

## Division 54: Insituform Lining

**54.01 GENERAL:** This section includes all labor, materials, transportation, and equipment necessary to rehabilitate by means of Insituform deteriorated sections of Sanitary Sewer within project limits. It is the intent of this Section of this specification to provide for rehabilitating sanitary sewer lines by the "Insituform" process. When complete the liner pipe should extend from one manhole to the next manhole in a continuous watertight length.

**54.02 REFERENCE SPECIFICATION:** This specification references American Society For Testing Materials (ASTM) standard specifications which are made a part hereof by such reference and shall be the latest edition and revision thereof.

### 54.03 TECHNICAL REQUIREMENTS:

- A. GENERAL - The line shall be fabricated from materials which when cured, will be chemically resistant to withstand internal exposure to sewage gases containing gases at normal levels for domestic sewage of hydrogen sulfide, carbon monoxide, carbon dioxide, methane, dilute sulfuric acid, external exposure to soil bacteria and any chemical attack which may be due to materials in the surrounding ground. In the event of unsuitable chemical residues remaining on the pipe walls or in the surrounding ground that will effect curing, the Contractor shall provide and install a PVC or equal pre-liner bag in the sewer before installing the actual liner.
- B. FELT CONTENT - The felt content shall be determined by the Contractor to ensure a cured thickness of liner as determined by the Contractor and approved by the Engineer for any individual job. Thickness of cured liner to be a specified (+10% -5%) and shall not include the thickness of the polyurethane inner liner.
- C. RESIN-CONTENT - The resin content of the liner shall be 10 - 15% by volume greater than the volume of felt in the liner bag.
- D. LINER SIZING - The liner shall be fabricated to a size that when installed will neatly fit the internal circumference of the conduit to be lined as specified by the Engineer. Allowance for longitudinal and circumferential stretching of the liner during insertion shall be made by the Contractor.
- E. LENGTH - The length of the liner shall be that deemed necessary by the Contractor to effectively carry out the insertion and seal the liner at the inlet and outlet of the respective manholes. The Engineer will specify the center to center on grade length for each manhole to manhole section on plans. The Contractor shall verify the lengths in the field before cutting the liner to length. Individual inversion runs can be made over one or more manhole to manhole sections as determined in the field by the Contractor and approved by the Engineer.

### 54.04 MATERIALS:

- A. GENERAL - All materials used in the lining and in the insertion process shall be of their best respective kinds and to the satisfaction of the Engineer. Any materials not approved by the Engineer shall be rejected prior to the insertions of the liner into the sewer. These rejected materials shall then be replaced, with approved materials, at the Contractor's expense.
- B. RESIN - The polyester resin shall be a resin for general chemical applications approved by the Engineer. A sample of each batch, suitably labeled, shall be tested or certified as indicated in Section 9.3C and approved by the Engineer prior to its use.

- C. FILLERS AND PIGMENTS - The polyester resins used shall not contain fillers, except those required for viscosity control or fire retardants. Up to 5% by mass thixotropic agent which will not interfere with visual inspection may be added for viscosity control. Resins may contain pigments, dyes or colorants which will not interfere with visual inspection of the cured liner.
- D. EPOXY RESIN - The use of epoxy resins compatible with the system to impregnate the liner bag may be permitted in some circumstances. The use of up to 40% by mass of suitable fillers may be permitted. The use of epoxy resin in any liner bag may be requested by the Contractor, if conditions are deemed to warrant their use, but approval in writing must be given by the Engineer before installations.
- E. REINFORCING MATERIAL - The reinforcing material of the liner bag shall be of a needle interlocked terylene felt or other material approved by the Engineer formed into sheets of required thickness. Bags may be made of single or multiple layer construction where any layer must not be less than 3mm thick. A suitable mechanical strengthener membrane or strips may be sandwiched in between layers where required to control longitudinal stretching. A polyurethane membrane used during insertion as the inflation bag may be left on the internal surface of the liner after curing. The minimum thickness of a bonded polyurethane membrane and inner liner, if used, shall be 0.25mm + 5% and shall not affect the structural dimension requirements of the cured liner.
- F. MECHANICAL PROPERTIES - The cured liner shall meet the following minimum strength requirements:

