SPECIFICATION FOR THE CURED-IN-PLACE PIPE LINING OF WATERMAINS

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TS 7.60.01 Scope

This specification (TS 7.60) is for structural Cured-in-Place Pipe (CIPP) tight fit lining of watermains in the city of Toronto up to and including 400 mm diameter watermains. The purpose of the CIPP lining is to effect a 50-year design life rehabilitation of the watermains. Information pertaining to the rehabilitation objectives and the performance requirements for the CIPP lining is provided in the further sections of this specification. The Work shall include performing the following operations: traffic control, temporary water lines and services, pavement cutting, excavation and access pits, cutting the watermain, dewatering, replacement of necessary valves or valve parts, replacement of hydrants, cleaning and preparing the watermain, grinding of service taps, disposal of water and waste products from cleaning operations, designing, sizing, installing and curing the CIPP lining, liner samples and testing, reinstatement of all services, protection of the lining, CCTV inspections at various stages of the work, chlorination and disinfection, cathodic protection, jumper and tracer wires, pressure testing, flushing, close-up of the watermain, back-filling of the excavation, restoration, repairs to pavement, repairs to the boulevard, clean-up of the site of the work, the guarantee and all other incidental work and services.

Where hydro pole support is required it shall be the responsibility of the Contractor. The Contractor shall make arrangements with Toronto Hydro. The Contract Administrator will assist in coordinating with Toronto Hydro if necessary.

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

TS 7.60.02 Information to be Submitted with Bid

The Tender Call requires the following information to be submitted with the Bid for the review and approval of the Contract Administrator. Further information for submission with tender may be required elsewhere in the Tender Call other than in TS 7.60 herein.

Submit with Bid:

1) The name of a professional engineer licensed in the province of Ontario who will provide the CIPP liner engineering designs required according to the liner design requirements in TS 7.60 herein. The professional engineer shall be authorized to perform such work by Professional Engineers Ontario (PEO).

2) An engineered liner design for each size of watermain to be lined that clearly shows the proposed liner thickness. The designs shall be according to TS 7.60 herein and shall identify all applicable existing watermain pipe design parameters and all applicable CIPP liner design parameters including the short-term and long-term CIPP properties used in the design. Bid submission design and design parameters shall be based on TS 7.60.32 Table 1 and the CIPP liner parameters shall be appropriate for the specific CIPP liner product(s) being bid. Each design shall include a lead-in summary clearly identifying the contractor's name, the design date, the Toronto contract number, the watermain location (if applicable), the watermain size, the liner product, the design liner thickness, the design pressure and the design watermain soil depth and water table depth. The designs shall be approved by an Engineer and bear the seal and signature of the required Engineer.

3) Approval certification, complete with any supporting literature and installation prescriptions, which are relevant to the approval, from the approval agency proving that the watermain liner(s) to be used has current NSF/ANSI Standard 61 approval for potable water.

4) Independent third party test reports and data to substantiate the CIPP material properties/performance used in the design as follows:

   a. Test reports and data for flexural modulus and flexural strength by ASTM D790 or ISO 11296, tensile strength hoop by ASTM D638 or ASTM D2290 or ASTM D1599, and tensile strength axial by ASTM D638. Testing by ASTM D790, ISO 11296, ASTM D638 and ASTM D2290 (or ASTM D1599) yields results that are commonly called short-term properties. Third party long-term creep testing reports and data for flexural modulus, flexural strength, tensile strength hoop and tensile strength axial by ASTM D2990. Testing by ASTM D2990 is to yield 75-year reduction factors that are used to reduce short-term properties to arrive at properties to be used in 75-year long-term design. Test reports and data shall be provided for each fabrication/construction class (or family) of watermain liner to be used on the Contract. By class (or family) is meant when there is a significant difference in the way the watermain liner is fabricated (such as different reinforcing materials) or is constructed (such as a different installation and/or cure method).

   b. Testing reports and data that substantiate the watermain lining's capability to undergo the required potential post lining deflections at existing host pipe joints or at potential host pipe failure locations without failure or leaking in the liner. Test report(s) and data that is/are relevant shall be provided so that the Contract Administrator will determine, based on the submission provided, whether the proposed watermain liner has the capability to meet this performance requirement regarding post-lining deflections. Should a recognized standard (such as ASTM or AWWA) become available for testing this performance requirement, then submitted test reports shall be in accordance with such standard. Refer to Special Specifications of Contract for any update on this submission's requirements.

   The testing shall be on samples from actual installed watermain liners except for long-term testing, burst pressure testing (when required), and other type testing. The submitted information shall be sufficient, clear, unambiguous, complete and identified so that the Contract Administrator is able judge the suitability of the material properties for used in CIPP watermain lining in the City of Toronto. Where in the opinion of the Contract Administrator these requirements are not met, the submitted information shall not be acceptable.

5) Material specifications of the proposed watermain liner in sufficient detail to enable confirmation by the Contract Administrator that the materials proposed will meet the objectives, performance requirements and design requirements in TS 7.60 herein.

6) Structural details of the proposed watermain liner in sufficient detail to enable confirmation by the Contract Administrator that the design will meet the design requirements in TS 7.60 herein. Include sufficient detail pertaining to the tight fit of the CIPP liner to the existing watermain that clearly indicates how the completed CIPP liner will not have any gap or annular space between the liner and the existing pipe.

7) Details regarding how both existing and new (post lining) water service connections will be reinstated into the lined watermain specifically identifying how the watertight seal will be made. Include details of any bond/adherence that will be employed to make the reinstatements. Refer to requirements in TS 7.60 herein.

8) Details regarding how post lining wet taps up to and including 50 mm (i.e.19mm, 25mm, 37.5mm and 50mm) are performed on the lined watermain.

9) A summary of the Contractor's proposed installation procedure including an example of the design process wet-out plan and curing cycle summary sheet to be submitted for each liner diameter.

10) A certified original copy complete with supporting literature from the resin manufacturer of the Infrared Spectrograph of the catalyzed resin mixture proposed for the Contract.

11) Sample CCTV inspection video file to show compliance with CCTV requirements in TS 7.60 herein.

TS 7.60.03 Operation of Valves and Hydrants

In the event that in-service watermain valves require operation during the course of construction, Toronto Water staff will be the only individuals permitted to operate these valves. The operation of all live valves and hydrants, in connection with cleaning and lining watermains and disinfection shall be done by the City's crew certified under Ontario Regulation 128/04 or under the direct supervision of a representative of the Contract Administrator.

In districts North York and Toronto /East York (former city of York, east of the Humber River) all valves supplied to these areas will open by operating in a clockwise direction.

In districts Etobicoke /York (former city of Etobicoke, west of the Humber River) and Scarborough all valves supplied to these areas will open by operating in a counter clockwise direction.

The Contractor will be required to keep and maintain a real time log book which logs the operation of any system valves—main line and bypass—found within the limits of the contract including valves on the temporary bypass system. Such a logbook is to be presented daily for copy and signature to the on-site Inspector. The logbook layout/format will be decided upon at pre-construction meeting. Primarily the Contractor will be asked to record the address of the valve, the date, time and reason for operation, time opened and/or closed as appropriate as well as the name of the individual operating the system valves.

TS 7.60.04 Notification to Public and Log Record

Unless otherwise required in the Special Specifications, three notices, as described below, shall be distributed to properties that will be affected by the work. Notice #1 shall be delivered by the City. Notices #2 and #3 shall be delivered by the Contractor. The Contractor shall maintain a log record of notices delivered by the Contractor and follow-up activities by the Contractor at each property throughout the contract work.

Notice #1 (Initial Notice)

A City notice, delivered by the City, that provides a brief introduction to the upcoming watermain CIPP lining construction contract, identifies the Contract Administrator and provides a contact phone number for the Contract Administrator. Notice #1 shall be delivered by the City to all properties in the contract area sometime well in advance of the start of onsite activities by the Contractor.

