

**Construction Specification for
the Cured-In-Place Pipe Lining of Sewers**

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TS 460.01**SCOPE**

This specification is for full length Cured-in-Place Pipe (CIPP) lining of various maintenance hole to maintenance hole sections of local sewers of 450 mm diameter or less and large diameter trunk sewers greater than 450 mm diameter or larger. The sewers may include sanitary sewers, storm sewers and combined sewers in the right-of-way or in easements.

The Work shall include performing the following operations: notification of public, CCTV inspections, determining sewer and liner dimensions, determining/confirming design parameters for liners, flow control and bypass pumping, cleaning and preparation of the sewers to be lined, service connection investigation and related work, installation and curing of the CIPP liners, reinstatement of sewer service connections, return of the lined sewer to regular service plus any other work required for and incidental to the foregoing.

The work involved requires special equipment to be handled by persons experienced in all phases of the Work.

Note: This specification not to be used for sewers on private property or where the Ontario Building Code (OBC) has jurisdiction and where diameters are smaller than 200 mm or above ground such as found inside buildings. Designer to complete a risk analysis and provide a minimum thickness based on burial depth and water table levels following ASTM F1216 CIPP design standards.

TS 460.02**REFERENCES**

This specification refers to the following standards, specifications or publications:

City of Toronto Standard Specifications

TS 4.01	Construction Specification for Sewer Bypass Flow Pumping for Local Sewers
TS 4.02	Construction Specification for Sewer Bypass Flow Pumping for Trunk Sewers
TS 409	Construction Specification for Closed-Circuit Television Inspection of Pipelines
TS 467	Construction Specification for Type A – Structural and Non-structural Maintenance Hole Rehabilitation

American Society for Testing and Materials

D790-10	Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D2990-09	Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
D5813-04(2008)	Standard Specification for Cured-In-Place Thermosetting Resin Sewer Piping Systems
F1216-07a	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube
F1743-08	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation and Curing of a Resin—Impregnated Tube
F2019-03(2009)	Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Pulled in Place Installation of Glass Reinforced Plastic (GRP) Cured-in-Place Thermosetting Resin Pipe (CIPP)

International Standards Organization

ISO 7685 Method for Determining Structural Thickness of Reinforced Liners
ISO 11296 Test Method for Short-term Flexural Modulus and Flexural Strength
TS 460.03 DEFINITIONS

For the purposes of this specification, the following definitions apply:

Engineer means the licensed individual or firm responsible for the design of the works or their designate and registered with the Professional Engineers of Ontario.

MH means maintenance hole or manhole.

NASSCO means the standards developed by the National Association of Sewer Service Companies for sewer inspections.

PACP means Pipeline Assessment and Certification Program

TS 460.04 DESIGN AND SUBMISSION REQUIREMENTS

TS 460.04.01 Detailed Design and Shop Drawing Submittal(s)

Submit detailed design of all CIPP liner segments only after field verification of pipe dimensions, pipe depth, water table, resin and other design parameter confirmation and shall be in accordance with the ASTM F1216-07a Appendix X1, Design Considerations for the fully deteriorated pipe condition and design parameters in the Table 1 below. The design must be prepared by an Engineer and shall comply with the requirements listed in TS 460 herein.

If after V1 and V2 actual field conditions are found to be different (e.g. dimensions of pipe, depth of sewer) than provided/suggested in the contract, the design shall be adjusted to actual field conditions. The adjusted design may result in a thicker liner to be installed. Any additional cost involved shall be determined according to the provisional adjustment items for additional liner thickness and if provisional items for additional liner thickness are not included in the tender, then shall be negotiated with the Contract Administrator.

No liner shall be installed that does not meet the requirements for actual field conditions, including required liner thickness for actual field conditions.

Designs shall be submitted to the Contract Administrator for approval as part of the shop drawings review and approval process. No lining shall be installed without an approved design.

- 1) Detailed design of all CIPP liner segments after field verification of pipe dimensions, pipe depth, water table, resin and other design parameter confirmation.
- 2) Include information of the proposed resin manufacturer, resin type and manufacturer's resin identification number, resin specific design parameters suggested by the resin manufacturer. Include the proposed liner tube manufacturer and the type of tube for each section and provide samples upon request by the Contract Administrator.
- 3) Resin to felt ratio and excess resin percentage according to ASTM F1216-07a

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- 4) Provide a certified original copy complete with supporting literature from the resin manufacturer of the Infrared Spectrograph of the catalyzed resin mixture proposed for this Contract.
 - 5) Provide a summary of the Contractor's proposed CIPP liner procedure. Include one example of the liner wet-out process sheet and one example of the liner curing process summary sheet to be used, for each type of liner the Contractor anticipated to use for the work.
 - 6) Provide the intended temperature curves during curing and cooling for each sewer section to be lined.
 - 7) Provide a certified original copy from the resin manufacturer of the cure temperature requirements and example resin volume calculation along with example cure time calculation.
 - 8) Provide the intended pressure curve for the inversion medium (hot water or steam) to facilitate expansion of the CIPP liner.
 - 9) Provide information for liner storage location, transport, transport vehicle temperature control, sequencing of liners for installation, power supply and back-up plan in case of failure, blowers/compressors and water supply required for hot water or steam production.
 - 10) Provide name of the lead on-site supervisor who will be responsible to oversee CIPP installation and curing operations. The lead on-site supervisor must have a minimum of 5 years of CIPP installation experience and must be on-site during the installation of the CIPP products.
 - 11) Identify the location (address) where the CIPP tube will be impregnated.
 - 12) Provide a complete list of equipment including CCTV cameras, robotic service connection cutters, reamers and other necessary major items to be dedicated to the work. The list of equipment shall specify type, manufacture and quantity of equipment.
 - 13) At no additional cost, the detailed design shall be resubmitted if the V1 Inspection reveals the sewer section to be lined has higher ovality and/or different dimensions or as deemed necessary by the Contract Administrator based on actual field conditions and measurements. Designs shall be corrected for actual field conditions.

Minimum – Thickness

All CIPP liners shall be at least 6 mm thick even if the design thickness calculation indicate a thinner liner will suffice. A design reconciliation based on installed liner test properties (such as from testing field samples of liners) shall not overrule this requirement.

Table 1: Design parameters for sewer rehabilitation

Parameter	Requirement for Liner
Design Method	All Design shall be fully deteriorated pipe condition For Gravity Pipe - ASTM F1216-07a, Appendix X1, Design Considerations, X1.3 Pressure X1.2.2 (ASTM F1216-07b or later not acceptable) For Pressure Pipe - ASTM F1216-16, Appendix X1, Design Considerations, X1.3 Pressure Pipe. X1.3.2
Design Life	50 years
Safety Factor	2.0 for all equations
Ovality	3% or the actual ovality of the sewer section, whichever is greater. For noncircular and irregular shape sewer, the calculation shall take in to consideration any additional consideration due to noncircular shape.
External Hydrostatic Pressure	Corresponding to ground water table maximum 1.2 m below ground surface or actual ground water table if geotechnical report suggests ground water can be found at less shallow depth than 1.2 m.
External Earth Load	Based on 2.0 m over top of pipe or the actual height of cover that exists at the liner location, whichever is greater. If the ground cover height varies by more than 0.5 m from one end to other, use the highest ground cover for that maintenance hole to maintenance hole section (more conservative depth)
Live Load	AASHTO HS-20 or the actual live load that exists at the liner location, whichever is greater (e.g. For railway crossing use E-80 live load)
Soil Weight	18.85 KN/m ³ (1922 Kg/m ³)
Soil Modulus	6.89 MPa
CIPP Liner Flexural Modulus used for design	The flexural modulus used for design shall be the long-term flexural modulus for the design life. The long-term flexural modulus shall be the amount of short-term flexural modulus (according to ASTM D790) retained for the design life. The short-term flexural modulus used shall be the value that will be reliably and repeatedly achieved in liner installations. The retention factor shall be derived from long-term testing and be appropriate for stress and stress duration in the installed liner. Independent third party test data is required (submit with tender) to substantiate the short-term and long-term values used in design. The design must identify the short-term and long-term values. Minimum Value should be as per below. For pipes with diameter less than and equal to 900 mm Flexural modulus (ASTM D790) – 250,000 psi (1,723 MPa) For pipes with diameter greater than 900 mm Flexural modulus (ASTM D790) – 400,000 psi (2,757 MPa)

Table 1: Design parameters for sewer rehabilitation (continued)

Parameter	Requirement for Liner
CIPP Liner Flexural Strength used for design	The flexural strength used for design shall be the long-term flexural strength for the design life. The long-term flexural strength shall be the amount of short-term flexural strength (according to ASTM D790) retained for the design life. The short-term flexural strength used shall be the value that will be reliably and repeatedly achieved in liner installations. The retention factor shall be derived from long-term testing and be appropriate for stress and stress duration in the installed liner. Independent third party test data is required (submit with tender) to substantiate the short-term and long-term values used in design. The design must identify the short-term and long-term values. Minimum short-term value shall be 4,500 psi (31 MPa)

Short-term Flexural Modulus and Short-term Flexural Strength

The short-term values of flexural modulus and flexural strength according to ASTM D790 used as the starting values from which the long-term design values are derived shall be values that will be reliably and repeatedly obtained in the installed liners as substantiated by testing samples from installed liners. These short-term values shall be identified in the liner design. Provide this information with backup data from the CIPP resin supplier at the time of tender closing and at the time of submitting detailed design calculations as shop drawings.

