2012 GREEN BOOK SECTION 500

PART 5

SYSTEM REHABILITATION

SECTION 500 - PIPELINE

500-1 PIPELINE REHABILITATION.

500-1.1 Requirements.

500-1.1.1 General. This subsection provides specifications for various pipeline system rehabilitation.

Section 500 does not address the structural capacity of any of the rehabilitation systems described herein nor their structural requirements. The method shall be capable of bridging cracks, holes, and joint displacements that have been determined not to require point repair. The type of rehabilitation materials and methods for a given Contract will be designated on the Plans and in the Specifications. Unless otherwise provided for in the Special Provisions, proof of meeting the chemical resistance and physical testing shall be submitted to the Engineer for approval in accordance with 2-5.3 as a submittal. The Agency may require testing of the materials and methods prior to commencement of the Work to verify manufacturing compliance with required quality control standards and that no damage occurred to the materials during shipment to the Work site. At the time of installation, materials shall not be more than 6 months old from the date of manufacture. Material safety data sheets (MSDS) shall be available at the Work site.

500-1.1.2 Submittals. Prior to rehabilitation, the Contractor shall submit working drawings of construction details and all other submittals per 2-5.3. The working drawings shall include the location, method of rehabilitation and, when applicable, any bypass locations with sufficient detail to assure that the work can be accomplished without sewage spill. All submittals required by these specifications shall meet the requirements as shown on the Plans and in the Specifications.

500-1.1.3 Storage and Handling. Liner pipes and rehabilitation materials shall be properly stored and handled to prevent damage in accordance with the manufacturer's recommendations and as approved by the Engineer. Damage is described as, but is not limited to, gouging, abrasion, flattening, cutting, puncturing, or ultra-violet (UV) degradation. Thorough inspection of the liner pipes and rehabilitation materials shall be performed prior to installation. Criteria for acceptance/rejection shall be per 500-1.1.8.

500-1.1.4 Cleaning and Preliminary Inspection. Pipeline cleaning shall be performed prior to closed circuit television (CCTV) inspection and rehabilitation. The Contractor shall protect the manholes to withstand forces generated by equipment, water, and air pressure. After cleaning, the Contractor shall also confirm the inside minimum and maximum size (diameter and/or configuration) of the pipeline. The Contractor shall be responsible for the removal of debris from the pipeline and restore the pipeline to a minimum of 95 percent of the original diameter or area, as shown on the Plans or in the Special Provisions. Pipeline debris is described as, but is not limited to, sludge, dirt, sand, rocks, grease, roots, and other solid or semisolid materials.

Some pipeline cleaning methods available are listed herein. When utilizing high-velocity hydraulic cleaning equipment independently or in combination with other cleaning methods, it is recommended that a minimum of 2 passes with the hydraulic nozzle shall be done unless otherwise approved by the Engineer. Root cutters and porcupines shall be attached to the winches if so specified in the Special Provisions or directed by the Engineer. The Contractor shall be responsible for conducting a site inspection of each pipeline prior to rehabilitation to determine which cleaning methods are to be used. These methods shall be submitted to the Engineer for approval in accordance with 2-5.3.

a) **Hydraulically Propelled Equipment.** The equipment shall be a movable-dam type and be constructed in such a way that a portion of the dam may be collapsed at any time during the cleaning operation to prevent flooding of the sewer. The movable dam shall be equal in size to the pipeline being cleaned and provide a flexible scraper around the outer periphery to ensure removal of grease and other debris. If sewer cleaning balls or other equipment which cannot be collapsed are used, special precautions to prevent flooding of the sewers and public or private property shall be taken.

b) **High-Velocity Hydraulic (Hydro-Cleaning) Equipment.** All high-velocity hydraulic cleaning equipment shall carry a water tank, auxiliary engines, pumps, and a hydraulically driven hose reel. The equipment shall have a selection of two or more high velocity nozzles capable of producing a scouring action from 15 to 45 degrees in all size lines designated to be cleaned. The cleaning units shall have high-velocity nozzles for washing and scouring manhole walls and floors. The nozzles shall be capable of producing flows from a fine spray to a solid stream.

c) **Mechanically Powered Equipment.** Bucket machines shall be used in pairs with sufficient power to perform the work in an efficient manner. Machines shall be belt operated or have an overload shutoff device. Machines with a direct drive that could cause damage to the pipe will not be allowed. Bucket machines shall not be used on any host or rehabilitated pipeline that is lined with a plastic pipe or material. A power rodding machine shall be either a sectional or continuous-rod type capable of holding a minimum of 750 feet (230m) of rod. The machine shall be fully enclosed and have an automatic safety clutch or relief valve.

For segmented liner systems 27 inches (675mm) and larger, a standard test section of liner pipe or mandrel shall be inserted prior to sliplining. The mandrel shall have a segment length equal to that of the liner pipe. The outside diameter of the mandrel shall be a minimum of one percent greater than the outside diameter of the liner pipe but shall not exceed 1/2 inch (13mm) without prior approval of the Engineer. The equipment used by the Contractor to insert the test section or mandrel shall conform to Table 500-1.1.4 (A). A baffle plate shall be attached to the test section with adequate height to guarantee removal of any debris which could be present.

If cleaning cannot be completed from one manhole, the equipment shall be moved and set up on the other manhole and cleaning shall be re-attempted. If successful cleaning still cannot be performed or the equipment fails to traverse the entire pipeline section, it shall be assumed that a major blockage exists. Efforts to clean the lines shall be temporarily suspended and the Contractor shall notify the Engineer. Upon removal of the obstruction, the Contractor shall complete the cleaning operation.

The Contractor shall dispose of all debris removed from the pipeline, in accordance with current applicable regulations. Any hazardous waste material encountered during the Contract shall be considered as a changed condition.

TABLE 500-1.1.4 (A)

Nominal ID of Liner Pipe, inches (mm)	Minimum Equipment Insertion Force, Tons (kN) [1]
27 (675) to and including 60 (1500)	25 (220)
Over 60 (1500) to and including 84 (2100)	32.5 (290)
Over 84 (2100)	50 (440)

1. The equipment at the insertion pit shall be capable of withdrawing the test section or mandrel, if necessary.

500-1.1.5 Television Inspection. Closed circuit television (CCTV) inspection will be required prior to rehabilitation to document the condition of the host pipeline and to verify that it was cleaned per 500-1.1.4. A post-installation CCTV inspection shall be performed to determine if the work was completed per the Contract Documents and that all service connections have been re-instated, as required. All video inspections shall be recorded on a four-head VCR in VHS format, standard play mode. All original videotapes, log sheets, and reports shall be submitted to the Engineer and will become property of the Agency.

CCTV equipment shall include television cameras, a television monitor, cables, power sources, and other equipment. Focal distance shall be adjustable through a range from 6 inches (150mm) to infinity. The remote-reading footage counter shall be accurate to less than 1 percent error over the length of the particular section of pipeline being inspected. This distance is measured from the centerline of the manhole to the centerline of the next manhole. The camera and television monitor shall produce a minimum 350 lines per inch (14 lines per mm) resolution. Telephones, radios, or other suitable means of communication shall be set up to ensure that adequate communication exists between members of the crew. The CCTV inspection system to be utilized on the project shall be approved by the Engineer prior to the work being performed. CCTV inspection for re-instating service connections shall be performed utilizing system b) or c).

CCTV inspection shall be performed utilizing one of the following video camera systems:

a) Remote-focus stationary lens cameras;

b) Rotating-lens cameras; or

c) Pan-and-tilt cameras.

The video camera shall be mounted on a skid, floatable raft system, or transporter based on the conditions of the pipeline to be televised.

The Contractor shall televise the pipeline during optimum low-flow level conditions, as pre-approved by the Engineer. The television camera utilized shall be specifically designed and constructed for sewer inspection. The camera shall be operative in 100 percent humidity conditions. Lighting for the camera shall minimize reflective glare. Lighting and picture quality shall be suitable to provide a clear, in-focus picture of the entire periphery of the pipeline for all conditions encountered during the work.

The camera shall be moved through the pipeline in a downstream direction at a uniform rate, stopping when necessary to ensure proper documentation of the sewer's condition, but in no case shall the television camera be pulled at a speed greater than 30 feet per minute (9m/min.). A clear picture shall be provided looking into each service connection for both the pre-lining and post-lining tapes. During the pre-rehabilitation video inspection, if the television camera will not pass through the entire pipeline section, the Contractor shall reset the equipment at the downstream manhole and attempt to inspect the section of pipe from the opposite direction. If the camera fails to pass through the entire section, it shall be assumed that an obstruction exists. Efforts to televise that section of pipe shall be temporarily suspended and the Contractor shall notify the Engineer. Upon removal of the obstruction, the Contractor shall complete the CCTV inspection.

If an obstruction is encountered during the post-rehabilitation or post-installation video inspection, the Contractor shall remove the obstruction by excavation, repair, or other means approved by the Engineer at the Contractor's expense, in order that television inspection may continue.

Documentation shall consist of a color, VHS-format videotape, log sheets, and a written report detailing the post-rehabilitation or post-installation condition of the pipeline and lateral connections/openings. The report shall note the time and date of video inspection, street name, upstream and downstream manhole, direction of view, direction of flow, surface material, pipeline length, pipe section length, pipe size, pipe material, lateral connections, video tape number, counter number, and a detailed logging of defects encountered. Any rejected

work shall be repaired, then re-televised. If the quality of the video tape is deemed to be unacceptable by the Engineer, the pipeline shall be re-televised at no additional cost to the Agency. Additional Agency requirements for performing CCTV inspection will be noted on the Plans or in the Special Provisions.

500-1.1.6 Sampling, Testing, and Installation. All materials shall be sampled and tested in accordance with 4-1. Rehabilitation materials shall be tested in accordance with the requirements of 211-2 and conform to the requirements for the specified material, unless otherwise specified in the following subsection. Test methods, specifications, standards, and the required quality control procedures for testing and installation are listed in each subsection. The Contractor shall install only those pipeline rehabilitation system materials that specifically meet the criteria in the following subsections.

500-1.1.7 Miscellaneous.

a) **Service Connections.** The Contractor shall be responsible for locating all service connections and cleanouts. The Contractor shall provide written notification of work activities to all local users and provide interim sewer service, as specified by the Agency.

Service connections shall be re-established as quickly as possible, not to exceed 24 hours, after completion of each liner pipe installation. Services requiring bypasses to be provided by the Contractor will be identified in the Special Provisions. When the service connection is re-established, the invert of the service connection shall match the bottom of the reinstated service opening. The service opening shall be reinstated from a minimum of 95 percent to a maximum of 100 percent of the original service connection. The new edge shall be smooth and crack free with no loose or abraded material.

If the service connection is to be re-established by a remote control device, the Contractor shall have a fully operational backup device on site. If for any reason the Contractor is unable to remotely re-establish the service connections, the Contractor shall immediately re-establish each service connection by open excavation at no additional cost to the Agency.

b) **Segmented Liner Pipes.** The rehabilitation processes specified in 500-1.8, 500-1.11 and 500-1.12 may be accomplished while flow exists in the host pipeline, without diverting the flow or bypass pumping. The Contractor shall consider the effects of varying floor levels on the buoyancy calculations in accordance with 2.5.3. Obstructions, including, but not limited to, roots, large offset joints, rocks, or other debris that could prevent passage or cause damage to the liner sections shall be removed. For variable exterior profile wall liner pipe, the Contractor shall consider the inside surface smoothness of the host pipe to minimize damage to the liner. The existing pipe joints shall be repaired prior to installing the liner pipes. Liner pipes shall be inserted one section at a time through an access/insertion pit constructed above the existing sewer. When segmented liner pipe sections are inserted from 2 locations to a common point, a coupling device shall be provided that is pre-approved by the Engineer. The top of the existing host pipe exposed in the pit shall be evenly removed down to the springline level. Liner pipe sections shall be inserted spigot end first with the bell end trailing and a pushing force shall be applied to the pipe wall and to the inside of the bell, unless otherwise approved by the Engineer.

Before insertion of segmented liner pipe 27 inches (675mm) and larger, a standard test section of liner pipe or an approved mandrel shall be pushed/pulled through the section of pipe being rehabilitated in accordance with 500-1.1.4 to ensure that it has been properly cleaned and all obstructions removed. A jacking or pulling ring shall be used to distribute the push/pull forces uniformly against the bell end perimeter of the liner pipe. The calculated forces shall include the frictional forces of the liner pipe against the invert of the host pipe or the soffit of the host pipe when buoyant forces cause the liner pipe to float. A load-measuring device, approved by

the Engineer, shall be used to measure the loads exerted on the liner pipe, so that the manufacturer's approved maximum loads specified in 500-1.8, 500-1.11 and 500-1.12 will not be exceeded.

c) **Access/Insertion Pits.** Upon completion of the rehabilitation process, and/or as directed by the Engineer, the access/insertion pit area shall be restored in accordance with working drawings approved by the Engineer in accordance with 2-5.3 and 7-9.

d) **Manhole Protection.** During the rehabilitation process, the Contractor shall protect the manholes to withstand the forces generated by equipment, water, and air pressures used while completing the rehabilitation installation.

e) **End Seals.** The beginning and end of the new pipe liner shall be sealed to the host pipe with an epoxy or other material. The epoxy or other material shall conform to 211-2 and be submitted for approval to the Engineer in conformance with 2-5.3. The approved epoxy or other material shall be compatible with the lining material and host pipe and shall provide a watertight seal. The finished liner shall protrude a minimum of 1 inch (25mm) and a maximum of 2 inches (50mm) into the manhole, unless otherwise shown on the Plans or specified in the Special Provisions. Liner material shall be cut smooth and parallel with the manhole wall. The interface between the host pipe and the pipe liner shall be sealed 360 degrees. When the pipe liner extends through the manhole it shall be sealed as shown on the Plans and as specified in the Special Provisions.