Notice #2

A City notice, delivered by the Contractor, that identifies the Contract Administrator and provides a detailed description of the upcoming construction work, contact phone number for contractor, including periodic interruptions of water service and details of temporary water servicing etc. Notice #2 may include information sheet(s) from the City for the property resident. Notice #2 shall be delivered to all effected properties in the contract area one week before any temporary bypass lines, temporary water services or excavations take place. Delivery of Notice #2 should be zoned based on construction activities and therefore may be separately distributed for different construction zone areas. The Contractor shall produce the number of copies of the notices including any information sheets required for distribution.

Notice #3

A Contractor notice, delivered by the Contractor, which advises the property resident of the opportunity to obtain a price for replacement of the private side of the water service by the Contractor. Such work is between the Contractor and the property owner and is not related to the contract or the City. Notice #3 shall be delivered to all effected properties once the construction activities have commenced and may be delivered by construction work zones using separate delivery schedules. The Contractor shall produce the number of copies of the notices required for distribution.

Record Log of Notifications and Follow-up Work

The Contractor shall make and maintain a log record. The log shall record the address where each notice was delivered, the date of delivery and any other information relevant to maintaining a record of notifications, such as follow-up telephone calls or property visits. The log shall also record date and description of any work performed at a property, such as installation of shut-off ball valves, disconnection of water meters and installation of hose bibs or other devices for temporary water service to the property, activation of temporary water service and deactivation of temporary water service. The log shall be maintained in a common electronic format, such as an MS Excel document. The log shall be provided to the Contract Administrator.

TS 7.60.05 Temporary Watermain Bypass Lines

Shall be in accordance with Toronto Standard TS 493

TS 7.60.06 Temporary Water Services

Shall be in accordance of Toronto Standard TS 493 with the exception that both the bypass line and private services may be chlorinated separately from the final connection. After connection to the temporary bypass the hose should be flushed from the bypass and then immediately connected to the private connection point. If after connection to the bypass the hose has to sit on site for a short period of time it should be capped on the private end, no hose should sit on site for a long duration. All hoses disinfected off site shall be stored and transported in such a fashion as to eliminate contamination.

TS 7.60.07 Temporary Hydrants

Shall be in accordance of Toronto Standard TS 493

TS 7.60.08 Burying Temporary Bypass Lines

Shall be in accordance of Toronto Standard TS 493

TS 7.60.09 Connection to Hydrants

All temporary bypass service attachments and any other attachments to fire hydrants shall be made with an approved backflow prevention device and shall be made in such a manner that if it becomes necessary, they can be easily removed so that the hydrant can be used for firefighting purposes.

TS 7.60.10 Disinfection of Temporary Bypass Lines and Service Connections

Disinfection shall be according to TS7.30 – *Procedure for Disinfecting Watermains*.

TS 7.60.11 Operation of Service Boxes

The Contractor shall locate, inspect and ensure that all curb stops operate properly in advance of working on the street. During construction, if a curb box becomes inoperable, the Contractor may be required to repair the curb box by an approved method. The Contractor shall adjust curb boxes to grade where necessary.

Before carrying out the repair of curb boxes the Contractor shall submit a list, in a format approved by the Contract Administrator, of defective curb boxes for inspection and approval by the Contract Administrator's representative.

The defective curb boxes shall be repaired or excavated/replaced as required with new curb box and stainless-steel rod, using a vacuum excavation method, connecting the rod to the curb stop with a cotter pin; adjustable ball bearings will not be permitted to make this connection.

The replacement shall be complete up to and including 25 mm water services including restoration according to the Special Specifications and supply and installation of extensions fittings, if required, to raise new curb box to grade site restoration. Where required, the work shall include raising or chip out or both of existing curb boxes.

TS 7.60.12 Shut-Off of Water Services

The Contractor shall make all shut-offs of property services and shall furnish water for the temporary bypass service from a hydrant or other temporary source.

TS 7.60.13 Protection of Public

The Contractor shall be required, at no extra cost to the City, to mound over the bypass pipe with asphalt or other acceptable material, wherever it crosses a street, driveway or sidewalk in order to prevent injury to pedestrians or damage to vehicles. The use of a polyethylene sheet shall be required as a barrier on concrete or interlocking driveways or both. If the work performed or the material used is not to the satisfaction of the Contract Administrator, action will be taken to rectify the problem to ensure the safety of the public. All costs incurred in such rectification shall be deducted from the Contractor's payment.

Safety flashers and barricades as may be required shall be furnished and maintained by the Contractor. In general, the temporary service pipe shall be laid where it will cause the least obstruction and is least liable to get damaged.

TS 7.60.14 Access Pits

The Contractor shall excavate pits for accessing the watermain for the CIPP lining process. The Contractor should use locations of existing tees, crosses, reducers and valves for access pits locations wherever this is feasible. When an access pit is excavated and a fitting is contained within it, the Contractor shall replace the fitting. The Contractor shall use existing valve, bend and tee locations as access pits as often as possible.

The Contractor shall note that the locations for all access pits shall be approved by the Contract Administrator prior to the beginning of construction. The work shall include all excavation, shoring, dewatering, bracing protection and restoration of access pits. Valves and fittings in close proximity to access pits shall be braced as required.

At the request of the Contract Administrator or due to unforeseen conditions, the Contractor shall excavate, supply and replace complete tees, bends including vertical bends, crosses, reducers and obstructions etc. including cathodic protection, jumper and tracer wire. The backfill and restoration shall be according to the Special Specifications.

When excavating bends/fittings/access points to watermains, and the access point requires the Contractor to remove water service connections, the Contractor shall be responsible to re-establish the water service connections to the watermain prior to backfill by re-tapping or relocating the service connection within the excavation.

Additional access pits may be required for the CIPP lining process due to unforeseen conditions. Such additional pits shall include all the work required for a regular pit. Payments for such additional pits shall be made at the Contract Price.

TS 7.60.15 Cathodic Protection, Jumper Wires and Tracer Wires

At all locations where cast or ductile iron watermain have been exposed and accessed, including all pit locations, sacrificial anode shall be installed. The Contractor shall supply and install 14.5 kg magnesium anode and the lead thermite welded to the iron pipe or fitting in according to TS 7.20 – *Construction Specification for Cathodic Protection of Existing Iron Watermains*.

At all locations where the iron pipe has been accessed, the Contractor shall install jumper wires to create or maintain the electrical continuity of the iron watermain including for existing and new iron pipe and iron fittings. Jumper wire shall be RWU90, number 10 gauge, single strand, insulated copper wire with 60 mil of polyethylene insulation. Jumper wire shall be attached to all pipe and fittings by thermite welding.

Where plastic pipe has been installed between sections of iron pipe, a tracer wire shall be installed directly above the plastic pipe. The tracer wire shall be thermite welded to the adjacent iron pipe at each end of the plastic pipe section to maintain electrical continuity of the iron watermain. Tracer wire shall be RWU90, number 10 gauge, single strand, insulated copper wire with 60 mil of polyethylene insulation.

TS 7.60.16 Cutting of Pipe

Where reconnection is required, watermain pipe shall be cut with proper cutting devices such as power operated cut-off saws or other approved methods. Cuts shall be neat and square to the watermain and be free of jagged ends or lips. Watermain pipe shall not be broken apart unless all pieces with broken ends are to be discarded.

TS 7.60.17 Capping Open Pipe Ends

All watermain pipes shall be capped, plugged or bulk-headed using a mechanical joint plug/cap anytime there is no work being performed on the pipe. The bulkhead must be capable of preventing water from entering or exiting the watermain pipe, and should be equipped with a relief valve and be properly braced when the possibility exists that the capped section could be pressurized.

TS 7.60.18 CCTV Equipment, Inspections and Reports

The Contractor shall carry out two CCTV inspections, the V2 and V3 as part of their contact deliverables. The Contract Administrator will use these CCTV inspections as part of the approval process for the work covered in the CCTV inspections.