TS 460.05 MATERIALS

The sewer lining shall be cured-in-place-pipe (CIPP) according to the requirements of ASTM F1216-07 for inverted liners or ASTM F1743-08 for pulled in place liners or ASTM F2019-03(2009) for reinforced pulled in place liners and ASTM D5813-04(2008).

Tube—The tube should consist of one or more layers of flexible needled felt or an equivalent nonwoven or woven material, or a combination of nonwoven and woven materials, capable of carrying resin, withstanding installation pressures and curing temperatures. The tube should be compatible with the resin system used. The material should be able to stretch to fit irregular pipe sections and negotiate bends to a certain extent. The outside layer of the tube should be plastic coated with a material that is compatible with the resin system used to prevent absorption of residual water from the sewer. The tube should be fabricated to a size that, when installed, will tightly fit the internal circumference and the length of the original conduit. Allowance should be made for circumferential stretching during inversion.

Resin—Unless specified elsewhere in the contract, for sanitary sewers a general purpose, unsaturated, styrene-based, thermoset resin and catalyst system or an epoxy resin and hardener that is compatible with the inversion or pulling process should be used. Unless specified elsewhere in the contract, for storm sewers non styrene-based resin and catalyst system or an epoxy resin and hardener that is compatible with the inversion or pulling process should be used.

The resin must be able to cure in the presence of water. The CIPP system can be expected to have as a minimum the initial structural properties given in Table 1.

The resin shall be selected such that it complies with any specific curing requirements listed in the contract (e.g. UV curing only if listed in the contract).

TS 460.06 EQUIPMENT – Not Used

TS 460.07 CONSTRUCTION

Lining can only commence upon:

- 1) Field verification and confirmation of actual field conditions, submission of detailed designs, shop drawings and other submittals as listed in clause TS 460.04.01 from the Contractor and review and acceptance of the detailed designs, shop drawings and submittals by the Contract Administrator.
- 2) Installation and operation of flow control as per Contract Specifications and as per the approved flow control plan. It is the Contractor's responsibility to employ flow control and no work requiring flow control shall proceed until the Contractor demonstrates that the flow control or bypass pumping capacity meets the requirement stipulated in the contract.
- 3) Installation of exhaust fans with odour control.
- 4) Compliance with other requirements as specified in the Contract Documents.

TS 460.07.01 Notification to Public

Prior to the commencement of any work on the Contract, the Contractor shall deliver written Construction Notice or Construction Update to all residents/businesses who will be impacted three weeks prior to any work commencing at each location. The notice/update shall be prepared in City of Toronto format and shall be reviewed and accepted by the Contract Administrator and City staff prior to distribution.

From time to time during the Contract other notices, such as the Service Interruptions Notices, shall be distributed by the Contractor. The Contractor's notices shall be prepared on the Contractor's letterhead and clearly indicate both daytime and after hours emergency contact telephone numbers and shall be distributed a minimum of 3 Days in advance of the work. The telephone numbers shall be either local area code or toll-free numbers and the person carrying the emergency phone line shall be able to mobilize resources to site within 1 hour if required. No work will be allowed to commence without such notices. Any Contractor's written notices shall be submitted to the Contract Administrator for review and acceptance prior to delivery of the notices.

The Contractor's notice for individual homeowners shall include instructions to limit their sewer use, including the use of any mechanical devices, for example sump or ejector pumps from discharging to the sewer service, in a manner that may adversely affect the lining process. The Contractor shall provide the Contract Administrator with a copy of any such notices for review and acceptance prior to delivery of the notices.

In emergency circumstances only, the Contractor shall notify the Contract Administrator and upon approval of the Contract Administrator verbally advise house occupants, building occupants or owners of work that will affect the occupants or owners and conduct any ongoing liaison that is required to resolve questions or other issues.

The Contractor shall ensure that all agents or employees carry identification when entering private premises or contacting the public. This identification shall be in the form of laminated and numbered identification cards, complete with photographs indicating that the cardholder is an authorized representative of the Contractor working for the City. The names, addresses and telephone numbers of all employees involved in the undertaking this Contract shall be provided to the City. All cards shall be returned to the Contract Administrator to return it to Toronto Water following the completion of the Contract

TS 460.07.02 Site Investigation

Before commencing any construction work the Contractor shall investigate each sewer access area including verifying the maintenance hole condition to determine the existing site conditions and identify any obstructions such as ladders, platforms, size of chimney and so on that may affect the completion of the proposed works. No additional payment shall be made on account of difficulties to complete the works because the Contractor failed to investigate the site prior to commencement of the work.

TS 460.07.03 Existing Video Inspection Records and Drawings

The Contract Administrator shall provide the Contractor with a list of sewer sections for CIPP lining, the City's available CCTV inspections, inspection reports and GIS data (for trunk sewers only) that identifies the location of sewer sections. This information may be either provided with the tender, or shall be provided either in full at the start of the contract or alternately on an incremental monthly basis during the contract. The method of provision either in full or incrementally will depend on the structure of the specific contract tender including the structure of the schedule of unit prices and quantities.

The Contractor shall review the inspection information and drawings prior to undertaking any work in the sewer sections. Where CCTV data is provided the Contractor and shall be responsible for estimating the actual amount of sediment and debris in the sewer to be removed prior to lining and, also determine the extent of the site specific repairs which may be required including reaming, grouting, root cutting, trimming of intruding connections and other localized repairs.

CCTV information may not be available for all maintenance holes and sewer sections for which rehabilitation is required. The Contractor shall assume that the maintenance holes and sewer sections which do not have CCTV information are in a similar, or worse, condition to the other nearby maintenance holes and sewer sections for which the CCTV information is provided.

On commencement of the Contract, the Contractor shall carry out a CCTV inspection (V1) of all maintenance holes and sewer sections and provide copies of the CCTV videos and inspection reports to the Contract Administrator for review. The Contract Administrator will review the CCTV videos and inspection reports and notify the Contractor of any preparation works required prior to CIPP lining of the sewer.

TS 460.07.04 Excavations for Retrieval of Equipment or Other Purposes

Where the retrieval of a lodged or stuck equipment is required by an open-cut excavation, the Contractor shall immediately advise and discuss risk to sewer operation and retrieval with the Contract Administrator and Toronto Water Operations staff. The Contractor shall mark the point on the surface where the equipment is lodged or stuck. The Contractor shall provide for retrieval including any permits, excavation, maintenance of flow, repair, backfill and restoration. If the equipment became lodged during the V1 CCTV inspection or during cleaning operations prior to the V1 in a portion of a sewer section where the condition of the sewer is unknown, or for which no previous CCTV inspection or other advice was provided to the Contractor by the City, and if the Contractor demonstrates due diligence in launching the equipment, then the City will pay the Contractor 75 per cent of the total cost for the above noted retrieval and repair as deemed reasonable by the Contract Administrator. However, the City will not entertain any other associated cost related to this work.

If it is necessary to excavate for any other reason such as repair of defective liner, reinstatement of service connections or bypass of flow, the Contractor shall carry out all work as per base scope. The Contract Administrator shall review the reasons why the Contractor deems excavation is required. Should the Contract Administrator determine that the excavation could not have been avoided and that the excavation is extra to the Contract works then additional payment may be negotiated for such work. Work shall not commence until any additional payment due has been agreed by the Contract Administrator.

TS 460.07.05 Weather Conditions

The Contractor shall review the Environment Canada weather forecast prior to commencement of lining operations. Where the weather conditions such as rain or snow melt are anticipated, sewer/drain flows may exceed the Contractor's bypass pumping capacity. The Contractor shall be aware that the installed plugs can surcharge upstream sewer during such weather conditions and may cause potential basement flooding.

CCTV Inspection and/or liner installation shall not be started when rain or snow melt is forecasted during lining operation. Lining operation includes liner insertion, curing time, reinstatement of services and until such time the temporary bypass is required in service. Lining operation does not include sewer cleaning and preparation.

Regardless of the scheduling of liner installations or the Contractor's decision on carrying out a liner installation, the Contract Administrator, at its sole discretion, has the right to direct the Contractor to delay a liner installation at no extra cost to the City, when, in the Contract Administrator's opinion, there exists a reasonable potential that a detrimental rain or snow melt event will occur which could cause unacceptable surcharge in the sewer.

This applies to all storm, sanitary and combined sewers to be lined.

TS 460.07.06 CCTV Inspections and Reports

CCTV inspections for V1, V2 and V3 assessments shall be in accordance with TS 409.