500-1.1.8 Rejection. If the Contractor has used any material or method that has not been approved by the Engineer, the Contractor shall, at its sole expense, remove the entire rehabilitated pipe and replace it with new pipe as directed by the Engineer. All damaged rehabilitation materials and pipe rejected by the Agency shall be promptly removed from the Work site at the Contractor's expense and disposed of in accordance with current applicable regulations.

500-1.1.9 Measurement and Payment. Pipeline cleaning and inspection, including CCTV inspection, will be paid for at the Contract Unit Price per linear foot (meter). If a separate Bid item is not included, then full compensation shall be considered to be included in the Bid price for the liner pipe and/or the pipeline point repair/replacement pipe.

Pipeline point repair/replacement and rehabilitation shall be measured along the longitudinal axis between the ends of the pipeline, as shown on the Plans, and shall not include the inside dimensions of structures.

The Contract Unit Price per linear foot (meter) or lump sum for pipeline point repair/replacement and rehabilitation shall be considered full compensation for furnishing and installing all fittings, connections, seals, and special work shown on the Plans and in the Specifications. Additionally, the Contract Unit Price shall include all labor, materials, and equipment required; removal of interfering portions of existing sewers, storm drains, and other improvements; closing or removing of abandoned pipelines and structures, if required CCTV inspection and/or leak testing; excavation of the trench and/or access/insertion pits; control of ground and surface waters; preparation of the subgrade; placing and joining of pipe, including any necessary annular space grouting; backfilling of the trench and/or access/insertion pits; temporary and/or permanent resurfacing; and all other work necessary for pipeline point repair/replacement and rehabilitation, complete and in place.

500-1.2 Pipeline Point Repair/Replacement.

500-1.2.1 General. This subsection specifies the point repair and/or replacement of host pipelines. The Contractor shall be responsible for repairing the pipeline where point repairs are identified on the Plans or in the Special Provisions prior to any rehabilitation. If this is not shown, it will constitute Extra Work per 3-3 when approved by the Engineer.

The work shall include verifying the location of the point repair and/or replacement through CCTV or person-entry inspection of the pipeline, locating all interfering utilities, excavation, dewatering, pipe repairs or replacement, backfilling, surface restoration, temporary flow bypassing, sewer dewatering, and traffic control.

500-1.2.2 Materials. The pipe and repair materials shall be the same as the host pipeline unless otherwise indicated, and shall comply with 207 for the type and class required.

500-1.2.3 Excavation. Trenching and excavation shall conform to 306.

500-1.2.4 Sewer Bypassing and Dewatering. When required by the Contract Documents or the process, the Contractor shall bypass the sewer flow around the work and dewater the work area, in accordance with 7-8.5 and 306-3.3.

500-1.2.5 Notification of Work. The Contractor shall notify the Engineer a minimum of 48 hours in advance of the planned time to begin pipeline point repair work/replacement at a particular location.

500-1.2.6 Installation and Field Inspection. The installation of the replacement pipe and/or repair work shall conform to 306. Prior to the demobilization of the Contractor performing open-excavation repairs, the post-cleaning video tape(s) shall be submitted to the Engineer. The results of the post-cleaning video tape(s) may indicate the need for additional excavation and repair prior to lining. The Contractor shall review all the post-cleaning tape(s) and identify any additional point repair, which impacts the placement of the liner and the reinstatement of the service connection(s) and shall provide these locations in writing to the Engineer. All pipeline point repairs/replacement shall be inspected and measured by the Engineer prior to any backfilling and compaction and leak testing/CCTV inspection prior to placing of permanent resurfacing.

500-1.3 HDPE Solid-Wall Pipe Liner.

500-1.3.1 General. HDPE solid-wall liner pipe for use in sanitary sewers, storm drains, and house connection sewers shall comply with ASTM D3350 and ASTM F714. Fittings shall comply with ASTM D2683 or D3261. Fittings fabricated by mitered, butt fusions are also permitted.

500-1.3.2 Material Composition. Pipe and fittings shall be made from HDPE compounds conforming with ASTM D3350, Cell Classification 345434C, D, and E and shall also meet the requirements of 207-19.2.

500-1.3.3 Liner Pipe Acceptance. Liner pipe acceptance shall conform to 207-19.3.

500-1.3.4 Marking. Liner pipe marking shall conform to 207-19.4.

500-1.3.5 Chemical Resistance and Physical Testing. The HDPE liner pipe shall conform to 207-19.5

500-1.3.6 Installation and Field Inspection. The HDPE liner pipe shall conform to 500-1.1 for the cleaning and inspection of the host pipeline; preparation of entry points as needed; and the storage, handling, and joining of HDPE pipe. A proofing pig shall be pulled through the host pipeline prior to liner insertion to verify adequate clearances.

500-1.3.7 Annular Space Grouting. The entire annular space shall be fully grouted. The maximum safe annular grouting pressure in psig for single-stage or multi-stage grouting shall not exceed the values shown in Table 500-1.3.7 (A).

TABLE 500-1.3.7 (A)
DIFFERENTIAL-PRESSURE (VACUUM OR EXTERNAL FLUID)
CAPABILITY FOR UNSUPPORTED PIPE AT 73.4°F (23°C) [1]

SDR	kPa (psi)
32.5	4 (28)
26	8 (55)
21	16 (110)
19	21 (145)
17	28 (193)
15.5	36 (248)

1. Safety factor not included.

500-1.3.8 Service Connections and End Seals. The Contractor shall be responsible for locating all service laterals and cleanouts. Service connections shall not be made until the liner pipe has stabilized, which is normally accomplished after a 24-hour waiting period. Service laterals shall be connected to the liner pipe by use of a heat-fused saddle or mechanical saddle as approved by the Engineer.

500-1.3.9 Repair and Rejection. Liner pipe may be repaired for minor superficial pipe damage. Damaged liner pipe which has been penetrated over 10 percent of the wall thickness at either the inner or outer wall surface, shall be repaired by cutting out the damaged section and replacing it with new pipe. All repair methods shall be submitted to the Engineer for prior approval in accordance with 2-5.3. The remaining liner pipe sections shall be a minimum of 8 feet (2.4m) in length. Liner pipes shall be inspected for damage immediately prior to installation. If liner pipe is found to be superficially damaged, the Engineer may allow the pipe to be repaired or may reject it. Rejected liner pipe shall be replaced with a new section of liner pipe.

500-1.4 Cured-In-Place Pipe Liner.

500-1.4.1 General. CIPP liner for the rehabilitation of pipelines shall be either the Type A - inversion process in compliance with ASTM F1216 or the Type B - pull-in-place process in compliance with ASTM F1743 for installation using heated-water cure. The CIPP liner shall use an approved epoxy or epoxy-vinyl ester-resin-impregnated flexible fabric tube. The tube is installed by an inversion method using a hydrostatic head or by pulling it through an existing pipe and inflating by inverting a membrane using a hydrostatic head.

500-1.4.2 Material Composition and Testing. The fabric tube shall consist of one or more layers of flexible, needled felt or an equivalent nonwoven material and have plastic coating(s). The material shall be compatible with and capable of carrying epoxy or epoxy-vinyl-ester resin, be able to withstand installation pressures and curing temperatures, and be compatible with the approved resins used. The approved epoxy or epoxy-vinyl-ester resin shall be compatible with the application and pipeline environment and be able to cure in the presence of water. The initiation temperature for cure shall be as recommended by the resin manufacturer and approved by the Engineer. The CIPP liner shall comply with ASTM D5813 and shall have, as a minimum, the initial structural properties per Table 500-1.4.2 (A).

TABLE 500-1.4.2 (A)

Epoxy Resin Properties	ASTM Test Method[1]	Initial Values psi (MPa)
Flexural Strength	D 790	5,000 (34.5)
Flexural Modulus	D 790	300,000 (2068)
Tensile Strength	D 638	4,000 (27.6)
Tensile Modulus	D 638	250,000 (1724)
Epoxy-Vinyl-Ester Resin Properties	**ASTM Test Method**	**Initial Values psi (MPa)**
Flexural Strength	D 790	4,500 (31.0)
Flexural Modulus	D 790	250,000 (1724)
Tensile Strength	D 638	3,000 (21.0)
Tensile Modulus	D 638	250,000 (1724)

1. The initial values are determined by ASTM D638 and D790.

The Contractor shall provide field-cured samples as directed by the Engineer and as specified in the Special Provisions. The physical properties of the finished CIPP shall be verified through a field-sampling procedure in accordance with ASTM F1216 or ASTM F1743 and in accordance with ASTM D5813.

500-1.4.3 Resin and Tube Acceptance. At the time of resin impregnation, the entire fabric tube shall be inspected for defects. The resin shall not contain fillers, except those required for viscosity control, fire retardance, or extension of pot life. Thixotropic agents that do not interfere with visual inspection may be added for viscosity control. Also, the opacity of the plastic coating shall not interfere with visual inspection. Resins may contain pigments, dyes, or colors that do not interfere with visual inspection of the CIPP liner or its required properties. Additives may be incorporated that enhance the physical and/or chemical resistance.

500-1.4.4 Chemical Resistance. The CIPP liner system shall conform to 211-2 and to the weight change requirement of Table 210-2.4.1(A).

500-1.4.5 Installation. The host pipeline shall be cleaned and televised in accordance with 500-1.1.4 and 500-1.1.5. The OD of the tube being installed shall be properly sized to allow for expansion so that the CIPP can fit tightly against the existing pipe.

The CIPP shall be installed in accordance with ASTM F1216 or ASTM F1743 and the Contractor's recommendations as approved by the Engineer. Immediately prior to installation, the CIPP liner tube shall be saturated with resin (on or off the Work site) and stored/transported at a cool temperature as recommended by the resin manufacturer.

500-1.4.6 Curing. After tube placement is completed, a suitable heat source and distribution equipment shall be provided by the Contractor to distribute or recirculate hot water throughout the installed CIPP liner tube. Temperature shall be maintained during the curing period as recommended by the resin manufacturer and approved by the Engineer. After the tube is cured, a cool-down period shall be used prior to opening the downstream end, reconnection of services, and returning normal flow back into the system. Heat curing of the resin shall occur within the manufacturer's approved recommended time frame (pot life). The water in the CIPP shall be cooled to below 100°F (38°C) before discharge.

500-1.4.7 Service Connections and End Seals. After the curing is complete, existing service connections shall be re-established. This may be done without excavation by means of a remote-control cutting device operating within small diameter pipe. A CCTV camera shall be attached to the cutting device for precise location of service connections and inspection of the CIPP liner.

500-1.4.8 Repair and Rejection. Internal and external repairs may be made to CIPP liner pipe in accordance with the manufacturer's recommendations and approval by the Engineer. Internal repairs may be made with approved fabric and epoxy or epoxy-vinyl-ester resins to restore strength and integrity. External repairs may be made by using standard plastic pipe repair techniques, including replacement of the damaged section using PVC pipe coupled to the CIPP liner, as approved by the Engineer.

500-1.5 PVC Pipe Lining System.

500-1.5.1 General. PVC profile extrusions with annular space grouting shall be installed for use in sanitary sewers and storm drains. This applies to the rehabilitation of small-diameter pipe and person-entry pipe (36 inches (900mm) and larger) or conduits in terms of materials and installations.

500-1.5.2 Material Composition. The material shall be made from unplasticized PVC compounds conforming to 207-17, having a cell classification of 12334, 12454, or 13354 as defined in ASTM D1784.

500-1.5.3 Material and Equipment Acceptance. At the time of manufacture, each lot of plastic strips shall be inspected for defects and the physical properties certified in accordance with the ASTM Standards listed in this subsection, or as indicated in the Special Provisions. There are 2 strips of PVC used in this process. The former strip is a ribbed panel which varies in width and height as a function of pipe diameter. The joiner strip is a "U"-shaped strip of PVC which is used to lock together the former strip edges as the PVC strips or panels are being spirally wound upon themselves. The minimum thickness of the strips and panels shall be per Table 500-1.5.3 (A).

TABLE 500-1.5.3 (A)

Nominal ID of Original Pipe inches (mm)	Minimum Thickness		Minimum Profile Height mils (mm)
	Former Strip mils (mm)	Joiner Strip mils (mm)	
8 to 12 (200 to 300)	25 (0.64)	25 (0.64)	192 (4.88)
15 to 18 (375 to 400)	30 (0.75)	31 (0.79)	242 (6.15)
24 to 36 (600 to 900)	45 (1.15)	58 (1.48)	480 (12.20)
30 to 72 (750 to 1800) [1]	60 (1.53)	–	488 (12.40)

1. In some lining applications for pipes and conduits 30 to 36 inches (750 to 900mm) in diameter, it may be determined to use person-entry techniques.

The initial stiffness factor shall conform to Table 500-1.5.3 (B).

TABLE 500-1.5.3 (B)

Nominal ID of Original Pipe[1] inches (mm)	Stiffness Factor (EI)[2] in^3 - lbf/in^2 ($Pa \cdot m^3$)
8 (200)	120 (14)
10 (250)	120 (14)
10 (250)	240 (27)
12 (300)	240 (27)
15 (375)	240 (27)
15 (375)	600 (68)
18 (450)	600 (68)
24 (600)	600 (68)
24 (600)	1600 (181)
30 (750)	1600 (181)
36 (900)	1600 (181)

1. For ID's larger than 36 inches (900mm), see Plans or Special Provisions.
2. Stiffness factors shall be determined in accordance with ASTM D2412. $EI = 0.149R^3$ (PS).