The V2 CCTV inspection shall be carried out on the completion of all cleaning and preparation of the existing watermain and prior to lining installation. The V3 CCTV inspection shall be carried out on completion of the liner installation including after all service connections have been reinstated. See further requirements for V2 and V3 CCTV inspections elsewhere in TS 7.60.

Other CCTV inspections may be carried out by the Contractor for the Contractor's own purposes. These other CCTV inspections shall be done in accordance with the Contractor's own requirements. The CCTV inspection requirements outlined below are only applicable to V2 and V3 and not applicable to CCTV inspections done for the Contractor's own purposes.

At the sole discretion of the Contractor, the Contractor may opt to undertake an initial CCTV inspection of the watermain in its as is condition. Should the Contractor elect to do this initial CCTV inspection, it shall be referred to as the V1 inspection. The V1 is not mandatory under the requirements of TS 7.60. The Contractor may choose to perform a V1 inspection for the purpose of documenting the baseline condition of the watermain.

Requirement for CCTV Equipment to Be Dedicated for Watermains

All CCTV camera equipment including the cable, any other related equipment that enters the watermain and any external containment or operating equipment, such as the cable reel shall be equipment that is dedicated to the inspection of watermains and shall not be used and shall not have been used for other purposes, such as inspection of sewers.

All CCTV equipment used shall be kept clean and free of contamination by periodically dousing of the equipment with chlorine as needed to assure cleanliness. The Contractor shall be responsible for the frequency of chlorine dousing to prevent any contamination of the watermain by the CCTV equipment.

The requirement for watermain dedicated CCTV equipment applies to any CCTV inspection of watermains and applies regardless of whether the CCTV inspections are Contract required or done for the Contractor's own purposes.

Requirements for CCTV Inspection V2 and V3

The required V2 and V3 CCTV inspections shall be carried out in accordance with the following:

1) The CCTV equipment shall be suitable for and allow viewing of the full perimeter of pipe for all watermain sizes included in the contract. The CCTV equipment shall employ a suitable colour camera with pan and tilt capability. The range of the camera equipment from one access shall allow single pass inspections of not less than 200 m of watermain length.

2) The Contractor shall provide 48 hours notice prior to a required CCTV inspection in order that the Contract Administrator can arrange, if required, to be present for the CCTV inspection.

3) The watermain shall be sufficiently dry so that any remaining water does not obscure any part of the interior of the watermain during the CCTV inspection. The inspection speed shall allow proper analysis of the watermain condition with a maximum travel speed of 5 metres/minute. The inspection must stop and view each service connection clearly and completely for at least 5 seconds. The camera shall provide sufficient light and proper focus to enable clear viewing of the pipe surface at all locations. The video inspection equipment shall be disinfected prior to insertion into the watermain and care shall be taken to avoid contamination of the main during inspection. If required by the Contract Administrator, the Contract Administrator shall be present to view the live CCTV inspection.

4) Each individual CCTV inspection shall be continuous over the watermain section. The CCTV shall have on-screen identification of the location of the inspection including a start screen (or screens) that shown all the information necessary to describe and locate the CCTV inspection. During the inspection the screen shall continuously show a brief watermain section identification and the metered location of the camera within the watermain.

5) Each individual watermain section, CCTV inspection shall be recorded and the recording shall be the complete continuous CCTV inspection. The recorded CCTV inspection shall be provided to the Contract Administrator on digital video disc (DVD) or other approved media. The file name in the DVD shall clearly and concisely identify the CCTV inspection. A DVD may contain more than one CCTV inspection providing that the file name for each inspection properly identifies the CCTV inspection. Filenames that do not properly identify the inspection video will result in rejection of the DVD by the Contract Administrator.

6) Video inspection file format shall be an MPEG-2 (or other Contract Administrator approved format) that is suitable for proper playback on commonly used video file playing software applications. The video files must play properly in correctly configured, up to date versions of Microsoft Windows Media Player, VideoLAN VLC Player, Apple QuickTime Player Windows and Apple QuickTime Player Mac. Video files that do not play properly on all these five players shall be rejected. In regard to Apple QuickTime, play properly includes meaning that the video may be advanced at any speed (by slider bar or jog shuttle) and the CCTV inspection video will play in a continuous fashion without jumping or other discontinuities in the playback. Video files that fail to play properly in Apple QuickTime Player (or other video players) are typically indicative of improper or inappropriate settings in the CCTV equipment itself in the way it converts the analog CCTV signal to digital format. The contractor shall make sure that the CCTV equipment produces the required digital format.

7) The video inspection shall be accompanied by an inspection report in PDF format on the same DVD. The report shall list and locate all features noted in the CCTV inspection including service connections. The CCTV inspection file and the PDF report file shall be grouped together on the DVD along with any other information relevant to the specific CCTV inspection. The inspection report for each section of watermain inspected shall report as a minimum: contract number, street name, date of inspection, pipe type and size, start and end locations, length of pipe inspected, summary comments, disk, tape and file numbers. The summary comments should identify all distinguishing features of the watermain to include but not limited to service locations, condition of liner (or pre-lining condition of watermain), bends, valves, ponding water and poor visibility.

8) CCTV inspections including reports shall be submitted to the Contract Administrator. These submissions will be used by the Contract Administrator to determine, in part, that the CIPP watermain lining work meets contract requirements and is acceptable to the Contract Administrator.

TS 7.60.19 Preliminary CCTV Inspection – V1

At the sole discretion of the Contractor, a CCTV inspection may be carried out to document the existing condition of the watermain prior to any work being performed on the watermain. Should this CCTV inspection be carried out, it shall be done in accordance with the Contractor's requirements and be referred to as the V1 in keeping with established industry terminology. TS 7.60 requirements for V2 and V3 CCTV inspections are not applicable to a V1. TS 7.60 requirement for CCTV equipment dedicated to watermain use applies to any CCTV inspection of watermains including a V1.

TS 7.60.20 Water Services Statement

For each section of watermain to be lined, a *Water Services Statement* form shall be prepared by the Contractor. The form shall list all the service connections, including relevant street address, size, location and so forth. Information shall be started with known service connections from the drawings and curb stops. Additional service connections or service connection information determined from the V1 and V2 CCTV inspections shall be added to the form and include service connections that are to be abandoned and ground flush.

The format for the *Water Services Statement* form shall be an MS Excel spreadsheet or equivalent suitable for electronic information handling. As the information on the form will evolve during the course of the work on the watermain section to be lined, the form shall clearly identify by section of watermain lining and the current date of the form.

A *Water Services Statement* form, finalized for commencement of lining, shall be submitted to the Contract Administrator before start of liner installation. Liner installation shall not proceed without the *Water Services Statement* submission. Where possible the form should accompany the V2 CCTV submission.

The *Water Services Statement* shall be used as a control document for reinstatement of service connections into the lined watermain. Once all service connections have been reinstated, the form shall be updated to identify the reinstatements.

A *Water Services Statement* finalized after lining to include a record of service reinstatements, shall be submitted to the Contract Administrator and accompany the V3 CCTV submission.

For a sample of the *Water Services Statement* form, see appendix herein.

TS 7.60.21 Cleaning and Preparation of Watermain

If there is existing cement mortar lining in the host pipe, the Contractor All corrosion deposits (including rust deposits), tuberculation, deposits and any foreign materials shall be removed from the inside of the pipe to the satisfaction of and by a method approved by the Contract Administrator. Candidate methods include (and not limited to) water-propelled cleaning devices, cable pulled scrapers, rack boring, high pressure water jet methods and pneumatically driven methods (such as blown specialty gravel methods). The Contractor shall employ a method that is suitable for cleaning and preparing the watermain for CIPP lining. The Contractor shall pass the cleaning device/method through the watermain as many times as is necessary and in each direction as necessary to obtain results satisfactory to the Contract Administrator.

If there is existing cement mortar lining in the host pipe, the Contractor shall remove the existing cement mortar lining as per applicable payment item to the satisfaction of and by a method approved by the Contract Administrator. Refer to Special Specifications of Contract for any further instruction and detail.