Inspection Reports

Each CCTV inspection submitted shall be accompanied by an electronic format sewer inspection report in PDF file format. The reports shall be in the format required by the City. The PDF reports shall be included on the USB storage media along with the video file.

Prior to the regular contract required submissions of CCTV inspections/reports, the Contractor shall submit a trial inspection report in PDF format for approval by the Contract Administrator.

CCTV Inspection Submission

When a required CCTV inspection has been completed, it shall be submitted to the Contract Administrator on a properly identified portable hard drive or other media approved by the Contract Administrator. The submission for a sewer shall include the video file and the PDF report file and NASSCO PACP access database.

The portable hard drive may include CCTV inspections for more than one sewer sections and service laterals. When there are multiple files, the data shall be properly organized with each CCTV inspection submission in its own folder. Such folders shall be clearly and properly identified in regard to the sewer service to which it pertains by the street number corresponding to the sewer service inspected.

The reports shall be in a format that will enable direct down loading of the data into a data management system.

TS 460.07.07 Preliminary CCTV Inspection – V1

The Contractor shall make a preliminary CCTV inspection—called the V1—of the sewer section before undertaking any work required for the CIPP lining of the section. The purpose of the V1 is to determine and record the initial condition of the sewer section and to determine if a significant changed condition exists versus the CCTV inspection provided during tendering or in accordance with clause TS 460.07.03. Significant changed condition means a condition that will prevent lining of the section, require an unexpected excavated repair before lining, require a change in the liner design resulting in an increased liner thickness to deal with the changed condition or any other situation, which in the Contract Administrator's opinion, is a significant changed condition.

Where a significant changed condition is encountered, the Contractor shall immediately inform the Contract Administrator.

In making the V1, the Contractor shall employ only such preliminary cleaning that is necessary to obtain a CCTV inspection sufficient to record the initial condition including a count and condition of service connections.

CCTV V1 inspection shall be in according to TS 409 and submitted to the Contract Administrator. The V1 shall be conducted during low sewer flow period between 2 a.m. to 6 a.m. when the flow is below 5 to 7 o'clock position. Otherwise sewer bypass operation is required to lower the flow at no additional cost to the City.

Sewer defect coding is required for V1 if the sewer inspection data was not provided to the Contractor by the City, and if the CCTV inspection data provided by the City is more than 2 years old from the date of V1 inspection

The Contractor shall be responsible for confirming the following design parameters as part of the V1 inspection:

- a) Sewer diameter
- b) Depth to invert (of pipe to be lined)
- c) Preliminary pipe ovality assessment (final confirmation of ovality during V2)
- d) Live load condition (e.g. pipe under train tracks)
- e) Number, size, location and clock position of sewer services and connections.

The Contractor shall provide the Contract Administrator with a record log of all verified field conditions prior to the ordering and installation of any liners. The log shall also include any further deterioration, higher ovality than design calculations, and additional repair required when compared to CCTV data provided by the City. This log will be used to determine the need for special designs and increased liner thickness. Should the Contractor order or install a liner without confirming field conditions and such conditions are found to have required a liner thickness increase, no payment shall be made for the installed liner.

TS 460.07.08 Field Measurement of Sewers and Liner Sizing

The Contractor shall measure the internal diameters of the sewer sections to be lined and the length of the sections to be lined. The measurements taken shall be suitable for proper sizing of the liners to be installed. The Contractor must not rely on dimensions provided by the City. The Contractor shall log all field measurement verification and provide this record log to the Contract Administrator prior to installation of the associated liners.

TS 460.07.09 Service Connection Statement

Where there are service connections, the Contractor shall record details of all service connections on a sewer section on a Service Connection Statement form. The form shall be fully completed identifying all service connections on the sewer section to be lined prior to installation of the liner. The Contractor with assistance from the City shall determine the presence of abandoned service connections within the sewer section to be lined. The form shall be completed as part of the V1 and V2 CCTV inspection work.

The statement shall be updated during service connections reinstatement to show which service connections have been reinstated with date and time of reinstatement and must be verified through V3 CCTV inspection

The statement shall be provided to the Contract Administrator on request.

For a sample of the Service Connection Statement form, see Appendix B.

TS 460.07.10 Service Connection Investigation

Where, in the Contract Administrator's opinion or the Contractor's opinion, service investigation is required the Contractor shall carry out the investigation. The service connection investigation when required, shall be completed as part of the V1 and V2 work and payment shall be through provisional items for service connection investigation, or in absence of such provisional item the cost shall be negotiated with the Contractor,

Whether or not a service investigation is carried out, the Contractor is always required to complete the Service Connection Statement as per base scope.

TS 460.07.11 Service Connection Investigation Procedure

Where a service connection investigation is required, the Contractor, in accordance with the approved procedure, shall investigate the sewer section(s). The investigation will require completion of two reports: *Master Service Connection Report* and *Dye Tester Drain Report*.

The drain locations (properties serviced) shall be identified for all service connections indicated on video inspection records, including the preliminary video inspection V1, except where the service connections are confirmed to be dead—not in use—either by visible plugs or by dye testing. There may be additional connections not shown on the records.

As per base scope, the Contractor shall submit to the Contract Administrator a *Drain Report* including the *Master Service Connection Report* and *Dye Tester Drain Report*. The *Drain Report* shall identify each drain on the sewer section and for each drain provide the following information:

- property serviced by the drain
- location of drain relative to reference maintenance holes
- result of dye testing (provisional item or additional cost) —live or dead drain
- size of drain
- material of drain (e.g. clay, concrete, plastic, other material)
- colour of drainpipe as seen by CCTV camera
- clock position of drain as seen by CCTV camera
- drain entry type (e.g. protruding, flush, recessed, factory tee, other)
- drain end condition (e.g. smooth, ragged, broken, other)
- existence of a visible plug in the drain as seen by CCTV camera
- any other identifying information indicating live or dead drains

The Contractor shall obtain an accurate measurement to the centre line of each service, either by remote means or physical measurement verified with the electronic distance counter utilized in the CCTV recordings.

The reference point for all measurements shall be at the intersection of the sewer obvert and the inside wall of the maintenance hole and mark the reference location with permanent marking where feasible.

The Contractor shall carry out testing to the extent necessary to confirm whether or not each drain connection is live. Use different and distinct colours of dye to determine the source when multiple locations are being dye tested at once. If necessary to confirm the status of a particular drain, testing of the following shall be carried out:

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- 1) All sanitary drains and storm drains in the first four buildings located in either direction from the drain, on both sides of the street. For drains adjacent to intersections, the first four buildings in either direction on adjacent streets.
 - 2) Catch basins, hydro chambers and vaults and adjacent lane drains in the vicinity of the drain connection.
 - 3) Storm and sanitary maintenance holes in the general vicinity must be checked to confirm the discharge location for any drains not entering into the sewer to be lined. All observations and results must be clearly and accurately noted on the Dye Tester Drain Report.

In order to ensure accuracy of the investigation, constant electronic communication shall be maintained between members of the investigation crew.

During the course of the dye testing all information must be recorded in a continuous, ongoing basis as the work progresses. If this is not done, the Contractor shall be required to retest all locations

Once a specific investigation crew commences the service connection investigation at any site location the members of that crew shall remain the same until the service connection investigation is completed at that site location. All members of all service connection investigation crews must carry and clearly display a picture identification card, which clearly identifies them as being employees of the Contractor.

The Contractor shall submit the Drain Report including three copies of the *Master Service Connection Report* and *Dye Tester Drain Report* both typed along with copies of original field notes to the Contract Administrator for review and approval 2 Days prior to the on-site drain review and at least 5 Days prior to the scheduled lining installation. No on-site drain review will occur until the *Drain Report* is submitted.

The on-site drain review will require on site: all members of the dye testing crew, all drain investigation and dye testing reports, all drain investigation video recordings, a CCTV truck and any other information relating to the sewer section.

The on-site drain review will determine the service connections to be abandoned. No service connections shall be left abandoned without written approval from the Contract Administrator.

No lining installation work will be permitted without the final approved Drain Reports being on site.

TS 460.07.12 Sewer Cleaning and Preparation for Lining

Depending on sewer condition, the sewer shall be cleaned with hydraulically powered equipment, high-velocity jet cleaners, or mechanically powered equipment. All debris, encrustations, root balls and other foreign materials shall be removed. Precautions shall be taken to ensure that no flooding of public or private property occurs during any phase of the cleaning and reaming operations. Satisfactory precautions shall be taken to protect the sewer lines from damage that might be inflicted by the use of cleaning equipment.

All sludge, dirt, sand, rocks, grease and other solid or semi-solid material shall be cleaned from the sewer. Resulting debris from the cleaning operations shall be removed at the downstream maintenance hole of the section being cleaned. Flushing of any debris downstream of the cleaning area is not permitted. The Contractor shall install a screen in the downstream maintenance hole in order to catch debris and dispose of solid debris as per Disposal of Materials below.

