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## **A COMPREHENSIVE UNDERSTANDING of ASTM F2561-06 “The Standard Practice for Rehabilitation of a Sewer Service Lateral and its Connection to the Main Using a One-Piece Main and Lateral Cured-in-Place Liner.”**

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**ABSTRACT:** ASTM International, originally known as American Society for Testing Materials, was formed over a decade ago, when a forward-thinking group of engineers and scientists got together to address frequent rail breaks in the burgeoning railroad industry. Their work led to standardization on the steel used in rail construction, ultimately improving railroad safety for the public. According to the current “Regulations Governing ASTM Technical Committees,” a standard is defined as, “A document that has been developed and established within the consensus process of the Society and meets the approval requirements of ASTM procedures and regulations.”

The ASTM F2561-06 is a standard practice for rehabilitation of a service lateral and effectively seals the main fitting that connects the lateral service pipe to the main pipe. The standard specifies a one-piece, air testable, Main and Lateral Cured-In-Place Lining (MLCIPL) to be robotically installed from a city-owned mainline. The finished MLCIPL will create a structural lining that is continuous in length and extends from the main pipe up into the lateral pipe to a predetermined distance not-to-exceed 200 feet. The one-piece Main/Lateral lining will be leak-free, and will eliminate ground water infiltration and root intrusion. The renewal process is accomplished by non-invasive methods where no excavation is allowed.

This paper will discuss technical procedures and material composition in accordance with ASTM F2561-06 and why understanding this standard is important to any agency using public funds for infiltration correction, root control and structural renewal of a collection system. Specific sections in this paper include a purpose statement for explaining the key components and benefits incorporated within that section.

### **1. INTRODUCTION**

ASTM F2561-06 is an American Standard issued and printed by ASTM International. This practice covers requirements and test methods for the reconstruction of a sewer service lateral pipe having an inner diameter of three- to twelve-inches and a short section of the main pipe having an inner diameter of six to twenty-four inches without excavation. The lateral pipe shall be remotely accessed from the main pipe and from a cleanout. The renewal process shall be accomplished by the installation of a resin impregnated one-piece main and lateral lining by means of air inflation and inversion. The liner is pressed against the host pipe by pressurizing a bladder that is held in place until the thermo-set resin

cures. When cured, the liner shall extend over a predetermined length of the service lateral and a particular section of the main pipe as a continuous, one-piece, tight fitting, corrosion resistant, verifiably non-leaking cured in-place pipe.

## 2. REFERENCED DOCUMENTS

D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

F1216 Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube

D5813 Specification for Cured-In-Place Thermosetting Resin Sewer Piping Systems

NASSCO Guidelines Recommended Specifications for Sewer Collection System Rehabilitation

**PURPOSE:** The F2561 standard references documents and governs material testing and guidelines for cleaning and video inspection. The referenced standards above are applicable for the design of cured-in-place pipe (CIPP). Calculations are derived from formulas used to design cured-in-place pipe (hollow cylinder) that resist buckling and chemical resistance. However, a collar-type system is solely based on the strength of the surface bond for a connection seal and therefore a collar cannot utilize these design calculations as described in the referenced documents.

The physical properties of a collar-style connection are irrelevant because a collar is not a pipe that can be designed to resist buckling. The referenced documents describe Flexural Modulus, Flexural Strengths, Wall Thickness and Chemical Resistance for the application of cured-in-place, which engineers use to design a pipe to resist buckling and determine service life. ASTM F1216 and F2561 state that the CIPP will assume no bonding to the host pipe. Therefore, it should be noted that none of the referenced documents incorporate adhesion as part of the design criteria. Consider a collar that is constructed of carbon fiber having a wall thickness of three inches, is extremely strong and is bonded to the inner wall of the main host pipe: The strength of the collar is not relevant as the strength of the bond is the only attribute to sealing the connection. When the collar disbonds, the renewed connection has failed and the system leaks.

## 3. TERMINOLOGY

A terminology section includes definitions and terms that are specific to this standard. These terms are used throughout the Materials, Design Considerations, and Installation Sections.