The cleaned and prepared surface shall be suitable for CIPP liner installation and its long-term performance including the necessary bonding/adherence for the specific liner product to the watermain surface. In regard to necessary bonding/adherence, refer to TS 7.60.25 and TS 7.60.27.

Where any small hard deposit cannot be removed by cleaning and preparation operations and that such deposit is of a size and in a location that will not negatively affect long-term liner performance then, at the discretion of the Contract Administrator lining shall be permitted.

In the event that any service taps protrude too far into the interior of the existing watermain resulting in interference with required cleaning and preparation, or protrude to the extent that they will have a negative effect on the liner including its long-term performance, the service taps shall be trimmed back to an acceptable protrusion length. The method of trimming shall not damage the service taps and the method must be approved by the Contract Administrator.

Cleaning and preparation operations shall be carried out in a manner that will avoid the application of vertical or horizontal loads on the pipe. Boxes of adequate size with compartments or other suitable and approved means shall be provided to function as settling tanks for the retention of solids removed during cleaning, flushing and pumping operations.

On total completion of the cleaning and preparation (including grinding of any service taps), the post cleaning and preparation V2 CCTV inspection shall be made.

The required and necessary cleaning and preparation of the watermain is the Contractor's responsibility regardless of V2 submission to the Contract Administrator.

TS 7.60.22 Measuring Inside Diameter of Watermain

The inside diameter of the watermain to be lined shall be accurately measured throughout the length of each lining run using a suitable device. Suitable devices include a laser measuring device that will travel along the inside of the existing watermain. Inside diameter measurements shall be obtained at a maximum of 300 mm spacing along the watermain. The measurements shall be accurate to within 1.5 mm.

The inside diameter measurements shall be for the final inside diameter before lining and therefore shall be made after the existing watermain has been fully cleaned and prepared for lining.

The results of the inside diameter measurements shall be used for sizing the liner to be used for each lining run. These measurements shall be used for each lining runs to ensure each liner will provide the required tight fit to the inside surface of the watermain. The final installed liner shall leave no gap or annular space between the liner and the watermain at any location around the perimeter of the watermain along the full lined length with following exception. The exception to tight fit is allowed where joints in the existing watermain have a joint gap. Joint gaps are a normal and typical situation for joints in CI and DI watermain pipelines. The liner shall be permitted to bridge or partially bridge this gap and thereby may not be a tight fit to the inside surface of the existing watermain over the zone of the joint gap. A watermain liner that bridges or partially bridges a joint gap shall possess the necessary stress and strain properties such that the performance of the liner will not be degraded when joint gaps are bridged or partially bridged by the liner.

Where the measurements indicate that the proposed liner will not assure a 100 per cent tight fit over the full range of the diameters measured, the proposed liner shall not be installed and a different sizing of liner shall be used that will assure the 100 per cent tight fit.

Where the range of measurements is such that no available liner sizing will assure a 100 per cent tight fit, the Contractor shall advise the Contract Administrator of this finding within 48 hours. No lining shall take place until this situation has been resolved to the satisfaction of both the Contract Administrator and the Contractor. Where no resolution is possible due to the measured size range, the watermain shall not be lined.

Where, due to the diameter measurements and available liner sizes, a tight fit can only be obtained by an oversized liner, resulting in excess material (such as a fold, wrinkle or fin) in the finished liner, refer to the TS 7.60.30 and TS 7.60.36.

Documentation of Measuring & Results

Before a liner is installed in a proposed liner run, the Contractor shall provide the written results of the watermain inside diameter measurement survey for the entire length of liner run for each proposed liner run to the Contract Administrator. Included with the survey results the Contractor shall report on the impact of the watermain inside diameter survey on sizing the liner for tight fit, the liner diametric size to be used to obtain a tight fit and whether a tight fit throughout the liner run can only be obtained by using an oversized liner with corresponding excess material manifesting as a fold, wrinkle or fin either localized or over the full length of the liner.

TS 7.60.23 Grinding Flush of Abandoned Service Taps

Service connections that have been identified as no longer required shall be ground back flush with the inside surface of the watermain prior to the installation of the CIPP lining and prior to the V2 CCTV inspection. These service connections and their grind-off shall be identified on the Water Services Statement.

TS 7.60.24 Post Cleaning and Preparation CCTV Inspection – V2

When the cleaning and preparation has been fully completed for a watermain section, a post preparation CCTV inspection including report—called the V2—shall be done, recorded and submitted to the Contract Administrator. CCTV inspection and report shall be in accordance with the requirements in this specification. The V2 shall be a record that the watermain section has been cleaned and prepared for lining in accordance with requirements. Where the V2 shall demonstrate that the cleaning and preparation is proper, complete and in accordance with requirements the liner installation may take place at the Contractor's option prior to any submission to or review by the Contract Administrator of the V2.

When the Contractor opts to install the liner before the V2 has been submitted to and reviewed by the Contract Administrator, the Contractor accepts complete responsibility that the watermain has been cleaned and prepared as necessary for liner installation and in accordance with Contract cleaning and preparation requirements. In the case that the Contract Administrator finds that the V2 does not demonstrate that the cleaning and preparation requirements were met, the Contractor shall rectify any deficiencies to the satisfaction of the Contract Administrator, whether or not the lining has already been installed.

Regardless of the timing of the liner installation, the V2 shall always be submitted to the Contract Administrator for review no later than 48 hours after completion of the V2. At the Contract Administrator's option the 48 hour limit may be waived providing that the V2 is received no later than the V3.

TS 7.60.25 Objectives for CIPP Watermain Lining

The objectives to be achieved by CIPP lining of a watermain are:

- Prevent leaks out of or into the lined watermain over the design life of the CIPP lining.
- Prevent deterioration in water quality in the lined watermain over the design life of the CIPP lining.
- Prevent deterioration of flow capacity in the lined watermain over the design life of the CIPP lining.
- Reinstate small but not sub-standard water service connections (up to and including 50 mm) into the lined watermain without excavation.
- Utilize trenchless methods for the installation of the CIPP lining thereby minimizing excavation, ground surface disruption and carbon footprint due to and during construction.

- Allow for post lining wet tapping up to and including 50 mm taps. Wet taps must remain water tight with no migration of water between the liner and the host pipe for the design life of the liner.

The leaks to be prevented relate to leaks that typically develop over time in existing cast iron or ductile iron watermains due to deterioration over time of the physical condition of these watermains including their joints and connections. The CIPP lining shall achieve the leak prevention objective including in the situation that the existing watermain continues to deteriorate over the design life of the liner and therefore, without a CIPP lining, would develop leaks. Refer section TS 7.60.27 for further detail on leak prevention requirements.

While leaks out of a watermain comprise the vast majority of watermain leaks, leaks into a watermain, while rare, are a significant issue. Leaks into a watermain can occur when the watermain is at an internal pressure lower than the surrounding ground water pressure (typically can only occur when watermain has been depressurized) or can occur when the watermain experiences a vacuum condition. A vacuum condition, while a rare and short-term event, can both cause a leak when the watermain (or lined watermain) is not rated for sufficient vacuum or expose a pre-existing leak that was not active until exposed to a vacuum situation. Therefore, one of the objectives for CIPP lining of a watermain is to prevent leaks both out of and into the lined watermain.

TS 7.60.26 Lining Installation for Existing Watermain Alignments

The CIPP lining shall have the capability to be successfully installed and cured-in-place in existing watermain alignments typical for cast iron and ductile iron watermain pipelines. This requirement specifically includes:

- Through existing bends up to and including 45 degrees.
- Through existing deflected joints with deflections of up to and including 5 degrees.

Successfully means that the CIPP liner performance will not be degraded when installed and cure-in-place in these situations. For bends or defections greater than 22.5 degrees some bunching of the liner on the inside of the deflection will be acceptable provided it does not degrade liner performance.