At the time of delivery, the strips shall be homogeneous throughout, uniform in color, and free of cracks, holes, foreign materials, blisters, or other deleterious faults. For testing purposes, a lot is defined as production during an 8-hour shift, while a batch is defined as each 200 linear feet (60 linear meters) of PVC product. Testing shall be performed every 2 hours and records kept on file in conformance with 500-1.5.4. The Contractor shall furnish and maintain in good condition all necessary equipment required for the proper execution and inspection of the work.

500-1.5.4 Marking. Each PVC continuous strip on each reel shall be distinctively marked on its inside surface end with a coded number which identifies the manufacturer, strip thickness, minimum profile height, size, material, machine, date, and shift on which the material was extruded. These markings shall also appear on the PVC strips with a maximum distance between markings of 5 feet (1.5m), and shall be visible from inside the completed liner.

500-1.5.5 Chemical Resistance. PVC and cured sealant/adhesive shall be tested in accordance with the requirements of 211-2 and conform to the weight change requirements of Table 207-17.5(A).

500-1.5.6 Installation and Field Inspection. The host pipeline shall be cleaned of any obstructions and televised per 500-1.1.4 and 500-1.1.5. The condition shall be approved by the Engineer prior to insertion of the liner. The plastic strips or panels shall be handled with care to ensure that the plastic is not kinked, gouged, or otherwise damaged.

The former and joiner strips shall be engaged and an approved sealant/adhesive shall be injected onto the engaged locks. The Contractor shall ensure that the joiner strip is continuously engaged.

For person-entry pipe, the PVC panels shall be cut and trimmed to fit as near as practical to the internal perimeter of the existing conduit. A bead of approved sealant adhesive shall be applied to the female locking edge of the former strip. End joins shall be made with the plasticized end section, which shall overlap the joint by not less than 4 inches (100mm). End joins shall be staggered and shall remain below the normal flowline of the sewer.

500-1.5.7 Annular Space Grouting. For small-diameter pipe, the annular space between the outside of the liner and the inside of the existing pipe shall be grouted. Grouting of the annular space shall be performed in such a manner to prevent damage or collapse of the liner. Grout shall be pumped into the annular space at manholes, service connections, and wherever the liner is exposed.

Grout shall conform to 500-1.3.7.

For person-entry pipe, the grout shall be injected behind the liner by tubes placed on top of the liner or holes drilled through the liner. Any holes in the plastic shall be covered with a patch of similar material as approved by the Engineer.

500-1.5.8 Service Connections and End Seals. Service lateral connections shall be re-established with the liner in accordance with manufacturer's recommendations as approved by the Engineer.

500-1.5.9 Repair and Rejection. Prior to installation, the PVC shall be inspected for flaws such as cracks, blisters, scratches, blemishes, and other faults. Material rejected for any reason shall be replaced prior to installation. If after installation, flaws of a deleterious nature are detected, they shall be corrected in a manner suitable to the supplier and approved by the Engineer. If flaws are correctable by approved splicing or patching methods, that work shall be completed promptly. If approved corrections cannot be made, lining shall be removed from the pipe utilizing new PVC pipe.

500-1.6 (Not Used).

500-1.7 Deformed/Re-formed HDPE Pipe Liner.

500-1.7.1 General. Deformed HDPE extrusions for rehabilitating sanitary sewers and storm drains without excavation shall comply with ASTM D3350 and ASTM F714. This method applies to the rehabilitation of 4 through 18 inches (100 through 450mm) diameter pipe. Unless otherwise specified, liner for pipe shall have a minimum SDR of 32.5. This rehabilitation system may be capable of expanding up to 10 percent. Pipe stiffness shall conform to Table 500-1.7.1 (A).

TABLE 500-1.7.1 (A)[1]

Pipe Size Inches (mm)	Pipe Stiffness[2]		
	SDR 21	SDR 26	SDR 32.5
4 (100)	61	31	16
6 (150)	61	31	16
8 (200)	61	31	16
10 (250)	61	31	16
12 (300)	61	31	16
15 (375)	61	31	16
18 (400)	61	31	16

1. Minimum pipe stiffness (PS) when tested in accordance with ASTM D2412.
2. PS values are from ASTM F174 Table X1.1

500-1.7.2 Material Composition. Pipe shall be made from HDPE compound complying with ASTM D3350, cell classification 345434C, D, or E and shall also meet the requirements of 207-19.2, except that titanium dioxide pigment may be substituted for the 2 percent carbon black.

The Contractor shall provide the manufacturer's certified test results to the Engineer for approval, stating that the material conforms with the applicable requirements, including crystallization temperatures.

500-1.7.3 Material and Equipment Acceptance. Material and equipment acceptance shall conform to 207-19.3.

500-1.7.4 Marking. Marking shall conform to 207-19.4, except that the material shall be designated by HDPE cell classification.

500-1.7.5 Chemical Resistance and Physical Testing. HDPE pipe specimens shall be tested in accordance with the requirements of 211-2 and conform to 207-19.5, except the requirements shall be met with samples from pipes that have been subjected to the deformation and reforming process.

500-1.7.6 Installation and Field Inspection. HDPE pipe shall be installed as follows:

a) The existing pipeline shall be cleaned and televised per 500-1.1.4 and 500-1.1.5, and the condition approved by the Engineer prior to the insertion of the deformed pipe.

b) A cable shall be strung through the host pipe to be rehabilitated and attached to the deformed pipe through an existing manhole or access point. The pipe shall be pulled through the existing conduit by this cable. Pulling forces shall not exceed the axial strain limits of the deformed pipe. The measured pulling operation limits the pulling force to an allowable tensile stress (1,500 psi (10.3MPa) or 50 percent of the yield) times the pipe wall cross-sectional area. Care shall be taken not to damage the deformed pipe during installation. Appropriate sleeves and rollers shall be used to protect the pipe. Calculations for pulling force limits shall be submitted to the Engineer in accordance with 2-5.3.

c) When the deformed pipe is in place, the pipe shall be cut and the processing manifolds (pipe end-closing assembly used for heat and pressure control within liner) shall be inserted and secured at both pipe ends. The temperature and pressure measuring instruments shall be attached to the deformed pipe at both ends.

d) After the deformed HDPE liner is outfitted with temperature and pressure instruments, steam shall be introduced into the system until a minimum temperature of 226°F (108°C) to a maximum temperature of 244°F (118°C) is reached and shall not exceed the melting temperature of 260°F (127°C). The minimum outside pipe temperature at the terminating end of the pipe shall be 185°F (85°C). This temperature shall be held for a minimum of 20 minutes. The deformed pipe shall be pressurized up to 14.5 psig (100 kPa gage), maximum, while the termination point valves are kept open to provide heat flow. The pressure shall then be increased in increments up to a maximum of 26 psig (179 kPa gage).

e) The Contractor shall cool the re-formed pipe according to the approved manufacturer recommendations. When the temperature reduces to 100°F (38°C), the Contractor shall then slowly raise the pressure to approximately 33 psig (228 kPa gage), while applying air or water for continued cooling. The equipment shall be disconnected after ambient temperature is attained.

f) Temperatures and pressures shall be monitored and recorded throughout the installation process to ensure that each phase of the process is achieved at the approved manufacturer's recommended temperature and pressure levels.

g) If the testing of the installed HDPE liner pipe is required in the Special Provisions, the physical properties of the installed HDPE liner pipe shall be verified through field sampling and laboratory testing, all as approved by the Engineer. Unless the Special Provisions call for more than one sample, a sample shall be cut from a section of reformed/rerounded HDPE liner pipe at the upstream, downstream, or an intermediate manhole/access pit that has been inserted through a same diameter pipe acting as a mold. HDPE liner pipe samples shall be submitted to a certified laboratory which has been pre-approved by the Engineer and tested in accordance with ASTM D638 and ASTM D790 to confirm that the liner pipe conforms to the minimum tensile and elongation requirements per 500-1.7.2. All costs incurred for this testing shall be borne by the Contractor.

500-1.7.7 Service Connections and End Seals. Existing service connections shall be reinstated through the use of a remote control unit or excavation. Service connections and end seals shall conform to 500-1.1.7.

The beginning and end of the new HDPE pipe liner shall be sealed to the rehabilitated host pipeline. If sealing material is required, it shall be compatible with the HDPE pipe and shall provide a watertight seal.

500-1.7.8 Repair and Rejection. The Contractor shall provide an evaluation and repair specification to the Engineer for approval for liner pipe found to be damaged during or after installation. Any liner pipe damaged in transit or on the Work site prior to installation will be rejected and shall be immediately removed from the Work site.

500-1.8 CCFRPM Liner Pipe.

500-1.8.1 General. CCFRPM liner for use in lining sanitary sewers shall comply with ASTM D3262. Unless otherwise indicated, the minimum pipe stiffness shall be 18 psi (124 kPa), or greater, as tested in accordance with ASTM D2412.

500-1.8.2 Material Composition. The amount, location, and orientation of the chopped glass-fiber reinforcement shall be specifically designed for each application. The glass shall be a commercial grade of E-Type glass fibers with a finish compatible with the resin used. The sand shall be a minimum 98 percent silica kiln-dried and graded. The polyester wall resin shall be an isophthalic, orthophthalic or other approved resin with a minimum tensile elongation of 2 percent. A vinyl ester liner resin shall be used to meet the chemical resistance requirements of 211-2 and conform to 207-20.5. Designation per ASTM D3262 shall be Type 1, Liner 2, Grade 3, and a minimum pipe stiffness of 18 psi (124 kPa), unless a higher value is indicated on the Plans or in the Special Provisions. Elastomeric sealing gaskets shall conform to the requirements of ASTM F477.

500-1.8.3 Liner Pipe Acceptance. The liner pipe shall be free of cracks, holes, delaminations, foreign inclusions, blisters or other defects that would, due to their nature, degree, or extent, have a deleterious effect on the pipe performance as determined by the Engineer. Prior to installation, damaged pipe shall be either repaired or field cut to remove the damaged portion as approved by the Engineer.

For testing purposes, a production lot shall consist of all liner pipes having the same lot marking number, but shall not exceed a total of 50 pipes. Pipe length, wall thickness, joint dimensions, pipe stiffness, and deflection characteristics shall be verified by testing for each lot in accordance with ASTM D3262.

500-1.8.4 Marking. Each pipe section shall be marked on the inside and every 5 feet (1.5m) on the outside, to show the manufacturer's name, manufacturing number (identifies factory location, date, shift, and sequence), nominal diameter, pipe stiffness, ASTM D3262 and designation, and lot number.

500-1.8.5 Chemical Resistance and Physical Testing. Pipe liners and gaskets shall be tested in accordance with 211-2 and conform to 208-4 and 207-20.5 respectively. Verification shall be provided that physical testing of the product conforms to ASTM D3262 (qualification test only) and ASTM D2412.

500-1.8.6 Installation and Field Inspection. The existing sewer shall be maintained in operation during the relining process. The existing host pipeline shall be cleaned of any obstructions and televised per 500-1.1.4 and 500-1.1.5. Liner pipes shall be inserted one section at a time through an access pit constructed above the existing sewer. The top of the existing sewer exposed in the pit should be removed down to springline level (halfway). Liner pipes shall be inserted in accordance with 500-1.1.7 b). The pushing force shall be applied to the pipe wall end inside of the bell. Maximum jacking load shall not exceed Table 500-1.8.6 (A).

The pipe installation shall conform to 500-1.1.7 b). Maximum jacking loads shall not exceed the values shown in Table 500-1.8.6 (A).

TABLE 500-1.8.6 (A)

Nominal Diameter inches (mm)	SAFE AXIAL COMPRESSIVE LOAD Tons (kN) [1]	
	18 psi (124 kPa) Pipe Stiffness Tons (kN)	36 psi (249 kPa) Pipe Stiffness Tons (kN)
18 (450)	—	17 (151)
20 (500)	—	19 (169)
24 (600)	23 (205)	31 (276)
30 (750)	36 (320)	52 (463)
36 (900)	52 (463)	66 (587)
42 (1050)	71 (632)	95 (845)
48 (1200)	93 (827)	130 (1157)
54 (1350)	123 (1094)	171 (1521)
60 (1500)	155 (1379)	212 (1886)
66 (1650)	175 (1557)	240 (2135)
72 (1800)	209 (1859)	292 (2598)
78 (1950)	252 (2242)	351 (3123)
84 (2100)	307 (2731)	422 (3754)
90 (2250)	357 (3176)	485 (4315)
96 (2400)	411 (3656)	560 (4982)
102 (2550)	470 (4181)	640 (5694)

1. Factor of safety of 2:1 is included for longitudinal compressive load.

500-1.8.7 Annular Space Grouting. The entire annular space between the outside of the liner and the inside of the host pipe shall be grouted, in accordance with 500-3. The minimum radial annular space shall not be less than 1 inch (25mm) unless approved by the Engineer. In accordance with 2-5.3, the grout mix and placement procedure shall be submitted to the Engineer for approval. Grouting of the annular space shall be done in such a manner to prevent damage or collapse of the liner. Maximum safe grouting pressure is equal to the pipe stiffness divided by 3.

500-1.8.8 Service Connections and End Seals. Service connections and end seals shall conform to 500-1.1.7.

500-1.8.9 Repair and Rejection. Prior to installation, damaged pipe shall be field cut to remove the damaged portion and rejoined by approved methods. Superficial damage may be repaired without field cutting. Liner pipe gouges deeper than 50 percent of the vinyl ester lining shall be field cut and removed per 500-1.1.8.

500-1.9 External In-Place Wrap.

500-1.9.1 General. Existing sewer pipes experiencing crown corrosion may be rehabilitated utilizing a wrap of plastic liner with integral locking extensions followed by a cap of reinforcing steel and concrete.