Where the CCTV data provided by the City or V1 CCTV or sewer cleaning operations indicate the presence of deposits, roots, protrusions or other foreign materials in the sewer that are resistant to sewer cleaning operations, these shall be removed by sewer reaming cutting or grinding.

TS 460.07.12.01 *Disposal of Materials*

In accordance with the requirements of the Environmental Protection Act, R.S.O. 1990, Section 27 and subject to all terms and conditions related to Waste Management, the Contractor shall be responsible for the complete removal and disposal off-site, of all foreign materials flushed, scraped, or cut out of the sewer line. Flushing and abandoning of debris in sewer lines is not permitted.

Before disposing of solids, the Contractor shall decant all liquids into the City designated sanitary sewer main. There shall not be any dumping or decanting into any storm sewers. Decanting of solids into any sewer main is not permitted. The Contractor shall decant liquid only into sanitary or combined sewers greater than 250 mm in diameter clear of debris and with low flow. Filtering devices shall be used during the decanting process to prevent any debris from entering the sewer system. Prior to decanting, the Contractor shall verify the type of flow in the sewer. Should a blockage occur in the sanitary or combined sewer due to decanting, the cost of all sewer backups and cleaning shall be at no extra cost the City.

Prior to commencement of the Contract, the Contractor shall notify the Contract Administrator of the disposal site(s). The Contractor shall provide the Contract Administrator with the following documentation attached to all relevant invoices:

- a) Contract name and No.
- b) Vehicle ID – License Plate Number
- c) Date of disposal
- d) Time of disposal
- e) Net weight of load
- f) Provide log books and scale printouts to the Contract Administrator.

All debris must be decanted prior to disposal. Off-site debris dewatering facilities must meet provincial environmental regulations and requirements. Provide copies of required licenses, permits and relevant documentation required for dewatering facility to the Contract Administrator before starting the Work.

TS 460.07.12.02 *Active Infiltration*

The Contractor shall seal all locations with active infiltration within the sewer section to be lined, prior to the installation of the CIPP liner to the satisfaction of the Contract Administrator. The Contract Administrator will not permit lining if V2 CCTV demonstrates drips and leaks.

TS 460.07.13 **Sewer Reaming, Cutting and Grinding**

The sewer section shall be reamed to remove deposits and protrusions using an approved reaming method. Deposits and protrusions can include calcite build up, roots and protruding service connections. An acceptable CCTV camera must monitor reaming operations.

Reaming Tolerances

All protrusions, deposits, previous liner wrinkles, build-ups and other foreign material in the sewer section shall be removed such that the internal diameter of the sewer pipe is not reduced by more than 7 mm for sewers 450 mm diameter or less, and no more than 10 mm for sewers greater than 450 mm. Any material remaining after reaming must be hard and firmly attached to the sewer wall. All sharp encrustations and debris shall be removed, as they can damage the liner during installation (inversion or by pull-in method).

Protruding Service Connections

Service connections that protrude into the sewer section must be cut or ground back prior to reaming of the sewer with any type of reaming device that may damage the service connection. Protruding service connections shall be cut back sufficiently to preclude damage from reaming operations and the extent of the protrusion left in place must not interfere with the installation or long-term performance of the CIPP liner. Cut back protruding service connections shall be smooth and even with no jagged edges. If the service lateral piping or service connection is damaged or broken by the Contractor, then the Contractor shall repair the damage by using excavation if necessary. The Contractor shall submit for review and acceptance, the proposed method of repair and reinstatement for damaged drain piping or service connections.

Precaution to Prevent Damage to the Sewer Section

The Contractor shall plan and execute the reaming operation to prevent damage to the sewer section and any service connections in the sewer section. Proper precautions shall be taken by the Contractor to ensure that the reaming operation does not cut into the sewer itself, to ensure that the reaming tools do not become jammed in the sewer and that any areas of the sewer that are structurally unsound are not further damaged. Any extraction of reaming tools or other equipment, including extraction by excavation, is the responsibility of the Contractor and shall be carried out in accordance with clause TS 460.07.04 herein.

TS 460.07.14 Filling of Voids**Voids Identified for Filling in the Contract**

The Contractor shall fill voids as per methods specified for filling voids in the Contract Documents. Void filling shall ensure structural integrity of the lined sewer and prevent bridging by the liner. The Contractor shall submit for the review and acceptance of the Contract Administrator a detailed method statement outlining the procedures and materials to be used in filling the voids. The method statement shall correspond with requirements that may be specified for void filling such as in the Contract's Sewer Section Lining Summary Table.

All costs associated with the requirements of filling of voids identified in the contract shall be included in unit price item for the installation of CIPP lining system; no separate payment will be made.

Voids Requiring Filling Not Identified in the Contract

If additional voids are identified during V1 or V2 and void filling is required to ensure the structural integrity of the liner and to prevent bridging by the liner, the Contractor shall advise the Contract Administrator of the number and location of these voids. Where the filling of such voids is deemed necessary by the Contract Administrator, the Contractor shall submit a detailed method statement outlining the procedures and materials to be used in filling the voids. Where the Contract Administrator requires filling of the voids, the cost shall be based on the unit price in the contract or a negotiated unit price if the unit price is not available as part of the base bid. However, this provision shall not apply to any voids created as a result of the Contractor's work unless, and at the discretion of the Contract Administrator, the creation of such voids was an unavoidable repercussion of the work.

TS 460.07.15 Post Cleaning and Preparation CCTV Inspection – V2

After completion of the cleaning and preparation of the sewer section including all reaming, cutting, grinding and void filling, a CCTV inspection—called the V2—of the full length of the sewer section shall be done. The V2 shall be completed according to the CCTV specifications TS 409 and requirements of TS 460 herein.

The V2 complete with all reports shall be provided to the Contract Administrator at least 3 Business Days prior to lining for the Contract Administrator's review and acceptance of the cleaning and preparation. The Contractor shall build this review duration in their schedule.

At their discretion, the Contract Administrator may waive the requirement for the V2 to be submitted for acceptance 3 business days prior to lining, such as when approval for lining was provided by the Contract Administrator at a live viewing of the V2. However, in such cases the V2 submission shall still be submitted to the Contract Administrator prior to liner installation. The Contractor shall inform the Contract Administrator of their intention to perform live V2 inspection 3 business days prior to the inspection to allow for advance planning.

Lining shall not commence until the Contract Administrator has reviewed and accepted the V2 cleaning and preparation work.

In the event that, after the V2, a deficiency in the cleaning and preparation is identified that requires correction, the V2 shall be repeated after the additional cleaning and preparation work has been completed. The second V2 inspection shall be submitted to the Contract Administrator 5 business days prior to liner installation.

Sewer defect coding is required for V2.

TS 460.07.16 Variable Sewer Inside Diameter for Lining

In the event that an inside diameter variance exists along the sewer section to be lined to the extent that the liner may be oversized or undersized for zones of the lining run, the Contractor shall present the liner sizing situation and anticipated lining results (regarding fit and finish) along with a recommendation for liner sizing for the MH-MH section to the Contract Administrator. The Contract Administrator shall discuss the situation with the Contractor and in conjunction with the Contractor determine and accept the sizing of the liner for the installation.

TS 460.07.17 CIPP Lining – Resin Impregnation

In accordance with the requirements of TS 460.04.01 herein, within the design submittals, the Contractor will designate a location where the tube will be impregnated. The CIPP liner tube shall be wet-out with resin in accordance with ASTM F1216, F1743 or F2019 as applicable to the type of liner. A vacuum impregnation process and a roller shall be used to remove air from the tube and to uniformly distribute the resin throughout the tube. The resin quantity placed into the liner tube shall be in accordance with the applicable ASTM standard. A minimum of 5% and up to 10% excess resin shall be used to allow for polymerization shrinkage and the loss of resin.

If the tube is impregnated at the factory or Contractor's other facility, the tube shall be stored until the liner installation at the temperature as per manufacturer's recommendation and a temperature log during storage and transportation must be provided to the contract administration prior to the installation. It is the responsibility of the Contractor to ensure the tube is stored and transported in a climate controlled environment as per the resin manufacturer's recommendation. The Contract Administrator may reject the tube and cancel the installation if the storage and transportation conditions are compromised.

The Contract Administrator shall have the right to inspect the Contractor's wet-out facility at any time during the wet-out of a liner tube for this contract. As part of such inspection and if requested by the Contract Administrator, the Contractor shall weigh a sample of dry felt and a corresponding sample of wet-out felt from any tube being wet-out for this contract. Where the results of this sampling do not verify that sufficient resin was placed in the liner tube, the liner will not be acceptable to the Contract Administrator and shall not be used for the work.

The Contractor shall not install any impregnated liner that has expired, been stored in a warehouse for more than 1 month, or has been compromised in anyway. If the liner is impregnated in advance of lining, the Contractor shall provide a temperature log documenting storage of the liner at the facility prior to installing the liner to demonstrate that the liner has not been compromised and is acceptable.

Additional Requirements for UV Cured Liners

The resin impregnated liner shall be stored and shipped in a UV light proof container. The resin impregnation shall be according to ASTM F2019.