TS 7.60.27 Performance Requirements for CIPP Watermain Lining

1. Reinstatement of Water Service Connections without Excavation

The CIPP watermain lining shall allow for remote reinstatement of existing water service connections into the lined watermain of size 50 mm or less. Remote means that the reinstatement shall be done internally within the lined watermain and no excavation to the watermain shall be required to make the reinstatement. The reinstated service connection shall not leak.

The CIPP liner shall create a pressure tight seal to the existing watermain in the area of the service connection and to the service connection tap so that the service connection can be reinstated by accurately removing (by drilling or other means) the liner blocking the service connection opening. The pressure tight seal shall be sufficient to prevent any leakage at or around the reinstated service connection. The pressure tight seal shall remain sufficient over the design life of the liner to prevent any leakage at or around the reinstated service connection over the design life of the liner. The pressure tight seal shall be created by adherence or bond of the liner to the existing watermain over the area required to create the pressure tight seal to the service connection tap. The required level of adherence or bond shall be the responsibility of the Contractor and shall be compatible with the specific watermain lining product being used by the Contractor. Failure to achieve a pressure tight seal will be regarded as a failure of the Contractor to achieve the bond or adherence that was necessary for and predicated by the watermain lining product being used. The bond or adherence required is specific to the specific watermain lining product being used and therefore is not specified by the City.

2. Provide Required Capacity for External Loads

External loads on the lined watermain include loads due to groundwater hydrostatic pressure, ground cover (soil) loads, live loads (such as from surface vehicles) and an equivalent external load due to a vacuum condition within the lined watermain. The CIPP watermain liner shall provide the necessary resistance to these loads for the occasions and durations than they will come to bear on the watermain lining.

When and where the lined watermain is a normally pressurized pipe and the internal pressure is greater than twice the external load pressure, the required resistance shall be based on considering the external loads as a short-term effect. When the lined watermain will not be a normally pressurized pipe, the required resistance shall be based on considering the external loads (except for vacuum) as a long-term effect.

Required resistance to external load shall consider the situation where the existing watermain portion of the lined watermain has deteriorated into the fully deteriorated condition (see ASTM F1216 X1.1.2) and cannot support external loads. This is considered a worst-case scenario that shall be addressed in providing required resistance to external loads.

3. Provide Localized Internal Pressure Resistance Prior to Any "Failure" of Host Pipe

By "failure" in this context is meant a loss of ability of the host pipe portion of the lined watermain to carry internal pressure and/or remain watertight. The watermain liner shall have the ability to perform structurally against in the situations where a gap exists between the liner and the existing watermain portion of the lined watermain. Such gaps will occur wherever the liner is not a tight fit against the inside surface of the old watermain. In these cases the liner will experience the effect of the internal pressure even though the existing watermain portion of the lined watermain remains fully capable of carrying the full internal pressure. The prime example of such gaps is where the liner bridges or partially bridges joint gaps in the CI or DI portion of the lined watermain.

The performance mechanisms required in the watermain liner in this situation includes bending without cracking.

4. Survive Future Joint Deflections in the Host Pipe Portion of the Lined Watermain

CIPP watermain lining installed in CI and DI pipelines (or other pipeline materials as applicable) shall not fail when subject to post lining deflection than may occur in the joints of the host pipe portion of the lined watermain. Failing in this context means any loss in the structural integrity of the lining that results in a leak, a potential leak, cracking or a loss of other structurally related performance of the liner including in its ability to fully resist the internal design pressure as a stand-alone pipe.

The liner shall survive (meaning it will not fail in any way) up to and including 5 degrees joint deflection that may occur post lining in any direction regardless of the existing joint deflection in the host pipe prior to lining.

The liner shall accommodate changes in joint deflection in the host pipe portion of the lined watermain on an ongoing basis over the design life of the liner. This means if the changes in joint deflection are dynamic over time, the line shall accommodate this situation and maintain its ability to accommodate such joint deflection without failing (as defined above).

5. Prevent Watermain Leaks Due to Failure of the Host Pipe Portion of the Lined Watermain

The watermain liner shall prevent leaks that would have occurred in the unlined watermain due to a partially deteriorated or fully deterioration condition of the host pipe portion of the lined watermain occurring over the design life of the liner. This shall include the watermain liner's surviving (meaning it will neither fail nor leak) a failure in the host pipe portion of the lined watermain that results in: A deflection at a failure in the host pipe up to including 5 degrees in any direction.

- An offset at a failure in the host pipe up to and including 2% of pipe diameter (i.e. offset between the two separated pipe pieces up to 2% of the nominal pipe diameter (E.G. for a 250mm watermain an offset of 5 mm).
- A hole in the host pipe of unlimited size or shape.
- A loss of pressure carrying capacity in the host pipe due its loss of sufficient tensile hoop wall strength.
- Any other type failure of the host pipe that is due to deterioration of the physical condition of the host pipe.

Excluded from the above are leaks caused by deterioration of the host pipe at couplings and regressed saddle service taps.

Excluded from required liner leak prevention performance are situations that are caused by excavated damage to the lined watermain, catastrophic undermining of the soil support around the lined watermain due to unrelated events that causes excessive loads on or deflections in the lined watermain and exposure of the lined watermain to a corrosive environment that is not normal or expected for municipal watermains.

TS 7.60.28 Materials and Standards

The lining shall be cured-in-place-pipe (CIPP) according to ASTM F1216-16, ASTM F1743-08 or ASTM F2019-03(2009) with exceptions made for where the watermain liner is required to differ specifically from requirements in these standards. For CIPP liner design requirements refer to the section TS 7.60.32 herein.

The liner shall have current NSF/ANSI Standard 61 certification for potable water use. Approval certifications for the watermain lining product to be used, including NSF/ANSI Standard 61 certification shall be provided with tender submission. The liner potable water certification must be submitted with the tender for the Contract Administrator's review. The Contract Administrator reserves the right to accept/reject the certification(s).

All materials must be delivered to the site in their appropriate containers that clearly show that the product has various agencies' approvals.

The liner shall utilize a thermally cured epoxy type resin where the cure does not rely on ambient heat for curing. The liner shall be uniformly impregnated with the correct quantity of resin to produce a cured result that has homogeneous and uniform physical properties throughout the liner wall that meet or exceed the required physical properties premised in the liner design. In this context the liner wall does not include with the surface waterproof membrane layer. The correct quantity of resin shall be determined by the Contractor and be in accordance with the specifications of the liner manufacturer.

TS 7.60.29 Watermain Liner Material Properties

Flexural Properties

Flexural properties short-term test minimum values shall be as specified in ASTM F1216. Because the ASTM F1216 does not specify testing direction the minimum values shall apply whether tested in the hoop or axial direction as may be required. Flexural properties shall be determined by either ASTM D790 or ISO 11296. ISO 11296 uses curved test specimens from the circumference of the liner. For further detail on testing refer to TS 7.60.37.

Should the Contractor's watermain liner design(s) use short-term test values higher than the ASTM F1216 minimums then the short-term test results for flexural properties obtained on samples from the installed liner(s) shall meet the higher values used in the Contractor's design. The Contractor's design(s) shall identify the short-term test values from which the long-term design values were derived.

Tensile Properties – Hoop Direction

Tensile properties short-term test minimum values shall be as specified in ASTM F1216 or a minimum of 21 MPa whichever is greater. Tensile properties shall be determined by ASTM D2290, ASTM D1599, ASTM D638 or approved ISO equivalent. For further detail on testing refer to TS 7.60.37.

Should the Contractor's watermain liner design(s) use short-term test values higher than the above minimums then the short-term test results for tensile properties obtained on samples from the installed liner(s) shall meet the higher values used in the Contractor's design. The Contractor's design(s) shall identify the short-term test values from which the long-term design values were derived

Tensile Properties – Axial Direction

Tensile properties short-term test minimum values shall be as specified in ASTM F1216, a minimum of 21 MPa whichever is greater. Tensile properties shall be determined by ASTM D638 or approved ISO equivalent. For further detail on testing refer to TS 7.60.37.