Plastic liner sheet, weld strip, adhesive products and cleaners shall conform to 210-2. Prior to the plastic liner installation, the existing line shall be uncovered and the pipe exposed to accommodate the coverage shown on the Plans or stated in the Special Provisions. Liner shall be applied and secured to the host pipe and inspected and approved by the Engineer prior to placement of reinforcing steel and concrete.

500-1.9.2 Installer Qualifications. Applicators and welders shall be qualified in accordance with 311-1.2.

500-1.9.3 Preparation of Existing Pipe for Installation of Plastic Liner. The concrete surface shall be etched by sandblasting to develop a slightly granular surface. When permitted by the Engineer, the concrete surface may be acid etched in lieu of sandblasting. After sandblasting, the concrete surface shall be thoroughly cleaned of dust. Surfaces etched with acid shall be neutralized with clean water.

a) **Coverage.** The circumferential coverage shall be the upper 270 degrees unless otherwise indicated on the Plans or in the Special Provisions.

b) **Positioning Liner.** Liner installed on the existing pipe shall be positioned with the locking extensions outward and aligned with or perpendicular to the longitudinal axis of the pipe.

Liner shall be centered with respect to the field top centerline of the pipe. Liner shall be set to fit over the existing pipe joints with the field welded seams located away from the joint portion of the pipes. Liner shall be closely fitted to the existing pipe. Sheets shall be cut to fit curved and warped surfaces using the minimum number of separate pieces.

Prior to installation, the Contractor shall indicate to the Engineer the proposed layout of liner sheets, including the location and type of all field welds.

The Engineer may require working drawings per 2-5.3, the use of patterns, or the marking of sheet layouts directly on the existing pipe where complex or warped surfaces are involved.

At transverse joints between sheets of liner used along the pipeline, the space between ends or edges of locking extensions, measured longitudinally, shall not exceed 4 inches (100mm).

c) **Securing Liner in Place.** Liner shall be held snugly in place against the existing pipe by use of adhesive materials, in accordance with the liner manufacturer's written recommendations as approved by the Engineer.

Liner shall be bonded to the existing pipe a minimum of 6 inches (150mm) along both longitudinal bottom edges. This shall be accomplished by the application of an approved adhesive system.

500-1.9.4 Field Joining of Liner.

a) **General.** Liner joints shall be free of all foreign material and shall be clean and dry before joints are made. All field joints are to be made and tested prior to placement of reinforcing steel and concrete.

b) **Field Joints in Pipe Rehabilitation Installation.** Field joints in the liner plate shall be Type R-2 unless Type R-1 or R-3 is approved by the Engineer.

1) Type R-1 joint shall consist of a 2-inch (50mm) wide weld strip, centered over the 1 inch (25mm) maximum gap between sheets and securely welded along each edge of adjacent liner.

2) Type R-2 joints shall be made with an integral joint flap with locking extensions removed per 210-2.4.6, extending 1-1/2 inches ± 1/4 inch (38mm ± 6mm) beyond the end of the sheet. The sheet shall be overlapped not less than 1/2 inch (13mm) and the overlap secured to the adjacent liner by means of a 1 inch (25mm) welding strip. The downstream sheet shall overlap the upstream sheet.

3) Type R-3 joint shall consist of a 1 inch (25mm) wide weld strip centered over a 1/4 inch (6mm) maximum gap between sheets and secured along each edge of adjacent liner by means of a 1 inch (25mm) welding strip.

c) **Installation of Welding Strips.** Installation of welding strips shall be in accordance with 311-1.5.4.

500-1.9.5 Protection and Repair of Liner. Protection and repair of liner shall be in accordance with 311-1.9.5.

500-1.9.6 Field Testing. Field testing shall be in accordance with 311-1.10.

500-1.9.7 Steel Reinforcement. Before placing reinforcing steel, the Contractor shall submit a reinforcing steel placing plan in accordance with 2-5.3.

Reinforcing bars shall conform to 210-2 and be placed in accordance with 303-1.7. They shall be held in position by the use of concrete or plastic chairs. Metal chairs will not be allowed.

Caution shall be taken when installing reinforcing steel to ensure against puncturing or damaging the liner.

500-1.9.8 Concreting Operations.

a) **General Placement.** Concrete placed against the liner shall be carefully conveyed, deposited, and consolidated to avoid damage to the liner and to produce dense concrete, securely anchoring the locking extensions into the concrete. Vibrators shall be used to consolidate concrete with particular attention along the bottom edge of the liner.

b) **Forms.** The trench walls may serve as the outer form for the new concrete encasement. When outer forms are required, they shall be in accordance with 303-1.3.

500-1.10 Folded and Re-formed PVC Pipe Liner.

500-1.10.1 General. Folded and re-formed PVC liner pipe shall be inserted into sanitary sewers, force mains, and storm drains in order to rehabilitate the existing pipeline system without excavation.

500-1.10.2 Type A Folded and Re-formed PVC Pipe Liner.

a) **Scope.** This method applies to the rehabilitation of 4 through 15 inches (100 through 375mm) diameter pipe. The standard dimension ratio shall be SDR 35, 41, or 50 as specified in the Special Provisions. This rehabilitation system may be capable of expanding up to 10 percent. The initial pipe stiffness factor shall conform to Table 500-1.10.2 (A).

TABLE 500-1.10.2 (A)[2]

Nominal ID of Original Pipe Inches (mm)	SDR	Stiffness Factor (EI)[1] in^3- lbf/in^2 ($Pa \cdot m^3$)
4 (100)	35	40 (4.5)
6 (150)	35	133 (15)
8 (200)	50	109 (12)
	41	198 (22)
	35	320 (36)
10 (250)	50	213 (24)
	41	388 (44)
	35	624 (70)
12 (300)	50	369 (42)
	41	671 (76)
	35	1076 (122)
15 (375)	50	720 (81)
	41	1307 (148)
	35	2105 (238)

1. Pipe Stiffness (PS) shall be determined in accordance with ASTM D2412. Stiffness factor is $EI = 0.149r^3(PS)$. The stiffness factors listed in the table are typical values for gravity flow conditions. For pressure applications the stiffness factors are usually higher.
2. Effects of ovality and safety factor are not included.

b) **Material Composition.** The folded pipe shall be made from unplasticized PVC compounds having a cell classification of 13223, as defined in ASTM D1784.

c) **Material and Equipment Acceptance.** At the time of manufacture, the extruded materials shall be inspected for defects and physical properties in accordance with ASTM F1504, to show compliance with 500-1.10.2 b), or as specified in the Special Provisions. Testing shall be performed once per shift, change in material batch or coil. A Certificate of Compliance shall be supplied per 4-1.5.

At the time of installation, the material shall be homogeneous and free of defects, cracks, holes, blisters, foreign materials, or other deleterious faults.

The Contractor shall furnish and maintain in good condition all equipment necessary for proper execution and inspection of the work.

d) **Marking.** Marking shall conform to 207-17.2.1, except that under Item 3, there is no ASTM standard for this product.

e) **Chemical Resistance and Physical Testing.** The PVC material shall be tested in accordance with 211-2 and conform to Table 500-1.10.2 (B). The various requirements shall be met with samples taken from pipe that has experienced the folding and re-forming process.

TABLE 500-1.10.2 (B)

Property	ASTM Test Method	Initial Values	Values After 112 Days Exposure
Tensile Strength psi (MPa)	D638	5,000 (34.5) min.	5,000 (34.5) min.
Impact Strength ft-lbs/inch (J/m)	D256 Method A Size 1/2 x 1/8 x 2-1/2 inches (12.7 x 3.175 x 63.5mm)	1.5 (80) of notch, min.	1.5 (80) of notch, min.
Weight Change % Unconditioned Conditioned	D543		 + 1.5% max. + 1.0% max.

f) Installation and Field Inspection.

1) The existing pipeline shall be cleaned of any obstacles and televised per 500-1.1.4 and 500-1.1.5, and the host pipe condition shall be satisfactory to the Engineer prior to the insertion of the folded pipe.

2) If necessary, a flexible heat containment tube shall be permanently placed inside the existing pipe for retention of heat necessary to soften the folded pipe. A cable shall be strung through the heat containment tube.

3) Steam shall be applied to the folded pipe until pliable for a minimum of 15 minutes prior to insertion into the existing pipe. Once the material has become pliable, the cable shall be attached to the folded pipe. Using a winch at the termination point, the folded pipe shall then be inserted into the existing pipe through a manhole or access point. Pulling force shall not exceed 2,000 pounds (8.9kN).

4) After the folded PVC pipe is inserted into the existing pipe, it shall be cut off at the starting point and restrained at the terminating point. Thermocouples shall be placed on the exterior of the liner pipe at both the upstream and downstream ends for monitoring of the re-forming and cool-down process. Steam shall be introduced at the insertion end of the folded pipe until a minimum temperature of 150°F (66°C) is attained at the terminating end. This temperature shall be held for a minimum of 5 minutes and shall not exceed 240°F (115°C).

5) After the material has reached the required temperature, a specifically designed pressure driven rounding device shall be used to progressively round the folded PVC at a maximum rate of 5 feet per second (1.5 meters per second) using steam at 5 to 8 psig (34 to 55 kPa gage). The rounding process shall not cause any scraping, tearing, abrasion, movement, or other damage to the liner.

6) When the rounding process is complete, the steam shall be converted to air, maintaining an internal pressure of 5 to 12 psig (34 to 83 kPa gage). After the conversion to air pressure, water may be introduced until the system is completely filled. A minimum of 8 psig (55 kPa gage) air or water pressure shall be maintained until the system is cooled to at least 120°F (49°C) at both ends. At this point, the pressure shall be relieved and both ends shall be cut off in the manholes.

7) If testing of the installed PVC liner pipe is required in the Special Provisions, the physical properties of the installed PVC liner shall be verified through field sampling and laboratory testing as approved by the Engineer. Unless the Special Provisions call for more than one sample, a sample shall be cut from a section of reformed/re-rounded PVC liner pipe at the upstream, downstream, or an intermediate manhole/access pit that has been inserted through a same diameter pipe acting as a mold. PVC liner pipe samples shall be submitted to a certified laboratory, which has been pre-approved by the Engineer. The samples shall be tested in accordance with ASTM D638 for tensile strength, ASTM D790 for flexural modulus, and ASTM D2444 for impact resistance to confirm that the liner pipe conforms to the minimum requirements per 500-1.10.2 b). All costs incurred for the testing shall be borne by the Contractor.

500-1.10.3 Type B Folded and Re-formed PVC Pipe Liner.

a) **Scope.** This method applies to rehabilitation of 4 through 18 inches (100 through 450mm) diameter pipe. The standard dimension ratio may be SDR 26, 32.5, or 41 as specified in the Special Provisions. This rehabilitation system may be capable of expanding up to 10 percent. The initial pipe stiffness factor shall conform to Table 500-1.10.3 (A):

TABLE 500-1.10.3 (A)

CELL CLASS 12111		
Nominal ID of Original Pipe Inch (mm)	SDR	Stiffness Factor (EI)[1, 2] Pa - m^3 (in^3 - lbf/in^2)
4 (100)	32.5	23 (2.7)
	26	47 (5.3)
6 (150)	32.5	79 (9.0)
	26	153 (17)
8 (200)	32.5	187 (21)
	26	365 (42)
10 (250)	32.5	364 (42)
	26	711 (81)
12 (300)	32.5	630 (72)
	26	1228 (140)
15 (375)	32.5	1226 (140)
	26	2397 (274)
18 (450)	41	1057 (121)

1. Pipe Stiffness (PS) shall be determined in accordance with ASTM D2412. Stiffness factor is EI = $0.149r^3$ (PS). The stiffness factors listed in the table are typical values for gravity flow conditions. For pressure applications, the stiffness factors are usually higher.
2. Effects of ovality and safety factor are not included.

b) **Material Composition.** The folded pipe shall be made from PVC compounds having a cell classification of 12111, as defined in ASTM D1784.

c) **Material and Equipment Acceptance.** At the time of manufacture, the extruded material shall be inspected for defects and physical properties in accordance with ASTM D7901, D2122, D2152, D2412, and F1057 to show compliance with 500-1.10.3 b) or as indicated in the Special Provisions. Testing shall be performed once per shift, change in material batch, or coil. A Certificate of Compliance shall be supplied per 4-1.5.

At the time of installation, the material shall be homogeneous and free of defects, cracks, holes, blisters, foreign materials, or other deleterious faults.

The Contractor shall furnish and maintain in good condition all equipment necessary for proper execution and inspection of the work.

d) **Marking.** Marking shall conform to 207-17.2.1, except that under Item 3 there is no ASTM standard for this product.

e) **Chemical Resistance and Physical Testing.** The PVC material shall be tested in accordance with 211-2 and conform to Table 500-1.10.2 (B), as modified in Table 500-1.10.3(B) and 210-2.3. The various requirements shall be met with samples taken from pipe that has experienced the folding and re-forming process.

TABLE 500-1.10.3 (B)

		CELL CLASS 12111	
Property	ASTM Test Method	Initial Values	Values After 112 Days Exposure
Tensile Strength Yield, psi (MPa) min.	D638	3,500 (24.1) min.	3,500 (24.1) min.
Impact Strength Foot-lbs/inch (J/m) min.	D256 Method A Size 1/2 x 1/8 x 2-1/2 inches (12.7 x 3.75 x 63.5mm)	1.2 (64) of notch, min.	1.2 (64) of notch, min.
Weight Change (%)	D 543		
Unconditioned			± 1.5% max.
Conditioned			± 1.5% max.

f) **Installation and Field Inspection.**

1) The existing pipeline shall be cleaned of any obstacles and televised per 500-1.1.4 and 500-1.1.5, and the host pipe condition shall be satisfactory to the Engineer prior to the insertion of the folded pipe.