Tensile Strength at Yield 20 Degrees C	=	3,000 PSI
Ultimate Elogation at Yield	=	2%
Modulus of Elasticity	=	200,000 PSI
Flexural Strength	=	4,000 PSI
Shear Strength	=	5,500 PSI
Impact Strength	=	15 ft.-lb./in.
Hardness	=	(Barcol) 33
Heat Distortion	=	Temp 70° C

- G. FINISH - The finished lining shall be continuous over the entire length of an insertion run between two manholes and be as free as commercially practicable from visual defects such as foreign inclusions, dry spots, air bubbles, pinholes, pimples and delamination. The lining shall be impervious and free of any leakage from the pipe to the surrounding ground or from the ground to the inside of the lined pipe.

The inner surface shall be free of cracks and crazing with smooth finish and with an average of not over two pits per 300 mm square, providing the pits are less than 3 mm diameter and not over 1mm deep and are covered with sufficient resin to avoid exposure of the inner fabric. Some minor waviness that in the Engineer's opinion will not appreciably decrease the flow cross-section or affect the flow characteristics or be the cause of a possible chokage shall be permissible.

The polyurethane inflation bag, if permanently bonded and attached to the felt bag, may be allowed to remain as an inner liner. This bag, if allowed to remain, is not to be considered as part of the liner or to

contribute to any of the specified properties required of the liner.

Any defects which will affect, the foreseeable future, the integrity or strength of the lining, shall be repaired or the liner replaced at the Contractor's expense.

**54.05 DESIGN:**

- A. GENERAL - The Contractor shall submit with PROPOSAL the recommended liner thickness for each manhole to manhole section if different than shown on the contract drawing and/or listed in these specifications. If liner thickness other than specified is proposed, the Contractor shall supply design calculations indicating how liner dimensions were obtained. All calculations used in liner design will assume a Factor of Safety of 6 and the liner to be a very close fit in the existing conduit which itself will contribute to the resistance of soil and ground pressure. Liner shall be designed to withstand internal and/or external water pressures as indicated by site conditions or as directed by the Engineer.
- B. GRAVITY SEWER LINES - Gravity sewer liners shall be considered to fit closely to the inner surface of the existing sewer and mechanically bonded to it by excess resin such that the existing sewer is restored to a structural condition that can continue to carry existing normal soil loads. In the event of soil loads being applied to the liner directly as in the case of severe damage to the existing sewer resulting in missing sections, or bedding erosion allowing potential major longitudinal pipe deflection exceeding 5%, or shallow lines subject to severe surface loadings, or potential soil shifting, then liner thickness shall be calculated to suit these conditions.

Circular gravity sewer liners shall be designed for failure due to wall crushing rather than buckling and shall be capable of resisting an external hydrostatic pressure equal to a head of water equivalent to the depth of the conduit below ground surface level unless otherwise specified by the Engineer. Liner thickness shall be calculated by the standard equation for ring compression.

$$P_h = \frac{2 \cdot f_y t}{6D}$$

where  $P_h$  = External hydrostatic pressure PSI

$f_y$  = Yield tensile strength PSI

$t$  = Thickness of liner in inches

$D$  = Diameter of existing conduit in inches

\* Liner thickness used shall be multiple of 3 mm (eq. 3 mm, 6mm, etc.) and shall be of thickness calculated. If a factor of the next multiple of 3mm, the next larger size shall be used.

- C. LINER THICKNESS - Notwithstanding the thickness of liner as calculated above to suit a specific job the minimum and maximum thickness of liner to be used in a circular conduit are shown in Table 1 below:

TABLE 1 MAXIMUM AND MINIMUM LINER THICKNESS									
Liner Thickness mm	Liner OD For Circular Pipe in Inches								
	6	8	10	12	15	18	24	30	36
6	X	X	X	X	X	X			
9				X	X	X	X	X	X
12							X	X	X

**54.06 PRIOR TO LINER INVERSION:** The following procedures prior to liner inversion shall be adhered to unless otherwise approved by the Engineer.