## 4. SIGNIFIGANCE AND USE

It used to be a challenge educating owners about the impact laterals have on our collection systems. But today's challenges have evolved and are more focused towards educating specifying engineers, regulatory agencies, owners and inspection organizations on proper materials and installation methods for the rehabilitation of sewer service laterals and their connections to the main pipe without excavation, while providing a long term solution. Refer to Fig 1.



Figure 1: Delaminated

**PURPOSE:** Cities and specifying engineers have been told for years that the resin used in CIPP has “glue like qualities” and that it **bonds with grease and all types of piping materials including polyethylene.**

Grease is present in all sewers, including newly lined main pipes as soon as flows are restored. The common practice for cleaning is to use mechanical balls, blades and high velocity jet nozzles. The jet flushing process simply uses tap water from a hydrant. There is not a standard for preparing a sewer pipe by using hot water and detergents to effectively clean the pipe surface from F.O.G. (fats, oils and grease). Therefore, it is not practicable to assume thermo-set resins will bond to the greasy film present in all sewers. Grease is not the only issue for this bonding theory as most CIPP used to renew the main pipe has a coating on its inner side -- it makes a nice smooth slick surface but it also makes for a "failed design." Lateral connections that are rehabilitated using materials that are solely designed around adhesion are subject to delaminating due to thermal movement and hydrostatic loads due to ground water pressure. Some materials such as olefin-based products naturally resist adhesion. Until recently, most all inner coatings were made of thermal plastic polyurethane (TPU). Two different types of TPU's exist: "Ether," or "Ester" grade. Ether grade TPU's are hydraulically stable in water but they are not chemically resistant to the thermo-set resins used in CIPP applications. Ester TPU's are not hydraulically stable but they are chemically resistant to thermo-set resins. Therefore, ester based TPU's have been the coating of choice for CIPP for many years now. However, over a period of time, the ester based TPU coating will dissolve because it is not hydraulically stable. Today, other coatings have derived from the olefin family of products such as Polyethylene (PE) and Polypropylene (PP) which are being used for cured-in-place pipe. In comparison to TPU coatings; Olefin based products are less expensive, stable in water and chemically resistant to the thermo-set resins used in CIPP. However, there are no conventional means of adhering to polyethylene or polypropylene, a major flaw for the "bonding to a sewer pipe" theory.

## 5. TUBE AND SHEET

The Tube and Sheet is the framework of the main and lateral cured-in-place liner (MLCIPL) and is generally constructed of an absorbent needle punched felt or a high pile knit with a polymer film coating on its outer surface. The tube is engineered to be extremely flexible yet robust, so to negotiate bends in lateral pipes at significantly reduced inversion pressures. The "tube" represents the lateral portion and the "sheet" represents the main portion. The sheet includes one-inch strips of compressible material attached at each end, is sixteen inches in length and has a width greater than the circumference of the main pipe. An aperture is located in the center of the sheet (refer to Fig 2). The lateral tube is attached at the aperture of the sheet by stitching. The stitched connection is permanently sealed by applying a polymer adhesive over the stitched connection. The tube is continuous in length forming a one-piece MLCIPL. The MLCIPL is permanently marked (lateral identification) with the physical building address. The mark may also contain other valuable information such as manufacturing codes and the installation contractor.



Figure 2: Main/Lateral Assembly

**PURPOSE:** The sheet is formed into a tube producing a structural self-supporting cylinder. The lateral tube is continuous in length and is essential to the long term service of a MLCIPL. Lining materials that are installed at different times by overlapping and curing a liner onto a cured liner produces a "cold joint", similar to that found in concrete. The lining material as described in this standard produces a one-piece MLCIPL that is resin impregnated and cured simultaneously.

### 5.1 TRANSLUCENT INVERSION BLADDER

The tube shall be surrounded by a flexible translucent bladder (refer to Fig 3) that will contain the resin and facilitate vacuum impregnation while monitoring the wet-out procedure. The tube and sheet shall be a one-piece "TEE" or "WYE" shaped unit. No intermediate or encapsulated elastomeric layers shall be in the textile that may cause de-lamination in the cured-in-place pipe. The main sheet will be flat with one end overlapping the second end and sized accordingly to create a circular lining equal to the inner

diameter of the main pipe. The lateral tube will be continuous in length and the wall thickness shall be uniform.