2) Prior to insertion into the host pipe, heat may be applied to the folded pipe (while on the spool) until pliable. Once the material has become pliable, the pulling cable shall be attached to the insertion end of the folded pipe. Using a winch at the termination point, the folded pipe shall then be inserted through the existing pipe via a manhole or access point. Pulling force shall not exceed 2,000 pounds (8.9kN).

3) After the folded PVC pipe is pulled through the host pipe, it shall be cut off at the starting point and restrained at the terminating point. Thermocouples shall be placed on the exterior of the liner pipe at the downstream end for monitoring of the re-forming and cool-down process. Steam shall be introduced at the insertion end inside the folded pipe until a minimum temperature of 200°F (93°C) is attained at the manifold with an instrument designed to monitor the temperature and pressure during the expanding and cool-down process at the terminating end. This temperature shall be held for a minimum of 5 minutes and shall not exceed 240°F (115°C).

4) After the material has reached the required temperature, a specifically designed pressure driven rounding/expanding device shall be used to progressively round/expand the folded PVC at a maximum rate of 5 feet (1.5m) per second using steam at a maximum of 10 psig (69kPa) gage. The rounding/expanding process shall not cause any scraping, tearing, abrasion, movement, or other damage to the liner.

5) When the rounding/expanding process is complete, the steam shall be transitioned to cooling air, maintaining an internal pressure of up to 10 psig (69kPa) gage. After the conversion to air pressure, the air will be exhausted at the downstream manifold to cool the liner. As the downstream manifold exhaust temperature approaches 100°F (38°C), the water valve on the upstream manifold shall be gradually opened to allow incoming air/water mixture to reach 80°F (27°C). At this point, the air/water pressure shall be relieved and both ends of the rounded/expanded pipe shall be cut off in the manholes.

6) If testing of the installed PVC liner pipe is required in the Special Provisions, the physical properties of the installed PVC liner shall be verified through field sampling and laboratory testing as approved

by the Engineer. Unless the Special Provisions call for more than one sample, a sample shall be cut from a section of rounded/expanded PVC liner pipe at the upstream, downstream, or an intermediate manhole/access pit that has been inserted through a same diameter pipe acting as a mold. PVC liner pipe samples shall be submitted to a certified laboratory which has been pre-approved by the Engineer. The samples shall be tested in accordance with ASTM D638 for tensile strength, ASTM D790 for flexural modulus, ASTM D2444 for impact resistance to confirm that the liner pipe conforms to the minimum requirements per 500-1.10.3 b). All costs incurred for the testing shall be borne by the Contractor.

500-1.10.4 Service Connections and End Seals. Service connections and end seals shall conform to 500-1.1.7.

500-1.10.5 Repair and Rejection. The Contractor shall provide to the Engineer for approval an evaluation and repair specification for liner pipe damaged during or after installation. Any liner pipe damaged shall be removed from the Work site.

500-1.11 HDPE Spirally-Wound Profile Wall Liner Pipe.

500-1.11.1 General. High density polyethylene (HDPE) profile liner pipe for use in lining sanitary sewers shall conform to the requirements of ASTM F894.

Unless otherwise indicated the minimum pipe stiffness shall be 22.5 psi (155 kPa). Pipe stiffness and its respective ring stiffness constant (RSC) are detailed in Table 500-1.11.1. These shall be tested in accordance with ASTM D2412 and ASTM F894. The profile configuration shall be either external or internal unless otherwise specified on the Plans or in the Special Provisions.

500-1.11.2 Material Composition. The material shall conform to 207-19.2. Rubber gaskets shall conform to the requirements of 208-3.

500-1.11.3 Liner Pipe Acceptance. At the time of manufacture, all lot components of the liner pipe and fittings shall be inspected for defects. At the time of delivery, the liner pipe shall be homogeneous throughout, uniform in color, free of cracks, abrasions, holes, foreign materials, blisters, or deleterious faults. For testing purposes, a production lot shall consist of all liner pipe having the same lot marking number, but shall not exceed a total of 50 lengths per day. Pipe length, wall thickness, and joint dimension shall be verified by testing each lot per ASTM F894 or more frequently as required by the Engineer.

TABLE 500-1.11.1 (A)

Nominal Diameter Inches (mm)	RSC (Min.)	Pipe Stiffness (PS) (Min.) psi (kPa)
18 (450)	64	22.5 (155)
21 (525)	74	22.5 (155)
24 (600)	84	22.5 (155)
27 (675)	95	22.5 (155)
30 (750)	106	22.5 (155)
33 (825)	116	22.5 (155)
36 (900)	127	22.5 (155)
42 (1050)	148	22.5 (155)
48 (1200)	169	22.5 (155)
54 (1350)	191	22.5 (155)
60 (1500)	212	22.5 (155)
66 (1650)	233	22.5 (155)
72 (1800)	255	22.5 (155)

Note: Higher RSC values with respectively higher pipe stiffness values may be available. RSC values are dimensionless.

500-1.11.4 Marking. Pipe sections having an exterior profile shall be marked at both ends on the inside of each pipe. Each pipe section having an interior profile shall be marked at both ends on the inside and outside of the pipe to show the manufacturer's name, manufacturer's number (identifies factory location, date, shift, and sequence), nominal inside diameter, minimum RSC, pipe stiffness, ASTM F894 designation, and lot number.

500-1.11.5 Chemical Resistance and Physical Testing. Liner pipes and gaskets shall be tested in accordance 211-2 and conform to the requirements of 207-19.5 and 208-3 respectively.

500-1.11.6 Installation and Field Inspection. This pipe installation shall conform to 500-1.1. Maximum jacking loads shall not exceed the values noted in Tables 500-1.11.6 (A) and (B).

TABLE 500-1.11.6 (A) – EXTERIOR PROFILE

Nominal Inside Diameter inches (mm)	Safe Axial Compressive Loads*	
	RSC 100 Tons (kN)	RSC 160 Tons (kN)
18 (450)	2.3 (20.4)	3.3 (29.3)
21 (525)	2.3 (20.4)	3.8 (33.8)
24 (600)	3.3 (29.3)	3.8 (33.8)
27 (675)	3.9 (34.6)	3.8 (33.8)
30 (750)	3.9 (34.6)	4.0 (35.5)
33 (825)	N/A.	5.8 (51.6)
36 (900)	N/A.	5.8 (51.6)
42 (1050)	N/A.	9.4 (83.6)
48 (1200)	N/A.	9.8 (87.1)
54 (1350)	N/A.	17.9 (159.2)

* Includes a Safety Factor of 2:1.

TABLE 500-1.11.6 (B) – INTERIOR PROFILE

Nominal Inside Diameter inches (mm)	Safe Axial Compressive Loads*	
	RSC	Tons (kN)
18 (450)	64	9.5 (84.5)
21 (525)	74	11.0 (97.8)
24 (600)	84	12.5 (111.2)
27 (675)	95	14.0 (124.5)
30 (750)	106	15.5 (137.8)
33 (825)	116	18.5 (164.5)
36 (900)	127	20.0 (177.9)
42 (1050)	148	25.0 (222.4)
48 (1200)	169	30.0 (266.9)
54 (1350)	191	45.0 (400.3)
60 (1500)	212	58.0 (515.0)
66 (1650)	233	72.0 (640.5)
72 (1800)	255	117.0 (1040)

* Includes a Safety Factor of 2:1.

500-1.11.7 Repair and Rejection. Liner pipe may be repaired for minor superficial pipe damage. Major damage which penetrates over 25 percent of the inner or outer wall thickness shall be repaired by cutting out the damaged section and replacing the damaged section with a new pipe. All repair methods shall be submitted to the Engineer for prior approval in accordance with 2-5.3. The liner pipe sections

shall be a minimum of 8 feet (2.4m) in length unless shorter sections are authorized by the Engineer. Liner pipe shall be inspected immediately prior to installation for damage. If liner pipe is found to be superficially damaged, the Engineer may allow the pipe to be repaired or may reject it. Major liner pipe damage shall be rejected and replaced with new section of liner pipe.

500-1.11.8 Annular Space Grouting. The entire annular space between the outside of the liner pipe and the inside of the existing host pipe shall be grouted. The grout mix and placement procedure shall conform to 500-3. Grouting of the annular space shall be performed in such a manner as to prevent damage or collapse of the liner pipe. Maximum safe annular space grouting pressure for single-stage or multi-stage grouting shall not exceed the pipe stiffness divided by 4.5.

500-1.11.9 Service Connections and End Seals. Service connections shall be exposed and connected to the liner pipe by use of a saddle approved by the Engineer. Service connections and end seals shall conform to 500-1.1.7.

500-1.12 PVC Closed Profile Liner Pipe.

500-1.12 Polyvinyl Chloride (PVC) Closed Profile Liner Pipe.

500-1.12.1 General. Polyvinyl chloride (PVC) closed profile segmented liner pipe for use in lining sanitary sewers shall conform to ASTM F1803. Unless otherwise specified, the minimum pipe stiffness shall be 46 psi (318 kPa), as tested in accordance with ASM D2412.

500-1.12.2 Material Composition. The material shall be made from unplasticized PVC compounds having a cell classification of 12364 as defined in ASTM D1784. Elastomeric sealing gaskets shall conform to the requirements of 208-4.

500-1.12.3 Liner Pipe Acceptance. The liner pipe shall be free from cracks, holes, blisters, foreign inclusions or other defects that would, due to their nature, degree, or extent, have a deleterious effect on the pipe performance as determined by the Engineer.

For testing purposes, a production lot shall consist of all liner pipe having the same lot marking number, but shall not exceed one shift of production for sizes 21 through 30 inches (525 through 750mm) or 2 shifts of production for sizes 36 through 48 inches (925 through 1200mm). Pipe length, wall thickness and joint dimensions shall be verified by testing for each lot in accordance with ASTM F794. Records of this testing shall be made available if so requested by the Engineer.

500-1.12.4 Marking. Each pipe section shall be marked at one end on the inside and every 5 feet (1.5m) on the outside showing the manufacturers name, manufacturing number (identifies production plant, date, shift), cell classification, lot number, nominal diameter, pipe stiffness and ASTM F794. Internally the pipe shall have a numbered air testing certificate (sticker) that can be correlated through plant records to each piece of pipe. A key of the manufacturer's production and lot codes shall be submitted to the Engineer prior to delivery.

500-1.12.5 Chemical Resistance and Physical Testing. Liner pipe and gaskets shall be tested in accordance with 211-2 and conform to the requirements of Table 500-1.12.5 (A) and 208-4 respectively.

TABLE 500-1.12.5 (A)

Property	ASTM Test Method	Value (Initial and After 112-Day Exposure) Cell Class 12364
Tensile Strength (Yield), psi (MPa), min.	D 638	6000 (41.4)
Impact Strength Ft-lbs/inch (J/m) of notch, min.	D 256 Method A Size 1/2 x 1/8 x 2-1/2 inches (12.7 x 3.17 x 63.5mm)	0.65 (34.7)
Weight Change %	D 543	
Unconditioned		± 1.5 max.
Conditioned		± 1.0 max.

Verification shall be provided that physical testing of the product confirms conformance to ASTM F794 (qualification test only) and ASM D2412.

500-1.12.6 Installation and Field Inspection. The existing sewer may be maintained in operation during the relining process. The host pipeline shall be cleaned of any obstructions and televised per 500-1.1.4 and 500-1.1.5. Liner pipe installation shall conform to 500-1.1.7b). The pushing force shall be applied to the grooved end of the pipe. Maximum pushing loads shall not exceed the values noted in Table 500-1.12.6 (A).

TABLE 500-1.12.6 (A)

Nominal Pipe Diameter in (mm)	46 psi (318 kPa) Pipe Stiffness Maximum Pushing Load – Tons (kN) [1]
21 (525)	12.5 (111)
24 (600)	12.5 (111)
27 (700)	12.5 (111)
30 (750)	12.5 (111)
36 (925)	12.5 (111)
42 (1050)	12.5 (111)
48 (1200)	12.5 (111)

1. A factor of safety of 2:1 is included for the maximum pushing load.

500-1.12.7 Annular Space Grouting. The entire annular space between the outside of the liner pipe and inside of the host pipe shall be grouted in accordance with 500-3. Grouting of the annular space shall be done in such a manner as to prevent damage or collapse of the liner pipe. Maximum safe grouting pressure is 10 psi (69kPa).

500-1.12.8 Service Connections and End Seals. Service connections and end seals shall conform to 500-1.1.7.

500-1.12.9 Repair and Rejection. Prior to installation, liner pipe shall be inspected for damage. Liner pipe with superficial damage may be repaired without field cutting. Major damage which penetrates 50 percent or more of the inner or outer wall shall be rejected. All repair methods shall be submitted to the Engineer for prior approval in accordance with 2-5.3. Rejected liner pipe shall be replaced with a new section of liner pipe.

500-1.13 Spiral Wound Polyvinyl Chloride (PVC) Pipe Liner.

500-1.13.1 General. Spiral wound PVC pipe liner for use in the rehabilitation of circular and non-circular pipelines shall be a PVC profiled strip with a continuously sealed spiral joint. The profile may include steel reinforcing if so specified on the Plans or in the Special Provisions. The profiled strip is

wound into the liner shape shown on the Plans to a size ranging from 6 inches through 15 feet (150mm through 4.6m). The profile may be designated as "Type 1" or "Type 2" on the Plans or in the Special Provisions. Type 1 is expandable to fit against the host pipe wall. Type 2 is installed with a fixed dimension, requiring annular space grouting between the liner and the existing host pipe. An end seal shall be provided at each manhole. Installation shall be in accordance with ASTM F1741 as modified herein.