- A. **Cleaning of Sewer Line:** Prior to any Insituform-lining of a line so designated, it shall be the responsibility of the Contractor to clean debris out of the sewer line in accordance with Section III "Sewer Line Cleaning" NASSCO Specifications for Sewer Collection System Rehabilitation. This work shall be considered incidental and shall be paid for as part of "Insituform Lining of Sewer" for the appropriate size and MH Section.
- B. **Television Inspection:** The Contractor shall inspect by closed circuit T.V. the section to be lined and shall record the locations of all obstructions and service taps. This work shall be considered incidental and shall be paid for as part of "Insituform Lining of Sewer" of the appropriate size and MH Section.
- C. **Bypassing Sewage:** The Contractor shall bypass the sewage around the sections of line that are to be Insituform-lined. The bypass shall be made by plugging an existing upstream manhole if necessary and pumping the sewage into a downstream manhole or adjacent system. The pump and bypass lines shall be of adequate capacity and size to handle the flow. All bypassing systems shall be approved by the Engineer. Approval of the Bypassing System by the Engineer shall in no way be construed as relieving the Contractor of any responsibility under this Contract as related to protection of the interest of the City and the general public.
- D. **Line Obstructions:** It shall be the responsibility of the Contractor to clear the line of obstructions, solids, dropped joints, protruding services, or collapsed pipe that will prevent the insertion of the liner. If inspection reveals an obstruction, such as badly dropped or misaligned joint, or service protrusion, then the Contractor shall make a point repair excavation to uncover and remove or repair the obstruction. Such excavation to uncover and remove or repair the obstruction. Such excavation shall be approved in writing by the Engineer prior to the commencement of the work and shall be considered as a pay item under Point Repairs if the misalignment or percent of the internal diameter of the sewer pipe being lined - as determined by the Engineer from television pictures. If the obstruction or protrusion is less than fifteen percent (15%) of the sewer I.D., or could have been removed by bucket machines or swabbing using conventional cleaning methods, no pay item will be granted.

**54.07 INSTALLATION:**

- A. GENERAL - The Contractor shall deliver the uncured resin impregnated liner bag to the site, provide all equipment required to place and invert the liner into the sewer and cure it once in place.
- B. TRANSPORTATION TO SITE - The liner bag shall be impregnated with resin not more than 24 hours before the proposed time of installation and stored out of direct sunlight at a temperature of less than 40°F (4°C). The impregnated liner shall be transported to the site just prior to inversion in a suitable light proof

container with the temperature maintained below 40°F (4°C).

- C. LINER INVERSION - The liner shall be inverted into the sewer from a suitable platform located above the manhole or any other point of inversion. The free open end of the folded liner bag shall be passed down a suitably reinforced column to an inversion shoe or bend. The protruding end of the bag should then be folded back over the shoe and each layer, if a multiple layer bag, firmly secured to the inversion shoe by means of a stainless steel strap. After the liner bag is secured to the shoe the shoe should be positioned in the inversion location so as the reporting portion of the bag is properly aligned with the open end of the sewer to be lined. Clean water at ambient mains temperature shall be available from the City at the nearest fire hydrant to the inversion location.

Line inversion rate shall not exceed 32 feet/minimum, (ten meters/ minimum) and the liner bag or the tag rope will be suitably restrained to prevent inversion rates in excess of that stipulated above. The inversion head shall be such that, allowing for minor impact, at no time the hoop tension in the felt liner shall exceed 8000 PSI or the hoop stress in the polyurethane membrane.

- D. LINER CURING - The Contractor shall supply a suitable heat source and water recirculation equipment capable of delivering hot water to the far end of the liner to quickly and uniformly raise the water temperature in the entire liner, once inverted in the sewer, above the temperature required to commence the exothermic reaction of the resin as determined by the catalyst system employed.

The heat source shall be fitted with suitable monitors to gauge the temperature of the incoming and outgoing water supply to determine when uniform temperature is achieved throughout the length of the liner. Water temperature in the liner during the initial and post cure period shall not be less than 160°F (71°C) or more than 194°F (90°C). Live steam shall not be permitted to enter the curing liner. In addition to the gauges on the incoming and outgoing water supply there shall be thermo-couples placed between the liner and the sewer pipe at the point of inversion and the end of the liner being cured to accurately measure the bag temperature.