**5.2 RESIN**

The resin/liner system shall meet the requirements of ASTM D5813 Section 8.2.2 – Strain corrosion requirements, a 10,000-hour test.

The resin shall be a corrosion resistant polyester, vinylester, epoxy or silicate resin and catalyst system that, when properly cured within the composite liner assembly, meets the requirements of ASTM F1216, the physical properties herein, and those properties that are to be utilized in the design of the CIPP for a particular project.

The resin shall produce CIPP, which will comply with the structural and chemical resistance requirements of ASTM F1216.



Figure 3: Liner/Bladder Assembly

Property (MPa)	ASTM Test	Minimum value psi	Minimum value psi
Flexural Strength	D 790	4,500	(31)
Flexural Modulus	D 790	250,000	(1,724)

Table 1 CIPP INITIAL STRUCTURAL PROPERTIES

**PURPOSE:** Materials that meet these requirements are used in the design criteria for CIPP to resist buckling and exposure to chemicals found in a sewer piping system.

**6. DESIGN CONSIDERATIONS**

The CIPP shall be designed per ASTM F1216, Appendix X1.

The CIPP design for the main and lateral tube shall assume no bonding to the original pipe.

**7. SAFETY RECOMMENDATIONS**

Access Safety – Prior to entering access areas such as manholes, or performing inspection or cleaning operations, an evaluation of the atmosphere to determine the presence of toxic or flammable vapors or lack of oxygen shall be undertaken in accordance with local, state, or federal safety regulations.

**8. CLEANING AND INSPECTION**

According to the Specification for Sewer Line Cleaning as provided by NASSCO Guidelines, the intent of sewer cleaning is to remove foreign materials from the lines and restore the sewer to a minimum 95-percent original carrying capacity or for proper seating of pipe plugs or other types of rehabilitation work (refer to Fig 4). High velocity water jet nozzles are often combined with mechanical cutting tools such as chains and carbide blades to remove root intrusions and de-scaling, especially in cast iron pipe.



Figure 4: Protruding Hammer Tap

## 9. ACCESSING THE LATERAL

The cleaning work is carried out through access of a cleanout (refer to Fig 5) which is typically set at the property line or near the building foundation. The cleanout fitting must be either TEE shaped or a set of back-to-back WYE shaped cleanout fittings. The cleanout must be located no less than two (2) feet of the finished liner. The cleanout fitting type and location are important factors for a successful lateral renewal project and will be discussed in greater depths in the following Plugging, Inspection and Curing sections of this paper.



Figure 5: Clean and Inspect

## 10. TRENCHLESS CLEANOUT INSTALLATION

In cases where no cleanout exist, a cleanout may be installed by conventional excavation or by a trenchless cleanout installation. A trenchless cleanout is installed by using a PVC saddle engineered to snap onto a lateral pipe, (refer to Fig 6) and sealed by use of a water activated sealant. Each saddle is sized for the outside diameter of various pipe types including; Clay, Cast Iron, Polyvinylchloride (PVC), Orangeburg (rolled tar paper pipe) and Concrete.

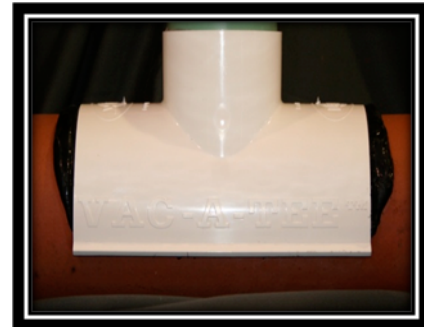


Figure 6: PVC Cleanout Saddle

## 11. LOCATING THE LATERAL PIPE

The owner typically specifies the distance of the cleanout from the center of the street. A lateral launch camera is inserted up the lateral pipe from the main pipe. The camera is outfitted with a sonde that transmits a signal detectable by a locator on surface (refer to Fig 7). The operator will also utilize the camera to ensure the mark is not placed where the pipe may bend or comprise other obstacles for the trenchless cleanout process. The pipe is located, marked, and is ready for vacuum excavation.