500-1.13.2 Material Composition. The profiled strip shall be made from PVC compounds conforming to ASTM F1697, Section 5. The gasket and/or sealing material shall be as recommended by the manufacturer and shall be submitted in accordance with 2-5.3. When so specified in the Special Provisions, the steel reinforcing strip shall be fabricated from steel conforming to ASTM F1697, Section 5.2. When so specified in the Special Provisions, annular space grout shall be self leveling and consolidating. Structural grout shall be of sufficient strength to support all required loads.

500-1.13.3 Material Acceptance. The material shall consist of a ribbed PVC profiled strip with interlocking, sealed edges, gasket material and steel reinforcing strip, if required. The edges lock together as the strip is wound into a pipe. The profiled strip shall have shaped ribs which vary in height and width as specified in ASTM F1697. The Contractor shall submit, in accordance with 2-5.3, a Certificate of Compliance that states that the PVC profiled strip material, gasket material, and the steel reinforcing strip conforms to ASTM F1697 and the requirements shown on the Plans and Special Provisions. The grout shall conform to ASTM F1741, and the requirements shown on the Plans and in the Special Provisions.

500-1.13.4 Marking. Each PVC profiled strip shall be distinctively marked on its inside surface at intervals not to exceed 30 feet (9m) measured longitudinally along the profiled strip with a coded number which identifies the manufacturer, plant, date of manufacture and shift, cell classification and profile type. This information shall also appear on each reel.

500-1.13.5 Chemical Resistance. The PVC profiled strip, gasket, end seals, sealants, and other material exposed to the sewer environment, as determined by the Engineer, shall be tested in accordance with 211-2 and, conform to the weight change requirements of Table 207-17.5(A).

500-1.13.6 Installation and Field Inspection. The existing pipeline shall be cleaned and televised in accordance with 500-1.1.4 and 500-1.1.5. When so specified in the Special Provisions, the existing pipeline may be inspected and televised by the man-entry method. The condition of the cleaned pipeline shall be approved by the Engineer prior to the installation of the liner pipe.

During this phase of operation all service openings shall be precisely located longitudinally and radially, and logged for subsequent reconnection after the installation of the liner pipe.

At the time of installation, the profiled strip material shall be homogeneous and free of defects, cracks, holes, blisters, or foreign materials.

The installed spiral wound PVC pipe liner shall be inspected and televised in accordance with 500-1.1.4 and 500-1.1.5 or by the man-entry method if so specified in the Special Provisions.

Spiral wound PVC pipe liner shall be of uniform appearance, undamaged, free of cracks, holes, unsealed joints, and shall be installed according to the manufacturer's recommendations and in accordance with ASTM F1741. End seals shall conform to 500-1.1.7, subparagraph "e".

500-1.13.7 Connections. Connections for Type 1 liners shall be re-established in accordance with 500-1.1.7, subparagraph "a".

The Contractor shall submit the data listed in 500-3.1.10, subparagraphs "a" through "i", for the structural grout in accordance with 2-5.3.

The procedure for re-establishing service lateral connections for Type 2 liners shall be submitted to the Engineer in accordance with 2-5.3. This procedure shall include the method of blocking the service connections during grouting and the sleeving system to be used between the liner and the host pipe. The sleeving system shall conform to 500-3 and be submitted to the Engineer in accordance with 2-5.3.

500-1.13.8 Annular Space Grouting. Annular space grouting shall conform to ASTM F1741, Section 6.5. The utilization of structural or non-structural grout shall be as specified in the Special Provisions.

A structural grout mix design shall be submitted to the Engineer in accordance with 2-5.3 and shall have a minimum compressive strength of 5,000 psi in 28 days when tested in accordance with ASTM C39. The submittal shall include the data listed in 500-3.1.10, subparagraphs "a" through "j", "l", and "o", for structural grout.

Non-structural grout material shall conform to 500-3.

The entire annular space shall be grouted. Grout penetration shall be verified by the Contractor. The method of verifying the penetration of the grout shall be submitted to the Engineer in accordance with 2-5.3.

500-1.13.9 Repair. The Contractor shall submit a repair method to the Engineer in accordance with 2-5.3 for any profile strips or liner pipe found to be damaged during or after installation, or if grouting deficiencies are encountered.

500-1.13.10 Measurement and Payment.

500-1.13.10.1 Measurement. Spiral wound PVC pipe liner shall be measured by the linear foot of pipe lined, or by lump sum. Re-establishment of service connections shall be measured by each or by lump sum.

500-1.13.10.2 Payment. Payment for spiral wound PVC liner pipe shall be made at the Contract Unit Price, or lump sum, as specified in the Bid.

Payment for re-establishing service connections shall be made at the Contract Unit Price, or lump sum, as specified in the Bid.

500-2 MANHOLE AND STRUCTURE REHABILITATION.

500-2.1 General. This subsection specifies various lining systems for manholes and structures. The types of rehabilitation materials and methods shall be as shown on the Plans and specified in the Special Provisions. Flow control, if required shall also be as shown on the Plans or as specified in the Special Provisions. Unless otherwise specified in the Special Provisions, proof of meeting the Chemical Resistance test per 211-2 shall be submitted to the Engineer per 2-5.3.

As used in this subsection "holiday" shall be defined as any discontinuity, bare or thin section in a lined or coated area.

500-2.2 Requirements.

500-2.2.1 Installer Qualifications. The installer, whether the Contractor or a subcontractor, shall be a certified installer of the lining system. The installer's personnel shall be adequately trained in maintenance and operation of the required installation equipment, as certified by the lining manufacturer. A letter from the manufacturer of the lining system, verifying the certification of the installer required to be on-site during installation, shall be submitted per 2-5.3.

500-2.2.2 Cleaning, Inspection, and Surface Preparation. Inspection and Surface Preparation. Prior to the installation of the lining system, the host structure shall be prepared to produce a concrete or masonry surface suitable for application and adhesion of the specified lining system. Cleaning and surface preparation shall include the inspection of the host structure for any damage or leaks, and the removal of any protrusions on the surface of the host structure that could interfere with the installation of the lining system. Any damage or leaks shall be reported to the Engineer. Cleaning methods may

include high pressure water cleaning at a minimum of 5,000 psi (34.5MPa), abrasive blast, or a method recommended by the manufacturer of the lining system, or another cleaning method submitted to the Engineer for approval per 2-5.3. The Contractor shall protect the host structure from damage by the cleaning equipment, water and air pressure. Flow bypassing, if required by the lining system, shall conform to 7-8.4 and 306-3.3.

Debris from the cleaning operation shall not be allowed to enter the sewer system. The Contractor shall furnish, install and remove any necessary debris containment devices while maintaining sewer flow. The Contractor shall remove and dispose of all debris collected from the cleaning operation. If reinforcing steel is exposed, either before or after removing deteriorated concrete, it shall be thoroughly cleaned to remove all contamination and rust particles. Immediately after the cleaned reinforcing steel is inspected and accepted by the Engineer, the Contractor shall place a protective coating on the exposed reinforcing steel. The protective coating shall be approved by the Engineer in accordance with the manufacturers' specifications.

Manhole steps, pull rings and lifting eyes shall be installed or removed as shown on the Plans or specified in the Special Provisions.

500-2.3 Repair, Resurfacing and Active Infiltration.

500-2.3.1 General. Repair, resurfacing and active infiltration elimination materials shall be compatible with the lining system. Proof of compatibility shall be submitted to the Engineer per 2-5.3.

500-2.3.2 Repair. Prior to installation, patching or localized repairs shall be performed using rapid setting repair mortars compatible with the lining system. Repair mortars shall be used to fill surface irregularities, voids, and deteriorated surfaces and to repair the host structure to a uniform surface. Manufacturer's specifications shall be followed when performing repairs, material handling, mixing, installation and curing. A copy of the manufacturer's specifications confirming the compatibility of the materials used in the repair shall be submitted to the Engineer per 2-5.3.

500-2.3.3 Resurfacing. Air-placed concrete (APC) materials, if required by the Special Provisions, shall conform to 303-2.3.1. Prior to the application of APC, the structure shall be prepared to produce a concrete or masonry surface that is suitable for application and adhesion of the specified APC. The APC shall be applied in continuous lifts of 1/2 inch (12mm) minimum thickness or as shown on the Plans and/or as specified in the Special Provisions. Containment devices, approved by the Engineer, shall be used to prevent rebound (non-adhering excess APC) from entering the sewer system. Immediately following the APC placement operation, the containment device shall be removed and the structure's cover reinstalled to provide a moist curing environment. Where moist conditions within the structure do not exist, the Contractor shall water cure the APC for a minimum of 24 hours prior to installation of the lining system. All defects in the APC shall be repaired per 303-2 prior to the installation of the liner system.

500-2.3.4 Active Infiltration. Active leaks within the host structure shall be eliminated prior to installation of the liner system. Leaks shall be eliminated by pressure grouting with chemical grout as specified in the Special Provisions and/or the application of hydraulic cement conforming to 201-1.2. Chemical grouts and hydraulic cements shall be compatible with the lining system used. A copy of the manufacturer's specifications confirming the compatibility of the materials used in the repair shall be submitted to the Engineer per 2-5.3. The host structures shall be visibly dry with no active infiltration prior to lining.

500-2.4 Inspection, Testing and Repair of Installed Liner Systems.

500-2.4.1 General. The party performing the following tests shall be as specified in the Special Provisions. If the testing party is to be selected by the Contractor, the name of the testing party and information on the testing instruments to be used for adhesion testing and its calibration shall be submitted to the Engineer per 2-5.3.

500-2.4.2 Spark Test. The cured lining system shall be spark tested for holidays with the high voltage holiday detector instrument specified by the coating manufacturer or as specified in the Special Provisions. The voltage shall be set at a minimum of 15,000 volts. For thicknesses greater than 150 mils (4mm), the voltage shall be set at 100 volts per 1 mil (25μm) of thickness of the applied lining material. Identified holidays shall be marked without contaminating the lining surface and repaired in accordance with 500-2.4.5.

500-2.4.3 Mil Gauge Test. During installation, a mil gauge shall be used to verify that the minimum thickness of the lining meets and/or exceeds the minimum thickness specified herein or specified in the Special Provisions.

500-2.4.4 Adhesion Testing. Adhesion testing shall be performed on a minimum of 1 structure or 15 percent of all rehabilitated structures, whichever is greater, or as shown on the Plans and/or specified in the Special Provisions. Adhesion testing shall be conducted after the liner system has cured in accordance with the manufacturer's specifications. Adhesion testing shall be in accordance with ASTM D4541 as modified herein.

A minimum of one 3/4 inch (19mm) dolly shall be affixed to the lined surface of the host structure at the upper section or cone area, the midsection, and at the bottom, unless otherwise specified in the Special Provisions. Each testing location shall be identified by the Engineer. The adhesive used to attach the dollies to the liner shall be rapid setting with tensile strength in excess of the liner material and permitted to cure in accordance with the manufacturer's specifications. The lining material and dollies shall be prepared to receive the adhesive in accordance with the manufacturer's specifications. Prior to the pull test, the tester shall utilize a scoring device to cut through the coating until the substrate is reached. Failure due to improper dolly adhesive or scoring will require retesting. The pull tests in each area shall meet or exceed 200 psi (1,400kPa) and shall include substrate adhered to the back of the dolly or no visual signs of coating material in the test hole. Pull tests with results between a minimum 150 psi (1,000kPa) and 200 psi (1,400kPa) may be acceptable if more than 50 percent of the substrate adhered to the back of the dolly. A test result may be disregarded, as determined by the Engineer, if there is a valid nonstatistical reason as specified in Sections 8.4 and 8.5 of ASTM D4541. If any test fails, a minimum of 3 additional locations in the section of the failure shall be tested, as directed by the Engineer. If any of the retests fail, all loosely adhered or unadhered liner in the failed area, as determined by the Engineer, shall be removed and replaced at the Contractor's expense. If a host structure fails the adhesion test, one additional host structure or 10 percent of the initial number of host structures selected for testing shall be tested as directed by the Engineer or as specified in the Special Provisions.

500-2.4.5 Liner Repairs. Holidays, uncured lining material, blisters, surface imperfections and damage to the liner resulting from the adhesion test shall be repaired to a point 1 inch (25mm) minimum beyond the limits of the damaged area. The repair shall be 125 mils (3mm) thick or the minimum thickness specified in the Special Provisions. Holidays shall be primed and recoated with the same lining system to a minimum additional thickness of 30 mils (750μm) unless otherwise specified by the liner manufacturer or approved by the Engineer. Blisters, uncured lining and surface imperfections shall be completely removed and the areas recoated with appropriate lining material to 1 inch (25mm) minimum beyond the repair areas at a minimum thickness of 100 mils (500μm). Additional spark testing shall be performed after repairs are completed.

500-2.5 Integral Locking PVC Manhole and Structure Lining System.

500-2.5.1 General. This subsection specifies an integral locking PVC lining system. This system consists of temporarily erecting a form inside an existing structure, installing PVC lining material with integral locking devices and filling the annular space between the erected form and PVC lining material and the walls of the host structure with portland cement concrete resulting in a new PVC-lined, monolithic structure within the host structure.

500-2.5.2 Materials.

500-2.5.2.1 Portland Cement Concrete. Portland cement concrete shall be Class 330-C-23 (560-C-3250) conforming to 201-1.1.2, or as specified in Special Provisions.

500-2.5.2.2 Integral Locking PVC Liner. The liner shall conform to the specifications in 210-2 and be as specified in the Special Provisions. A Certificate of Compliance conforming to 4-1.5 shall be submitted per 2-5.3.