TS 460.07.18 Installation of CIPP Liner

The installation methodology shall conform to the requirements of ASTM F1216, ASTM F1743 or ASTM F2019 as applicable to the type of liner. The tube should be pulled-in or inverted through an existing maintenance hole or an access pit and fully extended to the next designated termination point as per shop drawing submittal. If pulled into place, a power winch or equivalent should be utilized, and care should be exercised not to damage the tube as a result of pull-in friction. Where Bid submissions included a method statement with additional procedures, such additional procedures shall be followed. The specific details and execution of the installation are the responsibility of the Contractor.

Flow and odour control shall be in operation during the complete liner installation process including liner insertion, curing and opening of the liner ends.

The Contractor shall provide a minimum of 3 Working Days advanced notice to the Contract Administrator of any CIPP liner installation including time to review the V2 and to confirm the final design parameters after reviewing the V2.

All affected property occupants shall receive written notice in advance of any work that will cause service disruption as per the requirements of notifications section herein this specification.

The Contractor shall ensure that all required equipment and backup equipment are on site and in satisfactory working order prior to commencing the installation of a CIPP liner section.

The Contractor shall ensure that all maintenance hole's used for insertion of liners are adequate in size as not to impact the required finished liner quality. Where the Contractor identifies a maintenance hole opening size to be inadequate, the maintenance hole shall be modified appropriately. The Contract Administrator, at their discretion, may also require the Contractor to make adjustments to the maintenance hole opening prior to the insertion of the liner for future maintenance ease purposes. Any additional costs associated with modifying the maintenance hole opening and repairing the maintenance hole after installation of the liner shall be through provisional allowance items and in absence of such items, shall be negotiated with the Contract Administrator in advance of work.

Temperature gauges shall be placed between the tube and the host pipe's invert position at both ends to monitor the temperature during the cure cycle. A cool down process shall be conducted that complies with the resin manufacturer's specifications. The Contractor must submit the following upon completion of liner installation:

- the temperature curves for the steam leaving the boiler, and 2 locations in the sewer at both ends for the entire curing cycling including heating – maintaining temperature and cooling for each section and demonstrate that the recommended cycle was met. The anticipated curve should be provided to the Contract Administrator at the time of design review as part of the shop drawing submittals required

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- the pressure curve for the inversion medium (hot water or steam) to demonstrate the desired pressure was maintained during the entire cycle. If there is a drop in the pressure, the Contractor must demonstrate, that there are no lifts, bulges, excessive wrinkles or delaminations within the liner and the pressure logs should be evaluated for its ability to meet applicable specification and liner performance requirements.

A sufficient liner cool down period, under continuous cure head or pressure, shall be allowed to minimize shrinkage and thermal stresses in the liner. The new pipe should be cooled down to minimum 35 °C or as recommended by the resin supplier before relieving the static head in the inversion process. Under no circumstances the curing water shall not discharged to a storm water or directly to a water course as it is considered contaminated and not suitable for the water course.

TS 460.07.18.01 *CIPP Lining – Using UV Curing Method*

All steps, processes and duration of the cure shall be in complete accordance with the UV-CIPP manufacturer's recommended process and procedures.

UV curing of CIPP liners shall include a monitoring system capable of recording the duration of the liners' exposure to UV light to ensure adequate curing of the resin. The system shall be capable of recording the light train intensity throughout the entire duration of the installation. All UV cure technology shall be operated in accordance with the manufacturer's requirements and recommendations.

Prior to installing the liner in the host pipe, the UV cure monitoring system's proper functioning shall be confirmed by hooking it up to the computer and ensuring that the sensors are reporting the UV light output. No more than two sensors in sequence can be found faulty during this test. If three or more sensors in sequence are discovered faulty, a new sensor array shall be pulled into the host pipe replacing the previously installed array; and the new array shall be again tested for its proper functioning.

The sensor array's computer database shall have an output report that identifies each sensor by its station over the length of the UV-CIPP installation. The maximum temperature achieved during the steam cure process and the time sustained at or above the required curing temperature shall be recorded and submitted for each sensor.

TS 460.07.18.02 *Odour Control*

When the sewer has service connections, the Contractor shall provide notice to the affected residents indicating possible odour resulting from sewer lining and curing process. A *Template for Service Connection and Odour* notice should be revised by the Contractor according to the anticipated impact. The notice can be found in Appendix C. The notice shall indicate to the residents the reason for odour, what to expect, procedures to alleviate odour including ensuring all plumbing drain traps are full of water. The Contractor's on-site supervisor must have with them at all times a "calibrated styrene monitor" to be used when residents complain about styrene or a chemical smell is detected.

The Contractor shall provide 24 hours a day 7 days a week contact on the notice and is responsible to respond, investigate and act immediately on any odour complaint that may occur including after work hours and week end. Actions to be taken by the Contractor to alleviate an odour problem within a property shall include:

- Seeking permission to enter the property;
- Diagnosing the cause of odour and remedial actions;
- Requesting the resident to ventilate the property via open window and doors;
- Providing fans and blowers to maintain negative pressure in the sewer and also ventilating the property with fans/blowers; and
- Other actions that are useful in alleviating the odour problem.

The Contractor shall provide adequate sewer ventilation and odour mitigation during the sewer lining process. The following steps shall be taken:

Exhaust Fans for Sewer: During lining sewer maintenance holes are open and it may cause odour. Moreover, styrene also has odour. The Contractor shall install two exhaust fans with a minimum capacity of 990 l/s each to exhaust air from the sewer upstream and downstream of the sewer section being lined. The air leaving the fan shall be treated with activated carbon mixture and must not be vented without this treatment. In the event that odour control becomes a problem, the Contractor shall provide additional exhaust ventilation of the sewer to alleviate odour. Cost of exhaust fans and odour control shall be included with lining cost for that section and no separate payment will be considered to provide odour control.

Reinstatement of Sewer Service Connections

Reinstatement of the service connections shall be carried out according to the approved method statement submitted as part of the submittals requirement herein.

All live service connections shall be reopened to their full diameter, and the interface with the liner made leak tight by remote means.

Service connections must be reinstated to the entire opening of the service connection or service connection pipe, whichever is the greater. No sleeve or liner protrusions, sealer, grout or other foreign material is permitted into such area.

Following any installation that covers a live service connection the Contractor must open each service connection to a minimum of 75 per cent within 8 hours after curing and cooling. All service connections must be entirely opened by no later than the next day.

The Contractor shall continue to update the Service Connection Statement and record the time at which the reinstatement of each service connection is completed and submit the record to the CCTV operators and Contract Administrator for verification during V3. Where lateral lining is required the lateral lining shall be complete up to at least the property line or as specified in the contract.

CIPP Lining Termination Requirements at Maintenance Holes

Review in conjunction with TS 467.

Where a liner has been placed continuously through a maintenance hole, the upper portion of the liner shall be cut out over the full length within the maintenance hole from the existing sewer pipe entrance to exit so that the top edges of the remaining liner are level with the existing maintenance hole benching. Where the existing benching does not fit tightly to the portion of the liner left in place, any gaps or misfits shall be filled with a suitable concrete patching compound. The liner ends at the maintenance hole walls, above the location where the liner is cut out, shall be trimmed as close as practical to the maintenance hole walls considering any thermal contraction to occur, along with common industry practice, to allow a slight outward flare on the liner ends. The space behind the liner flare and the sewer pipe or the maintenance hole wall shall be sealed with epoxy and/or resin material. The liner may expand and contract at a different rate than the sewer pipe and hence the seal should be made considering differential expansion/contraction.

Where lining work necessitated or resulted in damage to the maintenance hole or the maintenance hole benching, it shall be restored to equal or better than original condition and shall meet the requirements for benching as previously specified.

Where a liner is not placed continuously through a maintenance hole, the liner ends shall be trimmed as close as practical to the maintenance hole walls considering any thermal contraction to occur, along with common industry practice, to allow a slight outward flare on the liner ends. The maintenance hole through shall be adjusted so that a smooth and uniform flow path at liner interface within the maintenance hole is maintained.

Material for adjusting the maintenance hole through shall be Speedcrete 20 MPa. Substitutions or requests for approval of alternative products to be submitted as part of the CIPP shop drawings submittal requirement as outlined in submittals section herein, not later 14 Days prior to use.

TS 460.07.19 Inspection of Completed Rehabilitation – V3

After completion of all work in the lining of the sewer section including reinstatement of service connections and maintenance hole benching, a CCTV inspection—called the V3—of the full length of the sewer section lined shall be carried out and submitted to the Contract Administrator. The V3 shall be completed in accordance with the requirements of TS 409. The Contract Administrator will review the V3 as part of its approval for payment process for the lined sewer.