Figure 7: Locating Lateral Pipe

## 12. VACUUM EXCAVATION

Vacuum excavation is environmentally friendly allowing soil to be pulled away from tree roots, where a backhoe pulls and rips roots out of the ground causing severe damage to trees. This excavation method is not only environmentally friendly; it is also homeowner friendly since yards are not torn up with a large pile of dirt left behind (refer to Fig 8). Further advantages are recognized as surrounding utilities such as a water service in the same trench is not damaged during the vacuum excavation process. Trenchless cleanout installations are being used by cities



Figure 8: Vacuum Excavation

throughout North America that want to reduce or eliminate homeowner complaints, protect their trees and protect surrounding utilities.



### 13. SNAPPING SADDLE ON PIPE

A depth measurement is taken, and the riser pipe is cut, prepared and connected to the saddle. A water activated sealant is applied to the underside of the saddle. The prepared saddle and riser pipe are lowered into the hole and snapped onto the lateral pipe (refer to Fig 9). The hole is backfilled with sand, a few inches of black dirt and sod. A leak test is performed by filling the riser pipe with a column of water. A diamond core bit is inserted down through the riser pipe to cut open the crown of the pipe. The coupon is removed and the cleanout is complete.



Figure 9: 20-inch DIA. Borehole

### 14. INSPECTION OF PIPELINE

The interior of the pipeline is carefully inspected to ensure the pipeline is clear of obstructions that could prevent the proper insertion and expansion of the lining system (refer to Fig 10). Changes in pipe size can be determined by use of a digital laser profiler outfitted on a lateral push camera. The lateral length and diameters shall be logged and used to specify a custom tailored MLCILP.



Figure 10: Protruding Hammer Tap

### 15. PLUGGING

A TEE shaped cleanout not only allows technicians to video inspect and clean the pipe, it also allows for plugging of the lateral pipe during liner insertion which reduces installation errors. Immediately before liner insertion, an inflatable plug is inserted through the cleanout and positioned on the upstream side towards the building. This plugging procedure prevents odors from entering the home through dry plumbing traps which reduces homeowner complaints. This plugging procedure also prevents the homeowner from flushing which can obstruct visual positioning or cause premature curing.

### 16. RESIN IMPREGNATION

The one-piece MLCIPL liner assembly within the translucent bladder is vacuum-impregnated with an approved thermo-set resin (refer to Fig 11) under controlled conditions. The volume of resin used shall be sufficient to fill all voids in the textile lining material at nominal thickness and diameter. The volume is adjusted by adding 5% to 10% excess resin per ASTM F1216 for the change in resin volume due to polymerization and to allow for any migration of resin into the cracks and joints. Most of the excess resin is consumed by fractures or open joints in the old pipe. This excess resin is essential to maintaining minimum wall thickness and ensuring the liner remains fully saturated through the curing stage.



Figure 11: Vacuum Impregnation

## 17. LOADING LINER

The resin saturated lateral tube and lateral bladder (liner/bladder assembly) are inserted into the launching device and drawn into a carrying device (lay-flat launch tube). The launching device is a rigid tube with a full size aperture located within its mid-section (refer to Fig 12). This liner/bladder loading operation is accomplished by a technician pulling an inversion/reversion rope that passes through the launching device and is connected to the end of the lateral bladder. An approved lubricant is applied to the bladder during the loading process to reduce friction and inversion pressures.



Figure 12: Inserting Liner/Bladder

## 18. MAIN BLADDER AND SHEET

The main bladder now surrounds the rigid launching device. The bladder is connected to the launching device by clamping each end. The resin impregnated sheet is then wrapped tightly forming a tube around the main bladder and remains firmly wrapped by placing four hydrophilic O-rings around the tubular shaped main sheet (refer to Fig 13). A non-shrink flexible adhesive sealant is applied to the main/lateral interface. The O-rings keep the liner wrapped tight as the MLCIPL is moved through the main pipe to the designated lateral. The main sheet will expand and the O-rings will become embedded between the liner and the main host pipe, which has typically already been renewed by a form of lining. The hydrophilic O-rings are water activated. After twenty-four hours the O-rings swell three to five times their original size causing a compression seal. This basic compression gasket forms a seal with all types of piping materials including polyethylene. Further, the compression gasket is a flexible seal that is not compromised by thermal expansion or contraction. This is basically the same type of gasket sealing technology used extensively for joining a bell and spigot pipe.