A record of the reading of these thermo-couples shall be kept and given to the Engineer for each section lined.

Temperature reading shall be taken at 15 minute intervals beginning when heat is applied and continuing through Curing and Post Curing until the temperature is reduced to 149°F (65°C). In lieu of 15 minute temperature readings the Contractor may use a suitable temperature recording device. The recording device must be approved by the Engineer as to type and accuracy.

- E. POST CURING - Initial cure shall be deemed to be completed when a uniform temperature, as determined by the Thermo-couples monitors on the liner wall, is achieved throughout the length of the liner and visual inspection of the exposed portions of the liner appear to be hard and sound. The post cure period shall commence with the heat source shut down but continue recirculation of the water to maintain the temperature in the liner at or just below a maximum temperature 194°F (90°C) but above 160°F (71°C) during the initial exothermic reaction period. Hot water may be bled out of the system and replaced by clean water at ambient mains temperature to control post cure water temperature. A minimum period of three (3) hours post cure under an inversion head to maintain a minimum hoop tension in the liner felt shall complete the curing period. Ends of liner cannot be fully opened until intake and discharge temperatures of boiler are less than 110°F (43°C).

**54.08 SERVICE CONNECTIONS:** After the line has been cured all existing active services shall be reconnected. All existing inactive services serving vacant or undeveloped properties shall be reconnected.

The camera directed cutting device shall reestablish the service in such a way that a smooth edge is established between the lateral and the pipeline. The liner shall be sufficiently tight so that there is no annular space between the

connection and the line. The cost of testing for and reconnecting service shall be considered incidental to the cost of "Insituform Lining of Sewers" in each MH section.

**54.09 VIDEO TAPING:** After the work is completed the Contractor shall supply the Engineer with video tapes showing the lined section before and after Insituforming including service connections. The cost of this item shall be considered incidental to "Insituform Lining of Sewers".

**54.10 TESTING AND INSPECTION:** The Contractor shall supply the Engineer with a certified Statement from each material supplier that the material supplied meets or exceeds the requirements of these specifications. The certification shall identify by name the project and specification.

A. INDEPENDENT TESTS GENERAL - Should the Engineer desire to make independent tests, the Contractor shall at the request of the Engineer furnish any reasonable number of test pieces or raw material samples as the Engineer may require, stamped or marked with the date of manufacture and batch number if applicable.

TESTING AUTHORITY - The above mentioned independent tests shall be carried out by an independent authority, who shall be agreed upon between the Engineer and the Contractor, or failing agreement within seven days of the posting of a written notice by the Engineer to the Contractor, one shall be appointed at the request of either party by a Federal arbitrator. The certificate of such authority shall be accepted by the Engineer and the Contractor as conclusive of the results of such test.

COSTS - The cost attendant on the carrying out of the independent tests, including the provision at reasonable cost of the test pieces, shall be charged against the Contractor if tests prove the material is unsatisfactory or against the City if the tests prove it acceptable.

B. TESTS

GENERAL - The polyester resin to be used in the liner and cured liner material shall be subject to the following tests as and when directed by the Engineer.

- a) Alkaline Resistance of Polyester Resin
- b) Ultimate Tensile Strength
- c) Ultimate Compressive Strength
- d) Flexural Strength
- e) Flexural Modulus
- f) Liner Thickness
- g) Terylene Felt and Resin Content
- h) Hardness
- i) Abrasion Resistance

The above tests shall be made on specimens of resin, catalyst and felt as supplied or pieces of cured liner cut from waste areas when possible. Otherwise, the specimens shall be cut from a piece of cured liner representative of the material inserted and prepared and cured in a similar technique to the process

equipment. In all cases, the average value of the indicated number of specimens shall be used to determine conformance with the detailed requirements.

The test specimen shall be conditioned in accordance with procedure for ASTM, Standard Methods for Conditioning Plastics and Electrical Insulating Materials for Testing.