500-2.5.3 Installation and Field Inspection. If existing, steps shall be removed flush with the inside wall of the host structure. Formwork for the lining system shall be installed in a manner that fits the existing walls and creates an equal and approximate 3-inch (75mm) annular space. Portland cement concrete shall be used to fill the annular space. The installation of the liner shall conform to 311-1. Replacement of steps, if required, shall conform to the requirements shown on the Plans and/or specified in the Special Provisions.

Prior to placement of the portland cement concrete, the installer shall connect the existing mainline pipe to the host structure as shown on the Plans and/or as specified in the Special Provisions. Exposed portland cement concrete surfaces within the host structure shall be protected as specified in the Special Provisions.

Field testing shall conform to 210-2.3.4 and 311-1.10 unless otherwise specified in the Special Provisions.

500-2.6 Segmented PVC Lining System.

500-2.6.1 General. This subsection specifies a lining system consisting of PVC liner strips placed so that an annular space is created between the liner and the walls of the host structure. This annular space is then filled with cementitious grout. A Certificate of Compliance conforming to 4-1.5 shall be submitted to the Engineer per 2-5.3 for each material. Surface preparation of the host structure and flow bypass shall conform to 500-2.1.3 unless otherwise specified in the Special Provisions.

500-2.6.2 Materials.

500-2.6.2.1 PVC Liner. PVC liner shall conform to 500-1.5.2 through 500-1.5.5 and Table 207-17.5(A).

500-2.6.2.2 Cementitious Grout. Cementitious grout shall conform to ASTM F1741, Section 6.4 and be submitted to the Engineer for approval per 2-5.3 or be as specified in the Special Provisions.

500-2.6.2.3 Sealant/Adhesive. The sealant/adhesive shall be compatible with the PVC lining material and cementitious grout. A copy of the manufacturer's specifications confirming the compatibility of the sealant/adhesive materials shall be submitted to the Engineer per 2-5.3.

500-2.6.3 Installation and Inspection. Installation shall be performed by either manually spirally winding PVC strips or placing PVC panels and engaging the complementary locks (male/female) at the edges of the strips/panels in a manner that creates an annular space, of 1 inch (25mm) minimum thickness, unless otherwise specified in the Special Provisions.

A bead of approved sealant/adhesive shall be applied to the female locking edge of the strip/panel prior to engaging the locking edges. Grouting of the annular space shall be performed in such a manner as to prevent damage or collapse of the liner and completely fill the annular space. Installation shall conform to 500-1.5.6 through 500-1.5.9. Testing shall be performed in accordance with 500-2.4, except 500-2.4.4. Holes in the liner shall be covered with a patch of sealant materials as approved by the Engineer.

500-2.7 Polyurethane and Epoxy Protective Lining System.

500-2.7.1 General. This subsection specifies a polyurethane and epoxy primer protective lining system.

500-2.7.2 Lining Material. Lining material shall consist of 100 percent solid polyurethane material and moisture tolerant epoxy. Polyurethane lining material shall be capable of spray application to 125 mils (3mm) minimum thickness in one continuous coat. Epoxy shall be capable of spray application to 5 mils (127μm) thickness in one continuous coat.

500-2.7.3 Installation and Curing. Lining material shall be applied to all prepared surfaces from 1 inch (25mm) below the low-flow water level to the base of the ring and cover unless otherwise specified in Special Provisions. All termination points of the lining material to the existing subsurface shall be keyed into the subsurface by mechanically scoring a minimum 1/4 inch x 1/4 inch (6mm x 6mm) keyway. Prior to application of the polyurethane, the subsurface shall be primed with the epoxy primer to a thickness of 3 mils (76μm) minimum to 5 mils (127μm) maximum. Polyurethane shall be applied to a thickness of 125 mils (3mm) immediately prior to the epoxy primer becoming tack-free. Lining material shall be uniform in color, fully cured, free of holidays, surface imperfections, blisters and sags and adequately adhered to the subsurface.

500-2.7.4 Inspection and Testing. The set or cured lining materials shall be tested in accordance with 500-2.4 unless otherwise specified in the Special Provisions.

500-2.7.5 Performance Requirements. The lining system shall meet or exceed the requirements specified in Table 500-2.7.5(A).

TABLE 500-2.7.5 (A)

	Polyurethane	Epoxy Primer
Tensile Strength ASTM D638, Type IV, psi (MPa) (min)	2,000 (14)	6,000 (41)
Elongation at Break, % ASTM D638, Type IV	40	5
Wear Resistance, mg. wt. Loss Taber abrasion, ASTM D4060	60[1]	100[1]
Hardness, Shore D, Durometer ASTM D2240	55	75
Tear Resistance, ppi (kg/mm) ASTM D624	150 (2.7)	N/A
Peel Strength, Concrete, pli (g/mm) ASTM D903	7[2] (125)	7[2] (125)
Weight Change[3]	± 1.5%	± 1.5%

1. Abrasive wheel No. CS-17, maximum value.
2. Tested as a system. Test results shall be verified on a per job basis or as specified in the Special Provisions.
3. Tested In conformance with 211-2.

500 - 2.8 Epoxy Lining System.

500-2.8.1 General. This subsection specifies an epoxy lining system.

500-2.8.2 Lining Material. Lining material shall consist of solvent free, high-build epoxy resin capable of spray application to 125mils (3mm) minimum thickness in one continuous coat.

500-2.8.3 Installation and Curing. Lining material shall be applied to all prepared surfaces from 1 inch (25mm) below the low-flow water level to the base of the ring and cover unless otherwise specified in the Special Provisions. Termination points of the lining to the existing subsurface shall be keyed into the subsurface by mechanically scoring a minimum 1/4 inch x 1/4 inch (6mm x 6mm) keyway. Epoxy shall be applied to a thickness of 125 mils (3mm). Lining material shall be uniform in color, fully cured, free of holidays, surface imperfections, blisters and sags and adequately adhered to the subsurface.

500-2.8.4 Inspection and Testing. The set or cured lining materials shall be tested in accordance with 500-2.4 unless otherwise specified in the Special Provisions.

500-2.8.5 Performance Requirements. The lining system shall meet or exceed the specifications in Table 500-2.8.5 (A)

TABLE 500-2.8.5 (A)

	Epoxy Liner
Tensile Strength ASTM D638, Type IV, psi (MPa) (min)	3,000 (21)
Elongation at Break, % ASTM D638, Type IV	0.9
Wear Resistance, mg. wt. Loss Taber abrasion, ASTM D4060	115[1]
Hardness, Shore D, Durometer ASTM D2240	80
Weight Change[2]	± 1.5%

1. Abrasive wheel No. CS-17, maximum value.
2. Tested in conformance with 211-2.

500-2.9 Epoxy Mastic and Flexible PVC Liner System.

500-2.9.1 General. This subsection describes the installation of the mastic primer and epoxy mastic that bonds to the cleaned, repaired and prepared interior concrete substrate, then follows with the mechanical locking of the flexible PVC liner into the epoxy mastic. The integral locking extensions in the flexible PVC liner are embedded to their full depth into the epoxy mastic.

500-2.9.2 Materials.

500-2.9.2.1 Plastic Liner. The liner shall be manufactured from a PVC compound in accordance with 210-2. The plastic liner shall be a flexible PVC liner with a minimum thickness of 1/16 inch (1.65mm) and conform to 210-2.4.

500-2.9.2.2 Mastic Primer. The epoxy mastic primer shall be a two-part coating that is applied to the prepared concrete substrate.

500-2.9.2.3 Epoxy Mastic. The epoxy mastic shall be a 2-part 100 percent epoxy coating for bonding and filling voids in properly prepared concrete substrate.

500-2.9.3 Locking Extensions. All liner to be embedded in the epoxy mastic shall have integral locking extensions and meet the requirements of 210-2.2.4 except for the dimensions requirement. The locking extensions shall have a shape, height, web thickness, and spacing that will allow the liner to be held permanently in place and be able to meet the pull-out requirements of 500-2.4.4.

500-2.9.4 Chemical Resistance and Physical Property Testing. The plastic liner sheet and accessories shall conform to 211-2 and 210-2.4.

500-2.9.5 Preparation and Repair of Substrate. Prior to applying the mastic primer, the structure shall be cleaned and prepared in accordance with 311-1.6 and repaired in accordance with 311-1.9.

500-2.9.6 Installer Qualifications. Applicators and welders of the plastic liner shall be qualified in accordance with 311-1.2.

500-2.9.7 Installation.

500-2.9.7.1 Priming. The mastic primer shall be applied to 3 mils (76μm) minimum to 5 mils (127μm) maximum thickness. The primer shall be allowed to dry before applying the epoxy mastic.

500-2.9.7.2 Epoxy Mastic Application. A finishing trowel or other suitable tool shall be used to apply the epoxy mastic to a uniform minimum thickness of 1/4 inch (6mm).

500-2.9.7.3 Plastic Liner Application. The plastic liner shall be placed while the wetting ability of the epoxy mastic is at its optimum, be pressed into the mastic, and rolled to remove any trapped air. The lining system shall be allowed to cure for the amount of time recommended by the lining manufacturer. The average dry film thickness of the cured lining system, including the liner sheets and the applied epoxy mastic, when completed shall not be less than 315 mils (8mm).

500-2.9.8 Field Jointing of Liner.

500-2.9.8.1 General. The Contractor shall utilize the maximum size plastic liner sheet that is practical and will provide the minimum number of seams. Vertical and horizontal seams shall overlap a minimum of 1/2 inch (13mm) and shall be welded with 1 inch (25mm) weld strips. Corner strips may be used at inside and outside corners, or liner may be wrapped around corners. The Contractor shall be allowed to heat the liner to facilitate turning corners. Excessive heating of the liner material to facilitate turning corners shall be avoided.

500-2.9.8.2 Field Joints in Manhole and Structure Rehabilitation. Field joints in the liner shall be Type AL-2 unless AL-1 or AL-3 is approved by the Engineer.

a) Type AL-1 joint shall consist of a 4-inch (100mm) wide joint strip centered over a 1 inch (25mm) maximum gap between sheets and securely welded along each edge of adjacent liner with a 1 inch (25mm) welding strip.

b) Type AL-2 joints shall be made with integral joint flaps with locking extensions removed 1 inch (25mm) from one side per 210-2.2.6. The flap shall be overlapped a minimum of 1/2 inch (13mm) and the overlap secured to the adjacent liner by means of a 1 inch (25mm) welding strip.

c) Type AL-3 joints shall consist of a 1 inch (25mm) wide weld strip centered over a 1/4 inch (6mm) maximum gap between sheets and securely welded along each edge of adjacent liner.

500-2.9.8.3 Installation of Welding Strips. Installation of welding strips shall conform to 311-1.5.4.

500-2.9.9 Pull Test for Locking Extensions. Liner locking extensions embedded in epoxy mastic shall withstand a test pull of at least 20 pounds per linear inch (3.5N per linear mm), applied perpendicularly to the concrete surface for a period of 1 minute without rupture of the locking extensions or withdrawal from the epoxy mastic or delaminating of the mastic from the concrete substrate. This test shall be made at a temperature between 70°F to 80°F (21°C to 27°C).

500-2.9.10 Inspection. After installation of the protective lining system, the surface of the liner shall be cleaned and prepared by the Contractor and then inspected by the Engineer. Field testing shall be in accordance with 311-1.10.

500-2.9.11 Repair of Defects and Holidays. The Contractor shall repair all defects and damage in the plastic liner in accordance with 311-1.9.

500-2.10 Measurement and Payment.

500-2.10.1 Measurement. Manhole and structure rehabilitation shall be measured by each.

500-2.10.2 Payment. Payment for manhole and structure rehabilitation shall be made at the Contract Unit Price or lump sum price in the Bid for each structure. The Bid price shall include the installation of the lining system as well as surface preparation and repairs, and performance of testing, unless otherwise specified in Special Provisions.

500-3 ANNULAR SPACE GROUTING.

500-3.1 Requirements.

500-3.1.1 General. This subsection covers various requirements of continuous annular space grouting of sliplining systems. The annular space (void between the host and liner pipes) shall be completely grouted to support the liner and provide long-term stability. The Contractor shall engage the services of an Agency approved testing laboratory to certify that the proposed materials and methods comply with these requirements. All proposals shall be submitted to the Engineer per 2-5.3, 201-1, and 500-3.1.10.

500-3.1.2 Preparation. Upon completion of sliplining but prior to grouting, bulkheading of the ends and appropriate venting will be required. This is to seal the annular space from sewer flow to permit the grout to set and withstand the loads imposed by the grout and groundwater. The Contractor shall test the integrity of the installed liner pipe and constructed bulkheads for any leaks by performing the following:

a) Dewater and inject dye water into the annular space (this alternative will not be permitted if the crown or any portion of the host pipe is severely deteriorated to the point where water may escape through the host pipe).

b) Pressurize the annular space to the maximum permissible grouting pressure per the manufacturer's recommendation with approval by the Engineer.

c) The Contractor shall submit a detailed plan to the Engineer that will hold the liner pipe on the invert for a period of time long enough to allow the grout to set where buoyant uplift is a factor.

500-3.1.3 Planned Vents. The Contractor shall submit working drawings, including the proposed number and location of vents relative to pipe diameter and stiffness and the depth of sewer flow in the pipeline for the grouting operation.