Figure 13: Four Hydrophilic O-rings

**PURPOSE:** The MLCIPL is an engineered structural liner that forms a flexible hermetic seal between the lateral liner and the main liner. A compression gasket seal is formed by hydrophilic gaskets that swell. This compression seal is compatible with all piping materials.

## 19. INSERTING LINER INTO MAIN PIPE

The technician on the left (refer to Fig 14) is holding a Launching device with the main bladder clamped and the main liner wrapped in a tube. The technician to the right is inserting the lateral liner carrying device (lay-flat launch hose) into the manhole. The launching device is outfitted with rotating skids that elevate the liner and prevent resin from being wiped off during insertion through the pipe. The blue piece of equipment on the pavement is a robotic positioner that will be quickly attached to the launching device.



Figure 14: Inserting Launcher

## 20. POSITIONING LINER ASSEMBLY

A portable robotic reel is located at the upstream manhole. The portable reel unit has a small foot print making it traffic friendly and easily accessible in tough terrain (refer to Fig 15). The robotic powered reel moves the liner through the pipe until it is aligned with the selected lateral pipe. The liner is then robotically positioned by extension and rotation movements. The robotic positioning is performed by the operator at the powered reel. The operator relies on a video signal supplied from a camera inserted into the cleanout which extends down to the main providing a full view of the MLCIPL.



Figure 15: Robotic Powered Reel

## 21. INFLATING MAIN LINER

Once the launching device and MLCIPL are properly positioned, a steam truck outfitted with all the necessary controls supplies air pressure causing the main bladder to inflate. The inflation of the bladder causes the sheet to expand and fully contact the main pipe (refer to Fig 16). The hydrophilic O-rings become embedded between the main liner and the main pipe. The sheet forms a structural, cylindrical CIPP that is sixteen-inches in length, and includes one-inch strips of compressible material at each end providing a smooth transition to the main pipe. The MLCIPL is engineered for main pipe diameters from six- through twenty-four inches and fit both tee or wye shaped connections.

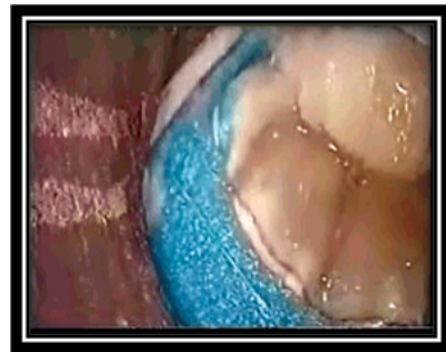


Figure 16: Main Sheet Expanded

## 22. INVERTING THE LATERAL TUBE

The lateral tube and bladder are inverted through the center of the main sheet, extending up into the lateral pipe (refer to Fig 17) and maintaining a minimum distance of two feet between the tube and the cleanout. The tube is continuous in length with no cold joints and the upper most end of the tube incorporates a two-inch strip of compressible material, which, when compressed, produces a smooth transition to the lateral pipe. A camera inserted at the cleanout verifies the tube has been fully deployed and inversion is complete, when the bladder extends past the open ended tube. The MLCIPL is engineered for lateral pipe diameters from three through twelve inches.

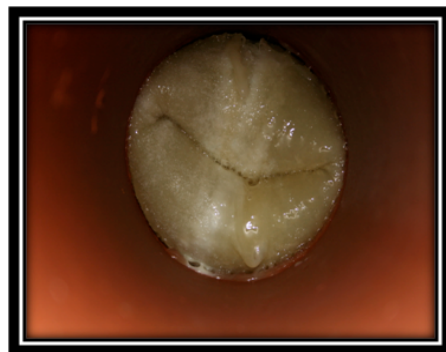


Figure 17: Lateral Tube/Bladder

## 23. CURING THE MLCIPL

The pressurized air supply is mixed with steam and is circulated through the MLCIPL to uniformly raise the temperature necessary to cure the resin. The lateral bladder is outfitted with a steam port at its closed end and when the inversion is complete, the port is open allowing steam to exit the bladder and exhaust out the cleanout (refer to Fig 18). Various resin systems are available, each with a different curing cycle; typically a MLCIPL can be cured quickly and thoroughly in 30-minutes. This steam curing technology increases production



Figure 18: Steam Exhausting



and the home owner is without service for less than one-hour.