Should the Contractor's watermain liner design(s) use short-term test values higher than the above minimums then the short-term test results for tensile properties obtained on samples from the installed liner(s) shall meet the higher values used in the Contractor's design. The Contractor's design(s) shall identify the short-term test values from which the long-term design values were derived.

Substantiation of Watermain Liner Material Properties

At least 30 days prior to the first liner installation, the Contractor shall provide substantiation in the form of third party test results that:

- Substantiate the short-term test values of the properties used as starting points for the Contractor's liner design by tests on field samples of the same liner product from other installations. The Contract Administrator reserves the right to reject the substantiation on the grounds that is insufficient or not applicable.

- Substantiate that the reduction in short-term test properties used to determine the values for long-term design are appropriate for the liner material and are appropriate for the expected levels and durations of stresses in the liner. Substantiation will require long-term testing results such as by ASTM D2990. The Contract Administrator reserves the right to reject the substantiation on the grounds that is insufficient or not applicable.

TS 7.60.30 Tight Fit of Liner to Watermain

On completion, the liner shall fit completely tightly to the inside surface of the watermain around the full perimeter and over the full length of the installation. There shall be no measurable gaps or annular space at any location. The liner shall have a fabrication, size and resin quantity that ensures the required 100 per cent tight fit will be obtained.

Where the liner has a diametric tight fit range, whereby the tight fit is achieved either by stretch capability or variable fold size capability, the contractor shall verify, before installation of the liner, that the diametric range of the liner is a suitable match for the diametric range of the watermain to be lined. Where the diametric range of the liner to be installed will not assure a 100 per cent tight fit, a differently sized liner shall be used.

The required tight fit shall be verified by inspection by the Contractor of all pieces of lined watermain that have been removed for samples or other reasons. All such removed pieces shall be made available to the Contract Administrator. Should the Contractor, in its inspections, identify any liner that did not obtain the required tight fit—either in removed liner pieces or by other means—the Contractor shall report such findings to the Contract Administrator within 24 hours.

Where the required tight fit has not been achieved throughout the entire installation, the liner shall not be acceptable, and the liner shall be removed and replaced with a new liner that is a tight fit. If the forgoing removal and replacement is not possible then a new watermain shall be installed.

TS 7.60.31 Diametric Sizing of Liner

The diameter of the liner shall be sized to assure a tight fit to the watermain being lined. The diametric sizing of the liner shall be based on the results of the required pre-lining continuous inside diameter measurement survey of the watermain. Refer to TS 7.60.22.

TS 7.60.32 Design Requirements

The Contractor shall provide engineered designs for each unique liner situation, including for each size of liner. The engineered designs shall demonstrate, to the satisfaction of the Contract Administrator, that the lining to be installed is rated to withstand the required external loads and internal pressures. Design checks A1 and A2 shall be done.

A1 Use ASTM F1216-16 Appendix X1, Design Considerations, Section X1.3.2 Fully Deteriorated Pressure Pipe Condition. The design method and the design parameters for the liner are prescribed below in Table 1.

A2 Check the axial thrust resistance capacity for the liner using tensile strength in the axial direction. The check will determine the required thickness of the liner to withstand the hydrostatic thrust force due to a closed end.

The greater thickness as determined from A1 or A2 above shall be the required liner thickness.

The design shall clearly and unambiguously identify all the properties used in design, including any short-term test properties, any reductions from short-term test properties and all other parameters, all depth, water table and vacuum parameters, all pressure parameters.

Engineering designs shall be approved by an Engineer and bear the seal and signature of an Engineer authorized to perform such work by PEO.

The Contract Administrator reserves the right to reject the liner design(s), design method or design parameters should they differ from those prescribed in this section or on the grounds that the design(s) is incomplete, inadequate, questionable, incorrect or incomprehensible.

The thickness determined by the design accepted by the Contract Administrator shall be the required wall thickness for the completed liner. The wall thickness for comparison to the design thickness shall be the wall thickness of the liner's structural zone only. Wall thickness measurements of the finished liner used to compare with design thickness shall not include such non-structural zones. If these zones have been included in the measurement, they shall be subtracted to determine the effective thickness of the liner. For determination of the actual wall thickness of the installed liner for comparison to the required thickness refer to Liner Wall Thickness and Tolerance in TS 7.60.36.

Table 1: CIPP Liner Design Parameters

Parameter	Requirement
Design Method	A1) ASTM F1216-16 X1.3.2 Plus A2) Check to confirm hydrostatic thrust capacity of liner.
Design Life	75 years or greater.
Safety Factors	For Internal Pressure: 2.0 For Axial Hydrostatic Thrust: 1.5 For External Loads (hydrostatic pressure, soil loads & live loads): 2.0 For Vacuum: 2.0
Design Operating Internal Pressure	862 kPa (125 psi)
Design Transient Internal Pressure	1207 kPa (175 psi)
Vacuum	50 kPa below atmospheric pressure.
External Hydrostatic Pressure	Based on ground water table at 1.5 m below ground surface. Also see sub section below.
External Earth Load	For 2.0 m cover or the actual cover at the liner location, whichever is greater.
Live Load	CHBDC CL-625-ONT
Ovality	2 %. The ASTM F1216-16 design method for Fully Deteriorated Pressure Pipe shall not be applied when ovality exceeds 2%.
Soil Weight	1920 Kg per cubic metre
Soil Modulus	6.90 MPa
CIPP Liner Flexural Modulus for F1216 Equations X1.1, X1.3, X1.4	The flexural modulus to be used in design equations X1.1 and X1.3 shall be the short-term test flexural modulus in the hoop direction reduced by an amount that depends on the estimated accumulated time duration of the external load. Where it is determined that a reduction in the flexural modulus is warranted for design (refer ASTM F1216-16 Note X1.1) the reduction shall be based on long-term creep testing of the liner product. The flexural modulus to be used in design equation X1.4 shall always be the short-term test flexural modulus. No reduction shall be made. See F1216 X1.2.2.1. The short-term test flexural modulus of the liner shall be determined by either ASTM D790 or ISO 11296 test methods. Long-term creep testing shall be in accordance with ASTM D2990 (or approved ISO equivalent). Unless specifically noted otherwise in the contract special provisions, the watermains shall be considered normally internally pressurized pipelines and at a sufficient internal pressure whereby external load shall not be considered a long-term effect. Therefore, no reduction in flexural modulus is required for use in Equations X1.1 or X1.3.

CIPP Liner Tensile Strength for F1216 Equation X1.7	The tensile strength used in F1216 equation X1.7 shall be the short-term test tensile strength in the hoop direction reduced by an amount that depends on the estimated accumulated time duration of the internal pressure. Where it is determined that a reduction to the tensile strength is warranted for design (refer ASTM F1216 Note X1.6) the reduction shall be based on long-term creep testing of the liner product. The short-term test tensile strength in the hoop direction of the liner shall be determined by either ASTM D638, ASTM D2290, ASTM D1599 test methods or approved equivalent test method. Where D638 method is used, provision shall be made for obtaining hoop direction results. When approved by the Contract Administrator factors based on liner diameter may be used to obtain tensile strength in the hoop direction from ASTM D638 results determined for the axial direction. Where D638 method is used for a liner containing folds, wrinkles, fins, or any other geometric imperfections, the pressure rating conversion factor shall be applied (refer TS 7.60.37). Long-term creep testing shall be in accordance with ASTM D2990 (or approved ISO equivalent). Unless specifically noted otherwise in the contract special provisions, the following applies: For Design Operating Pressure, use full 75-year reduction in short-term test tensile strength in hoop direction. For Design Transient Pressure no reduction in short-term test tensile strength in the hoop direction is required.
CIPP Liner Tensile Strength for Axial Thrust Resistance Capacity	The tensile strength to be used for determining axial hydrostatic thrust capacity for the liner shall be the short-term test tensile strength in the axial direction reduced by an amount that depends on the estimated accumulated time duration of the axial load on the liner. Where it is determined that a reduction to the tensile strength is warranted for design (refer ASTM F1216 Note X1.6) the reduction shall be based on long-term creep testing of the liner product. The short-term test tensile strength in the axial direction of the liner shall be determined by either ASTM D638 test method or approved ISO equivalent test method. Long-term creep testing shall be in accordance with ASTM D2990 (or approved ISO equivalent). Unless specifically noted otherwise in the contract special provisions, the following applies: For Design Operating Pressure, use full 75-year reduction in short-term test tensile strength in axial direction. For Design Transient Pressure no reduction in short-term test tensile strength in the axial direction is required.