In the event that, after the V3, a deficiency in the lined sewer section is identified that requires repair or remediation, the V3 shall be repeated after the repairs or remedial action have taken place. Where laterals connect to the main line sewer section that has been lined and the Contractor proposed removing the temporary bypass prior to reinstatement of the laterals, two V3 inspections shall be carried out and submitted to the Contract Administrator for review. One to inspect the empty sewer pipe with bypass immediately after curing and the second immediately after switching off the bypass prior to removing the bypass equipment to confirm the laterals can be inspected once bypass has been removed. The Contractor shall not commence removal of the temporary bypass until the Contract Administrator has reviewed and accepted the two V3 inspections.

As-Built CIPP Liner Physical Properties Requirements

The complete installed liner shall have the following required physical properties:

- Flexural Modulus: Shall meet or exceed the short-term value used in the liner design or the minimum value in the ASTM F1216-07a, whichever is greater.
- Flexural Strength: Shall meet or exceed the short-term value used in the liner design or the minimum value in the ASTM F1216-07a, whichever is greater.

In the case of long-term values of flexural modulus and flexural strength used in design, the liner shall possess the required long-term retention characteristics such that the long-term values used in design will be met by the liner over its design life.

TS 460.08.01 Sampling and Testing**Resin Samples – Field**

The sample should be stored in a clean bag and the bag should be marked with the following:

- 1) Contract Number:
- 2) Date:
- 3) MH# to MH# reference of CIPP liner where resin was used:
- 4) Location in the tube, where the sample was collected from:
- 5) Resin temperature and ambient temperature at the time of taking sample

The Contract Administrator may ask the Contractor to provide a cured sample for each maintenance hole to maintenance hole section which will be tested by Spectral Analysis(FTIR) and compare the resulting spectrograph to the "fingerprint" reference spectrograph of the resin used for the original creep testing to confirm that the correct, long term creep qualified resin is actually being installed. The IR analysis must match with the one provided in the tender submission for the resin identified for use by the Contractor for the CIPP lining work.

All field resin samples shall produce FTIRIR spectrographs that correspond to the reference FTIRIR spectrograph.

Cured Liner Samples – Field

The Contractor will be required to provide a field cured restrained cylindrical liner sample for each liner inversion for sewer sizes up to and including 450 mm as per ASTM F1216-07a.

For sewer sizes up to and including 450 mm the field sample shall be a restrained sample made by extending the liner installation through a cylindrical PVC pipe that closely matches the inside diameter of the installation or other form. The form shall not expand or otherwise distort during sample forming or processing. The Contractor shall make sure that the environmental conditions under which the field sample is made result in a cured sample that has properties representative of the cured liner within the sewer being lined.

As per ASTM F1216-07a, in medium and large-diameter applications and areas with limited access, the sample should be fabricated from material taken from the tube and the resin/catalyst system used and cured in a clamped mold placed in the downtube when circulating heated water is used and in the silencer when steam is used. Sandbags around the form can be used to restrain the form and to simulate the heat sink present around the actual installation.

Plate samples are not acceptable for field samples. For further information on sampling methodology, refer to ASTM F1216-07

The length and size of any sample shall be sufficient to obtain at least five (5) test specimens for ASTM D790 testing. The testing laboratory shall cut the samples and not the Contractor. The sample from which the test specimens are cut shall be sufficiently large so that sample edge effects can be eliminated from the test specimens. Sample size shall allow test specimen length of 16 times liner thickness for non-reinforced CIPP and 32 times liner thickness for reinforced CIPP, plus at least 100 mm additional sample length to eliminate edge effects. For example, a sample for a 300 mm by 6 mm thick non-reinforced liner shall be at least $16 \times 6 \text{ mm} = 96 \text{ mm} + 100 \text{ mm} = 196 \text{ mm}$ long.

The Contractor shall remove the restrained field sample (in its form) from the cured liner and, after identifying the field sample, provide the field sample in its form to the Contract Administrator. The Contractor shall identify on the field sample by permanent marker the contract number, lining section number, maintenance hole number, sewer size and date of removal.

The City reserves the right to change these requirements if deemed necessary or to request that samples be taken from any particular location at any time. The samples shall be used for inspection and testing purposes.

Testing of Field Samples of Cured Liner

The Contractor shall pay for the cost for testing of field samples of cured liner at an independent testing agency. Only the testing laboratory shall cut the required test/specimen samples and not the Contractor. It is responsibility of the testing laboratory to prepare test specimens from appropriate direction (longitudinal or hoop). The testing agency shall be subject to the approval of the Contract Administrator. At random, the City/Contract administrator may also complete testing at another testing facility. The Contractor shall authorize the testing agency to forward the test reports directly to the Contract Administrator via email and communicate with the Contract Administrator concerning the testing and results. The Contract Administrator will arrange for delivery of the field samples in custody to the testing agency. The field sample shall be tested for flexural modulus and flexural strength according to ASTM D790 and thickness according to ASTM D5813-04 (2008). The provision of testing service shall allow for the obtaining of test reports within 10 Working Days of delivery of the sample to the testing agency.

The Contractor shall provide the test agency with the design parameters for the liner corresponding with the field sample as follows:

- flexural strength short-term
- flexural modulus short-term
- required liner thickness
- design calculation

These values shall have been identified in the Contractor's liner design. The testing agency's report shall reference these values as the specified values.

ISO Methods Testing

For UV-CIPP use ISO 11296 test method for flexural properties of reinforced UV-CIPP. When the ISO 11296 test method is used, the structural thickness shall be determined by ISO 7685

ASTM Methods Testing

The ASTM testing methods shall be used for any samples from which it is not possible to obtain the test coupon configuration required for the ISO testing methods.

The ASTM D790 tests straight and flat coupons cut from the liner sample along its length. This type of coupon can be cut from a cylindrical formed restrained sample or other available pieces of liner large enough for obtaining test coupons. When using the ASTM D790 method, a cylindrical restrained sample is the preferred sample as it better represents the liner inside the sewer than either random pieces of liner or formed flat plate samples.

The ASTM D790 test method tends to produce lower results than the ISO 11296 method because the ISO method using the curved sample captures the effect of the liner reinforcing better than the ASTM method.

When the ASTM D790 test method is used, the structural thickness shall be determined by ASTM 5813

TS 460.08.02 Installed Liner Thickness and Reconciliation

Installed Liner Thickness

The wall thickness of the installed CIPP liner shall meet or exceed the required design thickness. Liner wall thickness measurements and determination of the actual effective thickness shall be in accordance with ASTM D5813-04 (2008) or ISO 7685. Measurements of the actual installed liner wall thickness shall not include the thickness of any non-structural components such as a pre-liner.

According to ASTM D5813-04(2008) liner thickness measurement is derived by taking a minimum of eight equally spaced thickness measurements around the circumference of the liner including maximum and minimum thicknesses with the effective liner thickness being the average of the measurements. Regardless of the average thickness result, the ASTM D5813 also requires that the minimum thickness at any point shall not be less than 87.5 per cent of the specified thickness. Measurements of liner wall thickness shall not include the thickness of any non-structural components.

The wall thickness tolerance is:

- minus 0%
- plus 25%

When actual liner thickness or liner properties appear to be deficient, design reconciliation based on test result values shall be permitted. Such reconciliation may or may not resolve the deficiency. Refer to reconciliation of liner sample test results of thickness versus test results flexural modulus and test flexural strength.

Liner Sample Test Results – Reconciliation and Deficiency

As previously mentioned, copies of all test reports will be provided to the Contractor through the Contract Administrator. The test agency must not reveal or send the test results first to the Contractor.

The sample test results shall conform to the values for thickness, flexural strength and flexural modulus provided in the Form of CIPP Materials, Properties and Thickness submitted with Contractor's approved CIPP detailed design and approved shop drawings. In the event that samples do not conform to the required values, the procedure for reconciling sample test results shall be used by the Contract Administrator in order to determine whether the corresponding installed liner is acceptable.

Procedure for Reconciling Sample Test Results

When any of the sample test results (flexural modulus, flexural strength or thickness) are not in accordance with the applicable design submission values, then the liner shall be deemed apparently deficient until the sample test results are reconciled, where this is possible, as described in this specification. If after reconciliation, the liner is still found to be deficient, the Contractor shall provide a plan for remedial action that is acceptable to the Contract Administrator.

Design reconciliation shall not be permitted when test results do not meet the minimum requirements for flexural modulus and flexural strength as stated in ASTM F1216-07a. If test results do not meet these minimum requirements the liner is automatically considered deficient without opportunity for reconciliation.

Reconciliation Example No. 1

For a 450 mm installation the required liner thickness is 7.6 mm designed at flexural modulus of 2413 MPa and flexural strength of 31 MPa. Tested results show thickness is 7.2 mm, flexural modulus is 2995 MPa and flexural strength is 38.9 MPa. There is an apparent deficiency in liner thickness. Reconciliation of apparent deficiency is shown below.