500-3.1.4 Materials. The grout materials shall consist of portland cement, portland cement and fly ash, and/or additives, providing materials are not biodegradable.

a) **Compressive Strength.** The grout shall have a minimum penetration resistance of 100 psi (690 kPa) in 24 hours when tested in accordance with ASTM C403 and a minimum compressive strength of 300 psi (2070 kPa) in 28 days when tested in accordance with ASTM C495 or C109.

b) **Performance Requirements.** The Contractor shall submit the proposed grout mixes, methods, plans, and criteria of the grouting operations. The grouting system shall have sufficient gauges, monitoring devices, and tests to determine the effectiveness of the grouting operation and to ensure compliance with the liner pipe specifications and design parameters.

c) **Mix Design.** One or more mixes shall be developed to completely fill the annular space based on the following requirements:

1) Size of the annular void
2) Void (size) of the surrounding soil
3) Absence or presence of groundwater
4) Sufficient strength and durability to prevent movement of the pipe
5) Provide adequate retardation, and
6) Provide less than 1 percent shrinkage by volume

d) **Density and Viscosity.** The Contractor shall design a grout mix with a density to meet the requirements of 500-3.1.6 and to prevent floating of the liner pipe. The apparent viscosity shall not exceed 20 seconds in accordance with ASTM C939 unless otherwise approved by the Engineer.

500-3.1.5 Qualifications. The Contractor shall demonstrate to the Engineer its worker's capabilities of filling the annular space and performing their work in conformance with the Plans and the Specifications.

500-3.1.6 Grouting Equipment. The materials shall be mixed in equipment of sufficient size and capacity to provide the desired amount of grout material for each stage in a single operation. The equipment shall be capable of mixing the grout at densities required for the approved procedure and shall also be capable of changing density as dictated by field conditions any time during the grouting operation.

500-3.1.7 Injection Procedure and Pressure. The gauged pumping pressure shall not exceed the liner pipe manufacturer's approved recommendations as stated in 500-1.3.7, 500-1.8.7, and 500-1.11.8. Pumping equipment shall be of a size sufficient to inject grout at a volume, velocity and pressure compatible with the size of the annular space and degree of host pipe corrosion. Once grouting operations begin, grouting shall proceed uninterrupted from bulkhead to bulkhead. Grout placement shall not be terminated until the following conditions are met, unless otherwise approved by the Engineer:

a) the estimated annular volume of grout has been injected;

b) the exhausted grout at each vent is not less than 85 percent of the density of freshly injected grout;

c) the exhausted grout at each vent is not less than 85 percent of the original viscosity of the freshly injected grout; and

d) when recommended by the grout installer.

A grout pressure gauge and recorder shall be installed immediately adjacent to each injection port. During operations, the recorder shall continuously record the actual grouting pressure versus the time on paper with ink. The gauge shall conform to an accuracy of ± 0.5 psi (± 3.5 kPa). The range of the gauge shall not be more than 100 percent greater than the design and attached to a saddle-type diaphragm seal (gauge saver) to prevent clogging with grout. All gauges shall be certified and calibrated in accordance with ANSI B40, Grade 2A. The grout pressure recordings shall be identified, as a minimum, with the date, batch, and time of day grouting was performed and shall be submitted to the Engineer at the end of the work day that grouting was performed.

500-3.1.8 Onsite Test. For each batch, the Contractor shall provide all equipment and personnel necessary to perform the following tests in the presence of the Engineer:

a) Density per ASTM C138 or by other methods as approved by the Engineer.

b) Viscosity per ASTM C939.

Grout that exceeds ± 3 pounds per cubic foot (48 kg/m^3) of the design density will be rejected.

500-3.1.9 Test Section. The Contractor will be required to perform a test on each type of grout and grout system proposed to be used. The test section to be grouted and the size of the annular space considered for each type of grout system shall be determined by the Contractor and approved by the Engineer.

500-3.1.10 Submittals and Required Calculations. The Contractor shall submit the following to the Engineer in accordance with 2-5.3:

a) The proposed grouting mix.

b) The proposed grout densities and viscosity.

c) Initial set time of the grout.

d) The 24-hour and 28-day minimum grout compressive strengths.

e) The grout working time before a 15 percent change in density or viscosity occurs.

f) The proposed grouting method and procedures.

g) The maximum injection pressures.

h) Proposed grout stage volumes (e.g., Stage 1, to springline; Stage 2, fully grouted).

i) Bulkhead designs and locations.

j) Buoyant force calculations during grouting.

k) Flow control.

l) Provisions for re-establishment of service connections.

m) Pressure gauge, recorder, and field equipment certifications (e.g., calibration by an approved certified lab).

n) Vent location plans.

o) Written confirmation that the Contractor has coordinated grouting procedures with the grout installer and the liner pipe manufacturer.

Data for a) through e) shall be derived from trial grout batches by an approved, independent testing laboratory.

For each different type of grout or variation in procedure or installation, a complete package shall be submitted. The submittal shall include each of the above items and the sewer locations or conditions to which it applies. The Contractor shall obtain approval from the Engineer for any changes to be made in grout mix, grouting procedure, or installation prior to commencement of grouting operations.

500-4 SERVICE LATERAL CONNECTION SEALING.

500-4.1 General. This subsection specifies various SLC sealing systems, and methods of installation. The type of sealing systems and methods to be used shall be as shown on the Plans or specified in the Special Provisions. Unless otherwise specified in the Special Provisions, proof of compliance with the Chemical Resistance Test specified in 211-2 using the weight change specified in Table 500-4.1 (A) shall be submitted to the Engineer in accordance with 2-5.3.

SLC sealing systems shall consist of either a cured-in-place resin saturated felt or fiberglass lining material and tube installed in an existing mainline and HC. Dry or unsaturated areas are not acceptable. The lining material and tube shall be sized such that when installed they are properly aligned, tight fitting and without wrinkles. SLC sealing systems shall be manufactured so as to provide smooth tapered edges after curing. The curing method and schedule shall be submitted to the Engineer in accordance with 2-5.3. The cured SLC sealing system shall meet or exceed the specifications in Table 500-4.1 (A).

TABLE 500-4.1 (A)

Property	ASTM Test Method	Initial. PSI (MPa)
Flexural Strength	D790	3,000 (20.7)
Flexural Modulus	D790	250,000 (1,724)
Tensile Strength	D638	3,000 (20.7)
Tensile Modulus	D638	250,000 (1,724)
Weight Change[1]	-	±1.5%

1. Tested In Conformance with 211-2

Bonding materials used with SLC sealing systems shall be compatible with the existing mainline and HC or with the lining system used in the mainline and HC, and shall be submitted in accordance with 2-5.3.

500-4.2 Requirements.

500-4.2.1 Installer Qualifications. The installer shall be certified by the manufacturer of the SLC sealing system. Personnel installing the SLC sealing system shall be adequately trained in maintenance and operation of the required installation equipment. A letter from the manufacturer of the SLC sealing system, verifying the certification of the installer, shall be submitted in accordance with 2-5.3. The installer shall be on site at all times during installation.

Prior to installation, the Contractor shall submit a detailed installation plan to the Engineer in accordance with 2-5.3. This installation plan shall provide verification of compliance with the physical properties specified in Table 500-4.1 (A), the manufacturer's specified curing time, chemical composition and a detailed description of the SLC sealing system.

500-4.2.2 Cleaning, Inspection, and Surface Preparation. Prior to the installation of the SLC sealing system, the HC, SLC and mainline shall be prepared, as specified by the manufacturer, to produce a surface that is suitable for application of the specified sealing system. Cleaning methods shall be as specified by the manufacturer of the SLC sealing system and submitted to the Engineer in accordance with 2-5.3. Cleaning and surface preparation shall include CCTV inspection of the mainline and HC for locating any damage or leaks. CCTV inspection shall conform to 500-1.1.5. The HC's shall be inspected 16 inches (400mm) beyond the end of the proposed lining unless otherwise specified in the Special Provisions. Any protrusions on the surface of the mainline and HC that could interfere with the installation of the SLC sealing system shall be removed. All roots larger than 1/8 inch (3mm) shall be removed during the cleaning operation, and any damage or leaks shall be reported to the Engineer. Flow bypassing, if required, shall conform to 7-8.5.2, 7-8.5.3, and 306-3.3.

Debris from the cleaning operation shall not be allowed to enter the sewer system. The Contractor shall furnish, install, and remove any necessary debris containment devices while maintaining sewer flow. The Contractor shall remove and dispose of all debris collected from the cleaning operation in accordance with 500-1.1.4.

500-4.3 Repair and Active Infiltration.

500-4.3.1 General. Material used to repair active infiltration shall be compatible with the SLC sealing system and mainline lining material. Proof of compatibility shall be submitted to the Engineer in accordance with 2-5.3.

500-4.3.2 Active Infiltration. Active infiltration shall be eliminated by pressure grouting with chemical grout as specified by the SLC system manufacturer or specified in the Special Provisions. Upon the completion of pressure grouting, if required, the area to be sealed shall be visibly clean with no excess grout prior to lining.

500-4.4 Field Inspection Testing and Repair of Installed SLC Sealing Systems.

500-4.4.1 General. The Contractor shall submit information on the equipment to be used in testing installed SLC sealing systems to the Engineer in accordance with 2-5.3.

500-4.4.2 CCTV Inspection. After the installation is complete, the Contractor shall perform CCTV inspection in accordance with 500-1.1.5.

500-4.4.3 Adhesion Testing. Adhesion testing shall be performed on each SLC seal installed. The Contractor shall notify the Engineer 24 hours prior to performing adhesion testing, if the Engineer cannot be on site during testing, the Contractor shall videotape the test at each seal and shall submit the videotape to the Engineer in accordance with 2-5.3.

Adhesion testing shall be conducted after the SLC seal has cured in accordance with manufacturer's specifications and before the final video inspection is performed. Adhesion testing shall consist of inserting a high velocity, hydraulic cleaning type, 360 degree spinning nozzle and CCTV camera in the mainline pipe and positioning the nozzle at the SLC seal. The water from the nozzle shall be directed downstream for a minimum of 1 minute, at each edge of the SLC seal in the mainline at the minimum pressure of 1500 psi (10MPa) and minimum flow rate of 65 gpm (246 liters per minute).

500-4.4.4 Air Pressure Test. Unless otherwise specified in the Special Provisions, cured SLC sealing systems shall be air pressure tested. A test plug shall be placed adjacent to the upstream and downstream end of the SLC sealing system in the mainline and adjacent to the upstream end in the HC Sewer. The test pressure shall be 4 psi (0.3MPa) for a 3 minute test time during which the pressure shall not drop below 3.5 psi (0.2MPa). If the SLC sealing system fails this test, the test plug in the HC Sewer may be moved onto the SLC seal and the test conducted again. If the second test passes, the SLC sealing system will be deemed to have passed the test.

500-4.4.5 Repairs of Sealing Systems. If the SLC sealing system fails either the adhesion or the second air pressure test, the Contractor shall remove and replace or repair the SLC sealing system as recommended by the manufacturer and approved by the Engineer.

500-4.5 Full Wrap "T-Style" SLC Sealing System.

500-4.5.1 General. This subsection specifies a full wrap "T-style" SLC sealing system.

500-4.5.2 Sealing Material. The sealing material shall consist of a cured-in-place resin saturated felt tube that provides a full-wrap tube in the mainline centered at the HC, with a tube section extended into the HC. The length of the tube section in the mainline and in the HC shall be as specified in the Special Provisions.

500-4.5.3 Installation and Curing. Installation shall conform to Section 7.0 of ASTM F2561. The installation method shall provide an air-tight seal of the SLC sealing system to the mainline pipe and HC Sewer as specified by the manufacturer and shall be submitted to the Engineer in accordance with 2-5.3. Prior to installation, the felt tube shall be saturated with resin at the Work site and stored at the temperature specified by the resin manufacturer. After installation, the felt tube shall be cured as specified by the resin manufacturer. The method of curing shall be submitted to the Engineer in accordance with 2-5.3.

500-4.6 "Brim Style" SLC Sealing System.

500.4.6.1 General. This subsection specifies a "brim style" SLC sealing system.

500.4.6.2 Sealing Material. The sealing material shall consist of a cured-in-place resin saturated fiberglass or felt material that provides a brim section in the mainline with the brim centered around the HC with a tube section extended in the HC. The length of the tube section in the HC and the size of the brim section in the mainline shall be as specified in the Special Provisions.

500.4.6.3 Installation and Curing. The fiberglass or felt material and tube shall be saturated with resin at the Work site or at the factory and stored at the temperature specified by the resin manufacturer. The resin saturated SLC sealing system shall be loaded on an applicator apparatus, attached to a robotic device and positioned in the mainline at the HC to be sealed. The robotic device shall be equipped with a CCTV camera which shall be used to align and center the SLC sealing system within the HC opening. The applicator apparatus shall include a bladder or an approved mechanical device of sufficient length in the mainline and HC such that the inflated bladder or approved mechanical device extends beyond the end of the SLC seal. The insertion pressure shall be adjusted to fully deploy the SLC sealing system in the HC and to hold the ends of the SLC seal against the pipe walls. The SLC sealing system shall produce a smooth transition between the SLC seal and the pipe walls without a ridge or gap between the SLC seal and the inner diameter of the mainline and HC. The insertion pressure shall be maintained for the duration of the curing process. Curing shall be as specified by the resin manufacturer. The method of curing shall be submitted to the Engineer in accordance with 2-5.3.

500-4.7 Measurement and Payment.

500-4.7.1 Measurement. SLC sealing systems shall be measured by "each".

500-4.7.2 Payment. Payment for SLC sealing systems will be made at the Contract Unit Price or lump sum price in the Bid for each SLC. The Contract Unit Price or lump sum price in the Bid shall include the installation of the SLC sealing system, surface preparation and repairs, preparation and tape submittal of all pre- and post-construction CCTV inspection, bypassing if required, and testing, unless otherwise specified in the Special Provisions.