External Hydrostatic Pressure

Where it is discovered by the Contractor that a CIPP liner is to be installed below a watercourse, below a culvert or storm sewer conveying a watercourse, or in a regulated flood area, the Contractor shall advise the Contract Administrator of this discovery as quickly as possible and before any liner wet out or installation. The Contract Administrator will prescribe any required changes in external hydrostatic pressure to be used for design. These changes could include external hydrostatic head at or above ground level.

Vacuum

In accordance with the ASTM F1216 design method, vacuum is treated as an equivalent external pressure. Vacuum shall be treated as a short-term transient effect.

Flexural Modulus and Tensile Strength (Hoop & Axial)

The flexural modulus and tensile strengths used as the starting values from which values for long-term design are derived shall be values that will be reliably and repeatedly obtained in the installed liners as substantiated by testing samples from installed liners. They shall not be values obtained from laboratory samples or maximum values obtained in testing. The liner designs shall identify the short-term test values of flexural modulus and tensile strength from which long-term design values are derived.

Check to Confirm Hydrostatic Thrust Capacity of Liner

This check shall determine that the capacity of the liner wall has sufficient tensile capacity to resist the longitudinal hydrostatic thrust generated by a close end. As such the liner tensile strength in the axial direction shall be used in the calculation and not the liner tensile strength in the hoop direction. A simple force balance approach is suitable and may utilize the following formula.

$P = (4\sigma a) / (N \times (DR-2)$
Where
P = Allowed Pressure
σa = Tensile Strength Axial
N = Safety Factor
DR = Liner Dimension Ratio (OD/t)

Designs Correct for Field Conditions

The Contractor shall check and determine that actual field conditions for any liner installation watermain section correspond with the liner design for that installation. The field conditions to be checked shall include:

- Surface vehicle live load. Is the field-identified vehicle more onerous than the CHBDC CL-625- ONT truck? For example is the liner run crossing under a railway track and therefore subject to railway live loading?

- Actual Cover over Watermain. Is it less than the minimum 2 m cover specified for design? Is it more than the cover use in the design? If field identified cover is less than 2 m, does the live load at the actual cover result in a total external load greater than used in the Contractor's design for the liner even though the design may have been for 2 m of cover or greater?

Where the existing liner design is not appropriate, by a significant factor, for the field external load conditions (such as because of higher cover, greater live load, shallow cover impact on live load etc.) and a significant increase in liner thickness is required the Contractor shall adjust the liner design accordingly and the liner installed shall meet the requirements of the adjusted design. The adjusted liner design shall be submitted to the Contract Administrator for acceptance.

Significant means that a 20% or greater increase in liner thickness is warranted over the proposed liner for the installation based on differences in external load parameters such as depth and live load.

Where a liner design previously accepted by the Contract Administrator is found needing adjustment due to determined actual field conditions, the Contractor shall advise the Contract Administrator within 48 hours and wait for the Contract Administrator's instructions. Where the adjusted design results in a thicker liner (or a liner with greater external load capacity) to be installed, any additional cost involved shall be determined according to the Contract Prices where applicable, and if Contract Prices are not applicable, 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 (or capacity) for actual field conditions.

Liner Thickness and Stretching Out for Tight Fit

Where it is expected that the liner will stretch out to a tight fit with the existing watermain and this stretching may result in a thinning of the liner's finished wall an increase in the liner thickness (or its pressure and/or external load capacity) may be required to compensate for the stretch out induced thinning. If this thinning decreases the liner's capacity for internal pressure and/or decreases the liner's capacity for external load it shall be compensated for by increasing the liner thickness to be installed such that the change in liner thickness (or change in its pressure and/or external load capacity) shall maintain the performance requirements required for the liner.

TS 7.60.33 Installation

The installation of the liner into the watermain complete with curing is the responsibility of the Contractor. The Contractor shall follow the liner manufacturer's installation recommendations to the extent that they are appropriate for specific circumstances.

Installation Procedure

The actual lining installation procedure shall be in accordance with the submission with Tender. Any proposed deviation from the submitted procedure shall be submitted, with explanation, to the Contract Administrator for approval and the submission shall include the approval of the lining manufacturer or senior licensor.

Equipment Ready for Lining

The Contractor shall ensure that all required equipment (including as required by the Contract) is on site and in satisfactory working order prior to commencing the installation of a lining section.

Wet Out, Curing and Cooldown Requirements

The Contractor shall maintain wet out, curing and cooldown records that shall include the following requirements at the minimum.

For the wet out of each watermain section lining run records shall include documentation identifying the resin batch numbers and product name and confirming that the liner to be installed complies with the product specification and tender design submissions. The wet out documentation shall include an information sheet recording the dimensions of the liner and the quantity of each material (including resin components) used in the watermain section liner run.

For curing of each watermain section lining run, records shall include documentation recording the boiler parameters, liner cure cycle temperatures and cooldown cycle temperatures (for example thermocouple temperatures) installation head and curing head. The format of the documentation shall allow for direct comparison with the process curing cycle submitted with the tender submission.

All records and documentation shall be readily available to the Contract Administrator upon request.

Quality Control

The Contractor shall have in place and follow a quality control program for the CIPP watermain liner that addresses: cleaning and preparation of the existing watermain, liner sizing, correct liner for the installation such as tube size, materials and design, liner thickness such as design and as cured, liner rating for external loads, liner rating for internal pressures, liner resin such as mix, impregnation and uniform distribution, liner fit and finish, liner service connection reinstatements and liner as cured physical properties. On the Contract Administrator's request, the Contractor shall provide full details of this program to the Contract Administrator. Where in the Contract Administrator's opinion, the program is not adequate, or not being followed, the Contract Administrator will require the Contractor to make rectification to the Contract Administrator's satisfaction.

Records

The Contractor shall keep detailed records that are sufficient to track the progress and parameters of each liner run installation. These records shall easily allow identification of individual liner runs and include, at a minimum: preliminary and final liner sizing, specifics of liner tube ordered, specifics of liner tube installed, location information independent of pit locations, number and size of services, GPS locating information (when required), installation dates, return to service dates and quality problems (if any). On the Contract Administrator's request, the Contractor shall show or provided these records. Where, in the Contract Administrator's opinion, the records are not adequate, the Contract Administrator will require the Contractor to make rectification to the Contract Administrator's satisfaction.

TS 7.60.34 Pressure Test

The lined watermain shall be pressure tested before the reinstatement of the service connections. The test pressure shall be 120 per cent of the operating pressure for the watermain location being tested.

The Contractor shall determine the existing operating pressure of the watermain to be lined prior to construction. The Contractor shall provide the determined operating pressure to the Contract Administrator prior to construction. Refer to Special Specifications of Contract for further detail on determining operating pressure.

The test duration and allowed make up water shall be in accordance with ASTM F1216-21 section 8.3. Refer to Special Specifications of Contract for further detail on pressure test procedures and requirements.

In addition to the above, for every 4000 meters of lined watermain, at a location specified by the Contract Administrator, the contractor shall include an end seal(s) and/or service connection(s) and/or coupling(s) to be pressure tested as part of the pressure test. The purpose of this test is to pressure test the final assembly. The section tested shall be at a suitable location without any services of up to and including 50mm diameter.

Failed pressure tests shall be reported immediately to the Contract Administrator.

TS 7.60.35 Reinstatement of Service Connections

The water service connections up to and including 50 mm in size shall be reinstated from inside of the lined pipe, using a robot equipped with a camera and activated by an operator using a remote control and television unit.