- C. ALKALINE RESISTANCE OF POLYESTER RESIN - Test pieces will be prepared from a 100 gm sample of resin and catalyst as supplied from any one batch of resin to be used by the Contractor. The resin will be cooled to 4°C then mixed and placed in a 14mm diameter test tube for curing for a period of four (4) hours at 4°C followed by a period of sixteen (16) hours at 80°C. The cured samples will then be cut into 2mm thick test pieces and polished with dry 210 grade emery paper before testing.

Three weighed test pieces will be immersed in 40ml of 10% sodium hydroxide (W/V%) contained in a test tube which will be placed in a boiling water bath for 48 hours then dipped in hydrochloric acid, washed with distilled water and dried at 110°C for two (2) hours. After cooling the samples will be weighed and the resin shall be deemed to be acceptable if the weight loss is less than 10% of the original weight of the samples under test.

- D. TENSILE STRENGTH - Tensile Strength shall be determined in accordance with ASTM Designation D638, for Tensile Properties of Plastics. The specimens shall be the actual thickness of the fabricated article. Specimens shall not be machined on the surface. Tensile Strength shall be the average of five specimens tested.

- E. COMPRESSIVE STRENGTH - The Compressive Strength shall be determined in accordance with ASTM Designation D695, Compressive Properties of Rigid Plastics. The specimens shall be the actual thickness of the fabricated liner. The tensile strength shall be the average of five specimens tested.

- F. FLEXURAL STRENGTH - Flexural Strength shall be determined in accordance with ASTM Designation D790, Standard Method of Test for Flexural Properties of Plastics. The specimens shall be the actual thickness of the fabricated liner. Other dimensions of specimens shall be as designated by the ASTM Standard. Specimens shall not be machined on the surface.

Tests shall be made with smooth (inner) face in compression using five specimens.

- G. FLEXURAL MODULUS - The tangent modulus of elasticity in flexure shall be determined by ASTM Method D790.

- H. LINER THICKNESS - The Thickness of the cured liner shall be accurately measured and shall not be more than 5% less the thickness specified.

- I. TERYLENE FELT AND RESIN CONTENT OF LINER - The samples shall be visually inspected to ensure the number of layers of felt to conform to the specified number of layers and thickness. Cured resin shall be leached from the liner by a suitable process and the resin to felt ratio by weight calculated. This ratio shall fall in the range 1.10:1 - 1.15:1.

- J. HARDNESS - The Barcol impression shall be used to determine the hardness of the cured resin at 25°C. The hardness shall be determined in accordance with ASTM Designation D2583. Indentation hardness of plastics by means of a Barcol impressor.

- K. ABRASIVE RESISTANCE - Abrasive Resistance of the polyurethane film and the liner shall be determined by a Tabor Abrader, in accordance with ASTM D-1004.

The wear on the polyurethane film shall not exceed 0.025mm when tested for 10,000 cycles using 500mm on H.22 Calibrate Wheels. The wear on the cured liner after 2020 cycles with H.18 Calibrate Wheels shall not exceed 0.6 on wet or 0.25 dry.

- 54.11 CLEAN-UP:** After the installation work has been completed and all testing acceptable, the Contractor shall clean up the entire project area and return any disturbed areas to a condition as good as existed prior to the work being performed. All excess material and debris not incorporated in the permanent installation shall be disposed of by the Contractor. Sidewalks, driveways, streets surfaces, and other surface restoration not part of an eligible Point Repair shall be considered incidental to "Insituform-Lining of Sewer" for the appropriate size and MH Section.
- 54.12 METHOD OF MEASUREMENT AND BASIS OF PAYMENT:** It is intent of these Specifications that Insituform lining, excluding eligible Point Repairs be a complete process. The length of sewer pipe satisfactorily "Insituform" will be measured in place by the Engineer. The pipe shall not be measured through manholes. Payment will be made for the quantities so measured at the unit prices specified in the Bid Proposal. Point repairs shall not be measured as such but shall be paid for at the lump sum price specified in the Bid Proposal which prices shall be full payment for all labor, materials, tools, equipment, excavation, backfilling, sheathing, shoring, dewatering, pavement patching, and any other costs necessary to complete the work as shown, directed and specified.

