remove all debris resulting from the installation of CIPP end seal units.

3.6 *Post-Construction Inspection of Completed Work –*

3.6.1 *Inspection Documentation* – Provide post-construction inspection video documentation showing completed work.

3.6.2 *Quality Assurance* – Correct all defects discovered during the television inspection before Conditional Acceptance. After the defects are corrected, repeat the Post-construction Inspection for that sewer line.

3.6.3 *Final Cleanup* – Upon completion of rehabilitation work and testing, clean and restore project area affected by the Work.

3.7 *Quality Control Tests –*

3.7.1 For each installation of CIPPL, collect a restrained pipe sample by placing a section of PVC pipe on the B-Side end (opposite of insertion side) of the liner in the downstream manhole for steam and ultraviolet cures and on the insertion end, A-Side of the liner in the insertion side manhole for water cures. Select PVC material and size to match the inside diameter of the sewer being lined as closely as practical. The length of PVC pipe shall be equal to the length of the two required samples plus 12 inches, minimum. Run the impregnated tube through the pipe and cure the CIPPL under restrained conditions. Cut two cylindrical samples from the center of the restrained pipe sample. Each sample shall be a minimum of 9 inches long or 25 times the CIPPL thickness, whichever is greater. Label samples with the Contract number, date of installation, street location, segment number(s), and specified thickness. Deliver one sample to Contractor's testing facility. Contractor may elect to take additional samples at no additional cost to the Owner.

3.7.2 The following tests at the following minimum frequencies will be performed by the Contractor on CIPPL liners installed. The Owner may elect to perform additional testing. The Contractor may, at his discretion and cost, conduct additional testing to improve the resolution of performance test characterization. Any testing Owner elects to perform shall be performed by an independent, certified ISO 17025 testing facility. Each test shall be performed by a laboratory with an American Association for Laboratory Accreditation (A2LA) for the specific test to be performed.

3.7.2.1 Short-term Flexural (Bending) Properties: The initial tangent flexural modulus of elasticity and flexural yield strength measured in accordance with ASTM D790.

3.7.2.1.1 Frequency: 1 test per inversion shot.

3.7.2.2 Thickness measured in accordance with ASTM D5813/D3567.

3.7.2.2.1 Frequency: 1 test per inversion shot.