Design Parameter	As designed	Reconciliation
Design Condition	Fully Deteriorated	Fully Deteriorated
Sewer Size	450 mm	450 mm
Invert Depth	3.5 m	3.5 m
Water table below ground surface	2.0 m	2.0 m
Ovality	3 %	3 %
Soil Density	18.85 KN/m ³	18.85 KN/m ³
Soil Modulus	6.89 MPa	6.89 MPa
Live Load	HS-20	HS-20
Other Load	0	0
Flexural Modulus Short-term	2413 MPa	2995 MPa (Test result)
Long-term Retention for Flexural Modulus	50 %	50 %
Flexural Modulus Long-term for design	1206.5 MPa	1497 MPa
Flexural Strength Short-term	31 MPa	38.9 MPa (Test result)
Long-term Retention for Flexural Strength	50 %	50 %
Flexural Strength Long-term for design	15.5 MPa	19.45 MPa
Enhancement Factor	7	7
Poisson's Ratio	0.3	0.3
Safety Factor	2	2
Required Liner Thickness	7.6 mm	7.1 mm
Tested Thickness	7.2 mm	7.2 mm
Conclusion on Liner Thickness Deficiency	Thickness is deficient based on design properties	Thickness is not deficient based on test result properties

In this example, the reconciliation shows that the as tested thickness of 7.2 mm is sufficient when the tested properties are taken into account. Therefore, the liner would not be deficient based on test thickness.

Reconciliation Example No. 2

For a 600 mm installation, the required liner thickness is 9.6 mm designed at flexural modulus of 2758 MPa and flexural strength of 31 MPa. Tested results show thickness is 8.8 mm, flexural modulus is 2465 MPa and flexural strength is 35.6 MPa. There is an apparent deficiency in liner thickness. Reconciliation of apparent deficiency is shown below.

Design Parameter	As designed	Reconciliation
Design Condition	Fully Deteriorated	Fully Deteriorated
Sewer Size	600 mm	600 mm
Invert Depth	3.6 m	3.6 m
Water table below ground surface	2.0 m	2.0 m
Ovality	3 %	3 %
Soil Density	18.85 KN/m ³	18.85 KN/m ³
Soil Modulus	6.89 MPa	6.89 MPa
Live Load	HS-20	HS-20
Other Load	0	0
Flexural Modulus Short-term	2758 MPa	2465 MPa (Test result)
Long-term Retention for Flexural Modulus	50 %	50 %
Flexural Modulus Long-term for design	1379 MPa	1232 MPa
Flexural Strength Short-term	31 MPa	36.6 MPa (Test result)
Long-term Retention for Flexural Strength	50 %	50 %
Flexural Strength Long-term for design	15.5 MPa	18.3 MPa
Enhancement Factor	7	7
Poisson's Ratio	0.3	0.3
Safety Factor	2	2
Required Liner Thickness	9.6 mm	10.0 mm
Tested Thickness	8.8 mm	8.8 mm
Conclusion on Liner Thickness Deficiency	Thickness is deficient based on design properties	Thickness remains deficient based on test result properties

In this example the reconciliation shows that the as tested thickness of 8.8 mm is not sufficient when the tested properties are taken into account. Therefore, the liner is deficient based on test thickness. In fact even at the designed 9.6 mm the liner would be deficient because the design properties were not achieved.

Liner Thickness Less than Required

Where the sample thickness does not meet the applicable design submission value and the sample flexural modulus and/or flexural strength exceed the applicable design submission values, the sample test results for flexural modulus and flexural strength shall be used to calculate the required liner thickness using the design method and all other parameters of the design submission. The Contract Administrator shall be responsible for this calculation. If the sample thickness meets with the requirements of this calculation, the liner will not be considered deficient. This reconciliation requires that sample be, in the opinion of the Contract Administrator, representative of the liner in the sewer.

Samples Cut from Liner Inside the Sewer

For UV cured liners and where the contract administration asks for test sample to be taken from inside the sewer, a sufficiently large sample shall be cut out from the liner within the pipe. The configuration of the cut out sample shall allow for ISO 11296 test method (curved test coupons from around the circumference of the liner). The removed section of liner shall be repaired with a fibre reinforced cementitious rehabilitation product such as Centri Pipe PL 8000 or approved equivalent.

Fit, Finish and Properties Requirements

The completed installed liner shall conform to the properties in Table 2.

Table 2: Fit, finish and property requirements

Item	Requirement for Liner
Continuity of Liner	The finished liner shall be continuous over the entire length of the liner installation from MH to MH without any breaks, separations or joints.
Liner Fit to Existing Sewer Liner	<p>The outside surface of the finished liner shall be in contact with the inside surface of the existing sewer subject to the contact tolerance. The inside surface of the existing sewer is the surface after the sewer has been cleaned and prepared for lining in accordance with the cleaning and preparation requirements. The contact tolerance is 1.0 mm. Where any space or gap between the outside surface of the liner and the inside surface of the existing sewer line exceeds 1.0 mm, the liner fit will be deficient, subject to exceptions noted below.</p> <p>The liner should also be able to negotiate vertical/horizontal elbows and bends with various degrees (angles ranging from 0 to 45 degrees).</p> <p>The liner shall extend into each MH a minimum of 12 mm and a maximum of 25 mm, such that epoxy or MH liner material application can be applied to the back (outer surface) of the liner, creating a seal around the CIPP liner, pipe and MH interface.</p>
Exception to Liner Fit at Existing Sewer Line Irregularities	<p>Existing sewer line irregularities include off set joints, protrusions, bumps or other similar situations in the existing sewer that remain after the sewer has been prepared in accordance with the cleaning and preparation requirements. Neither ovalization of the existing sewer nor curves made by joint deflection are irregularities in this context. Where an irregularity exists, exception to the liner contact tolerance requirements will be allowed in the irregularity zone. The irregularity zone is defined as a zone extending a distance of up to 25% of the liner inside diameter in any direction from the irregularity as measured along the inside surface of the liner.</p> <p>A liner fit exception at an existing sewer irregularity shall not present an obstruction to sewage flow whether or not it complies with the allowed exceptions.</p>
Liner Shape	The liner shape shall be as defined by liner fit to existing sewer line. In general the liner shape shall conform to the shape of the existing sewer line inside surface after its cleaning and preparation in accordance with requirements. However, where the existing sewer line shape is not defined (missing pieces of sewer line) the liner may either bridge the missing wall section or indent into the missing wall section. Where the liner bridges, the shape of the liner shall match the shape of adjacent sewer line and the inside diameter of the liner shall be as required for Contact Tolerance for the adjacent sewer line. Where the liner indents, the depth of the indent shall not reduce the liner wall thickness below the Wall Thickness Tolerance.
Liner Wall	The liner wall shall be free of any interior bulges, ribs, ripples, folds or other irregularities except where these irregularities comply with the liner wall thickness tolerance, fit, shape and wall thickness given above. The wall of the liner shall be free of any voids, cavities or bubbles.

Table 2: Fit, finish and property requirements (continued)

Item	Requirement for Liner
Liner Terminations	The ends of the finished liner shall be neat and smooth. Terminations at MHs shall be flush or extend slightly beyond the MH wall/sewer interface only a sufficient extension to allow for any longitudinal shrinkage.
Bulges, including Lifts and Sags	There shall be no bulges in the liner that are not consistent with the surface profile of the existing sewer before lining. Such bulges will be considered an indication of a major structural deficiency in the liner and will require major remedial action. Where bulges are suspected or proven to contain internal separations within the wall of the liner, remedial action up to and including removal and replacement of the liner will be required. This applies to bulges that may be called lifts or sags.

Deficiencies

When the liner is deficient, the Contractor shall rectify the deficiency(s) with a remedial method that is acceptable to the Contract Administrator. Where there is no remedial method acceptable to the Contract Administrator, the liner shall be removed and replaced at no cost to the Contract Administrator.

Excessive Fining or Wrinkling

Wrinkles generally can form due to larger liner than the host pipe and due to insufficient pressure or pressure fluctuations during curing. Maximum size of wrinkle or fin permitted is:

- 2% of sewer pipe inside diameter for wrinkle and/or fin location from 8 o'clock to 4 o'clock position.
- 1.5% of sewer pipe inside diameter for wrinkle and/or fin location from 4 o'clock to 8 o'clock position.

Excessive wrinkle and fin liner material shall be removed to the acceptance of the Contract Administrator at no cost to the contract. Wrinkles generally form due to larger liner than the host pipe and due to insufficient pressure or pressure fluctuations during curing.

Remedial Action: Radial wrinkles and all wrinkles or fins at the invert which can obstruct flow shall be removed. For thin liners use a wire brush technique and on thicker liners use a cutting blade or grinding technique. While removing wrinkles, if fins have cured in a tight configuration causing the resin to be contiguous in the fin cross-section then removal of the fin shall require no additional repair. If they have not cured in a tight configuration and the resin is not contiguous across the wrinkle, a short liner repair shall be installed where the wrinkles or fins have been removed. If the repair is extensive the Contractor may choose to install a thin liner into the entire section instead of multiple short liner repairs. It is up to the Contract Administrator to determine if the wrinkles are acceptable or not.

Bulges, Lifts and Sags

There shall be no bulges in the liner that are not consistent with the surface profile of the existing sewer before lining. Such bulges will be considered an indication of a major structural deficiency in the liner and will require major remedial action. Where bulges are suspected or proven to contain internal separations within the wall of the liner, remedial action up to and including removal and replacement of the liner will be required. This applies to bulges that could be called lifts or sags.