#### **24. EQUIPMENT REMOVAL**

Once the liner has cooled down to 100-degrees F, the air supply is shut off. A technician pulls the flexible cord causing the lateral bladder to peel away from the liner and re-invert itself as it is drawn back down inside of the launching device. The launching device and positioner are removed from the main pipe. A second launching device having a resin impregnated MLCIPL is connected to the positioner, inserted in the pipe, and aligned with the next lateral to be renewed.

#### **25. FINAL INSPECTION**

A final video inspection is performed from the cleanout. The MLCIPL is continuous over the entire length of the rehabilitated sewer service lateral and the full diameter for sixteen inches of the main pipe (5" on either side of a 6" lateral or 6" on either side of a 4" lateral connection). The MLCIPL shall be smooth with minimal wrinkling and increase flow rate. The CIPP shall be free of dry spots, lifts, and delaminated portions. The MLCIPL shall taper at each end providing a smooth transition for accommodating video equipment and maintaining proper flow. The installer will provide the owner with video footage documenting the repair and the visual lateral identification markings with the building address as completed work. The finished product must provide an airtight/ watertight verifiable non-leaking connection between the main sewer and sewer service lateral.



Figure 19: Lateral Indicia

#### **26. PURPOSE OF STANDARD**

Engineers, Owners, Contractors and technology providers who practice trenchless pipe renewal will appreciate the purpose of the F2561 Standard.

In summary, the ASTM F2561 standard is the result of specifying materials and methods that describes a one-piece cylindrically shaped main and lateral cured-in-place pipe (refer to Fig 20) installed remotely from the main pipe. Understanding the key components and benefits of this standard are essential to renewing a collection system. This standard practice when followed will produce a continuous lateral lining that has a uniform wall thickness, compressible tapered ends, hydrophilic O-rings that produce a compression gasket seal and lateral identification by marking the physical building address on the liner.



Figure 20: Cured MLCIPL

#### **27. RECOMMENDED INSPECTION AND TESTING PRACTICES**

Sampling – As designated by the purchaser in the purchase agreement, the preparation of a CIPP sample is required. The sample will be prepared by securing a flat plate mold using the textile tube material and resin system as used for the rehabilitated pipe.

Pressure – The pressure applied on the plate sample will be equal to the highest pressure exerted on the lateral tube during the inversion process.

Length – The minimum length of the sample must be able to produce at least five specimens for testing in accordance with ASTM D-790-03.

Conditioning – Condition the test specimens at  $73.4 \pm 3.6^\circ \text{F}$  ( $23 \pm 2^\circ \text{C}$ ) and  $50 \pm 5\%$  relative humidity for not less than 40 hours prior to testing in accordance with Practice ASTM D 618 for those tests where conditioning is required.

Short-Term Flexural (Bending) Properties – The initial tangent flexural modulus of elasticity and flexural stress will be measured for gravity and pressure pipe applications in accordance with Test Method D 790 and will meet the minimum requirements of Table 1.

CIPP Wall Thickness – The minimum wall thickness at any point will not be less than 87.5% of the specified design thickness as agreed upon between purchaser and seller.

Gravity Pipe Leakage Testing – If required by the owner in the contract documents or purchase order, gravity pipes should be tested using an air test method where a test plug is placed adjacent to the upstream and downstream ends of the main sheet CIPP and at the upper most end of the lateral tube. This test should take place after the CIPP has cooled down to ambient temperature. This test is limited to pipe lengths with no service connections. The test pressure will be 4 PSI for a three-minute) minute test time and during this time the pressure shall not drop below 3.5 PSI.