Remedial Action

Where deficiencies are identified, the Contractor shall perform the accepted remedial action without unreasonable delay and at no extra cost to City.

Where a deficiency will seriously impact sewer or service connection flow capacity and are considered likely to cause sewer back-ups onto properties or other overflows, the Contractor shall take immediate action to prevent such problems without waiting for acceptance of remedial method from the Contract Administrator. In such case, the final resolution of a deficiency, if required, shall be by a method acceptable to the Contract Administrator.

TS 460.09 MEASUREMENT FOR PAYMENT

TS 460.09.01 Measurement for Liner Sizing

Measurement of the length of the liner shall be verified by measurement of the section(s) of sewer to be lined, from the nearest edge of upstream maintenance hole to the nearest edge of downstream maintenance hole. Additional liner length may be required due to Contractor's means and methods and is generally cut and removed but payment will be based on installed length only and the Contractor shall provide bid prices accordingly.

If the installed length as per measurement above is more or less than the contract stipulated length by more or less than 1%, additional payment or credit amount shall be pro-rated.

If the pipe diameter is more or less than the contract stipulated diameter by more or less than 2%, additional payment or credit amount shall be pro-rated.

For payment, the measurement shall be verified by the Contract Administrator. Measurement can be confirmed based on the V3, actual measurement inside the sewer, measurement outside the sewer with high accuracy instrument as agreed and accepted by the Contract Administrator.

TS 460.10 BASIS OF PAYMENT

Payment at the Contract Price shall be full compensation for all labour, Equipment and Material required to do the Work and shall be as per below:

- 5% of payment for MH-MH section upon acceptance of detailed design, shop drawings and other submittals as specified in this specification by the Contract Administrator.
- 5% after receiving acceptable V1 with the report and the initial service statement report.

-
- 5% after field verification of dimensions, cleaning, and after receiving acceptable V2 CCTV inspection data and report including service connection report.
 - 5% after installing odour control system.
 - 50% after installing and curing of liner inclusive of actual pressure curve, actual temperature curves showing compliance with anticipated curves.
 - 5% after reinstating, receiving service statement report and acceptable V3 with a report.
 - 10% after testing and reconciliation
 - 15% after addressing deficiencies and final acceptance of the liner.
 - Deductions will be made for deficiencies as specified in this specification.

If required and complete documents are not submitted, Contract Administrator will not be able to recommend payment.

Substantiation for Increase in Nominal Size for Payment

Where an increase in nominal size for payment is warranted, the Contractor shall provide substantiation of the final size for lining that verifies the final size for lining based on measurements of the sewer or other substantiation method that is acceptable to the Contract Administrator. This shall be clearly documented in the pipe measurement records required to be kept by the Contractor.

Appendixes

Appendix A: Designer Notes

Appendix B: Service Connection Statement

Appendix C: Notice template for service connection and odour

Appendix 460-A, September 2019 For Use While Designing and Administrating City Contracts

Note: This is a non-mandatory commentary appendix intended to provide information to a designer and contract administrator during the design and construction stage of a contract on the use of this TS specification in a City contract. This appendix does not form part of the standard specification. Actions and considerations discussed in this appendix are for information purposes only and do not supersede an owner's design decisions and methodology.

Notes to Designer:

The designer should specify the following in the Contract Documents:

- Specific resin/liner combination where capacity is a concern to minimize cross section reduction
 - Resin: filled or vinyl hybrid resin
 - Liner: reinforced felt or fiberglass
- Use of styrene free (non-VOC) CIPP Resin in the following circumstances:
 - Environmentally sensitive areas such as near watercourses
 - Within proximity of hospitals, care and medical facilities, schools, homes for seniors
- Removal of all maintenance hole obstructions to accommodate equipment in and around the access maintenance hole to facilitate CIPP and maintenance hole rehabilitation activities

Provisional Items:

Include in the bid price form provisional unit rate items for:

- 2 mm additional thickness of various diameter liners, as required for the work, if required based on altered field conditions as identified in this specification.
- Dye testing and other relevant testing to investigate lateral services.
- Additional void repairs.

Flow Control Provision for Smaller Diameter Sewers (450mm and less)

Standard flow control shall be included as part of the lining items up to and including a capacity of 4,540 Litres/minute (1200 usgpm). Standard flow control and pumping/by-passing should include all necessary piping/fitting, fuel, traffic protection, road crossing devices and monitoring. For sewers that require additional flow control when flows exceed 4,540 Litres/minute (1200 usgpm), the bypass must be carried out (supply, install and maintain bypass system) in accordance with TS 4.01 and TS 4.02 as stipulated in the contract.

Construction Specification for Temporary Sewer Bypass Flow Pumping.

For trunk sewers and large diameter sewers not classified as trunk by the City, temporary bypass shall be in accordance with TS 4.02.

Where the Contractor has determined that the bypass requires capacities exceeding 4540 Litres/minute (1200 usgpm), the Contractor shall advise the Contract Administrator of the requirement and any additional cost for the higher bypass capacity. When it is necessary for lining and directed by the Contract Administrator, the Contractor must submit a detailed bypass plan stamped by a professional engineer registered in the province of Ontario at least two weeks prior to the scheduled work. The proposed by-pass must clearly demonstrate the ability to handle the identified flows for the period of time required to fully install the liner and re-commission the sewer to normal operations.

- 1) *The designer should insert the following text into the tender template in Section 4, Scope of Work*

Information to be Reviewed Prior to Bid Submission

If the sewer sections to be rehabilitated are identified in the Tender Call documents, Bidders shall review the CCTV inspection records, geotechnical and hydrogeological reports and other reports, drawings and data provided with the tender prior to preparing and submission of their Bid. The CCTV inspection record provided with the Tender Call can be a few years old and the Contractor shall acknowledge that the sewer condition may be further deteriorated including more encrustation, more debris, and more corrosion and, prepare the bid with such consideration.

If, for bidding purposes, the Contractor is of the opinion further inspection is required in order to properly assess the work to be undertaken, the Contractor will be responsible to perform such additional inspection at their own cost. Permission to enter the City's sewer system for inspection purposes during the bidding period shall be obtained through City's Purchasing and Materials Management division.

- 2) *The designer should insert the following text into the tender template in Section 2, Clause 8.1 Mandatory Bid Submission Requirements*

Information to be Submitted with Bid

The following information shall be submitted with the Bid to ensure the Contractor's preliminary design and the Bid is prepared based on requirements listed in the Tender Call.. This submission is not the design. A separate shop drawing submittal is required after the Contract award, after confirming field conditions and measurements.

Failure to submit this information to the satisfaction of the Contract Administrator may result in disqualification of the Bid.

Preliminary Design and Information to be Submitted with Bid:

- 1) The name of the professional engineer licensed in the province of Ontario who will prepare and stamp the CIPP liner engineering designs required according to the liner design requirements in TS 460. The professional engineer shall be authorized to perform such work by Professional Engineers Ontario (PEO).
- 2) Preliminary CIPP design calculations for all sewer sections identified in the Tender Call. The liner design shall be according to TS 460.
- 3) A CIPP liner example/sample preliminary design with calculations is required if no sewer sections are identified at the time of Tender: The preliminary liner design example shall be submitted according to TS 460. The example/sample shall be illustrative of future designs that shall be submitted during the Contract. As sewer sections are identified during the contract, the designs submitted shall bear the seal and signature of a Professional Engineer licensed in the province of Ontario.
- 4) Include information of the proposed resin manufacturer, resin type and manufacturer's resin identification number, resin specific design parameters suggested by the resin manufacturer. Include the proposed liner tube manufacturer and the type of tube for each section.
- 5) A certified original copy complete with supporting literature from the resin manufacturer of the Infrared Spectrograph of the catalyzed resin mixture proposed for this Contract.
- 6) Include one example of the liner wet-out process sheet and one example of the liner curing process summary sheet to be used, for each type of liner the Contractor anticipates using for the work.
- 7) The CIPP Installer/sub-Contractor must demonstrate at least 5 (five) years active experience in the municipal wastewater CIPP installation. In addition, the Installer must have successfully installed at least total 50,000 metre of a cured-in-place product in wastewater and storm collection systems. The 50,000 metre length shall not include lateral service connections. Acceptable documentation of these minimum installations must be submitted to the Owner.
- 8) Identify the location (address) where the CIPP tube will be impregnated.
- 9) Submit the Ministry of the Environment, Conservation and Parks (MECP) license to haul and dispose of materials from sewer lines.

Appendix 460-B

Service Connection Statement

Appendix 460-C

Notice for Service Connection and Odour

Go to www.toronto.ca/services-payments/building-construction/infrastructure-city-construction/construction-standards-permits/standards-for-designing-and-constructing-city-infrastructure/construction-specifications-for-sewers-and-watermains/?accordion=rehabilitation-specifications for MS Word Version of notice.