The robot shall be equipped with a drilling tool that allows the operator to drill a hole in the liner at the precise location of the connection. The service connection shall be opened to the full pre-existing flow opening size, including the removal of any resin slugging in or up the service connection that will impede flow. After opening the connections, the lined watermain shall be flushed clean, disinfected and restored to service.

The Contractor will be fully responsible to locate and successfully reinstate the existing service connection, without damaging the lining. Any damage to the service connection or the lining caused by the reinstatement process will require immediate corrective action by the Contractor.

If the Contractor is unable to reinstate a service connection from the inside, a suitable excavation will be required to access the main stop and to disconnect the existing service and reconnect using a City approved fitting.

If the Contractor is unable to effectively reconnect the service connection to the Contract Administrator's satisfaction, the Contractor shall be required to re-tap the watermain in accordance to the City's standards.

Clearing of Obstruction in Water Services

Should any services be partially or fully obstructed due to the ingress of liner resin or other foreign materials the Contractor shall remove such obstructions including by excavation, removal of any restrictions in the main stop or water service, replacement of the main stop, reconnection of the service, backfill and permanent restoration as ordered by the Contract Administrator. The Contractor shall clear all obstructed water services at the Contractor's expense. No additional payment will be made for this work.

TS 7.60.36 Liner Fit, Finish and Properties

The cured liner within the watermain shall meet the following requirements for fit, finish and properties.

Liner Continuity

The completed CIPP watermain liner shall be continuous over the full length of the liner installation run. There shall be no separations, cracks or discontinuities over the length of the liner installation run.

Liner Fit to Existing Watermain

The outside surface of the finished liner shall be in 100 per cent contact with the inside surface of the existing watermain and shall adhere to the inside surface of the existing watermain in accordance with requirements for the specific product – such as to affect pressure tight seal at and around water service connection. One hundred per cent contact means that there shall be no measurable or visible gap or annulus space between the liner and the watermain over the full circumference/perimeter and over the full length of the liner installation. The inside surface of the existing watermain is the surface after the watermain has been prepared for lining in accordance with the cleaning and preparation requirements. Where any space or gap exists between the outside surface of the liner and the inside surface of the existing watermain the liner fit (and liner) will be considered deficient.

Where the required tight fit has not been achieved throughout the entire installation, the liner shall not be acceptable and the liner shall be removed and replaced with a new liner that is a tight fit. If the forgoing removal and replacement is not possible then a new watermain shall be installed.

The only exception to the tight fit requirement is at normal joint gaps in the existing watermain pipe to pipe joints, where the liner may bridge or partially bridge the gap. Where a liner product bridges or partially bridges joint gaps, the liner must have the required properties to bridge the gap when under internal pressure (up to an including the design pressure) or subject to external load such that the liner does not crack or otherwise deteriorated due the bridging stress in the liner over the design life of the liner.

Finished Liner Installation

The liner shall be free of any interior bulges, ribs, ripples, tears, holes, cracks, separations, blisters, eruptions, stains or other irregularities except where these irregularities correspond with irregularities in the existing watermain after cleaning and preparation in accordance with TS 7.60 requirements.

Where folds, ridges, ribs, ripples and wrinkles are a direct result of obtaining the required tight fit, they shall be acceptable providing that the liner installed was correctly and properly sized for the existing watermain based on the inside diameter measurements (refer TS 7.60.22) made as required in TS 7.60 herein. Where such folds, ridges, ribs, ripples and wrinkles are due to improper or incorrect sizing of the liner, they shall not be acceptable.

Liner Terminations at Ends of Liner Runs

Liner terminations at the ends of liner runs shall be smooth, square and neatly cut. There shall be no separation from the inside surface of the existing watermain. The terminations shall be watertight to the requirements for external and internal hydrostatic pressure.

Liner Termination at Valves

At valves, the interface between the exterior surface of the liner and the valve shall be watertight to the requirements for external and internal hydrostatic pressure. The finished ends of the liner shall be neat and smoothly cut.

Liner Fold

A fold is defined as a longitudinal ridge in the liner that is due to the liner's circumference being in excess of the circumference of the post cleaning and preparation circumference of the watermain. Some types of liner tubes require sizing with an excess circumference to assure that the liner fully contacts the inside surface of the watermain and to provide the needed level of tight fit. Where such folds occur they shall be tightly compressed and have no void space either within the fold or behind the fold and no excess epoxy resin within the fold or behind the fold. A fold configuration shall not result in any annular space between the liner and the watermain. Folds shall not have any tube inner membrane material trapped within the fold.

Fold size may vary along the lined section in correspondence with variations in the watermain size along the same section. The fold size shall be the minimum that corresponds with the best available liner size for the installation that makes sure that a tight fit exists along the complete length of the lined watermain section and be as described by the contractor (see TS 7.60.22).

Regardless of fold size and configuration, no fold shall be permitted that will negatively affect the long-term performance of the liner for its intended purpose including liner performance in accordance with design requirements.

Liner Wall Thickness and Tolerance

The liner's finished in place wall thickness shall be as identified in the engineered design submitted with the Tender (or as submitted at a later date) meeting the requirements of the Contract and as approved by the Contract Administrator, subject to the following tolerances:

- Liner wall thickness minus tolerance is 0 per cent.
- Liner wall thickness plus tolerance shall not result in the watermain lined inside diameter being less than 92.5 per cent of the watermain pre-lining inside diameter.

The determination of the actual thickness of the installed liner shall be the lesser of:

a. The thickness measured in accordance with the method in ASTM D5813-04(2008). It is noted that among its provisions for measuring and for calculating the effective thickness from these measurements, the ASTM 5813 requires that no thickness can be less than 87.5 per cent of the required thickness.

b. The thickness of the sample taken in accordance with the method in ASTM D790 or ISO 11296 if the ASTM X1 governing equation is X1.1, X1.3 or X1.4; or the thickness of the sample taken in accordance with the method in ASTM D638 or ASTM D2290 if the ASTM F1216 X1 governing equation is design equation X1.7. Note that when design reconciliation is involved based on sample test results, the governing equation may differ from the governing equation in the approved design accepted by the Contract Administrator.

The effective thickness for comparison to the required thickness shall not include any non-structural layers or membranes. The thickness of non-structural layers or membranes shall be measured by micrometer of similarly precise measurement device.

Liner Physical Properties

The final installed liner shall have the physical properties as required in TS 7.60.29. See TS 7.60.38 for reconciliation of sample test results.

Damaged or Defective Liner

Should the lining be damaged as a direct result of the Contractor's operation or reveal evidence of defective work or materials prior to the completion of the contract, such damaged or defective portions shall be removed and replaced

TS 7.60.37 Samples from Installed Liners and Sample Testing

Samples of Finished Liner

The Contractor shall provide samples of completed liner from within the watermain and/or a restrained sample within the host pipe excavation pit and/or like diameter pipe from the same wet out and installation. A sample shall be of a sufficient size and length to allow the required testing, including containing both flat plate and cylindrical sections as required. Cylindrical samples shall be fully contained within a piece of the existing watermain. One sample shall be provided for each 600 m (on average) of lined watermain. The Contract Administrator has the right to request that these samples be taken from any particular location at any time. The samples shall be used for inspection and testing purposes.

The contract administrator reserves the right to increase the frequency of sampling.

The samples shall be marked with contract number, size, street address and date removed. Immediately upon removal the Contractor shall give the samples into the custody of the Contract Administrator. Where samples have been removed, the watermain shall be closed up with new pipe and fittings in accordance with the specifications.

Samples Testing

The Contractor shall provide for testing of the samples at a testing agency approved by the Contract Administrator. The Contractor shall authorize the testing agency to forward the test reports to the Contract Administrator and communicate with the Contract Administrator concerning the testing and results. The Contract Administrator will arrange for delivery of the samples to the testing agency.

The testing shall determine following properties of the liner sample(s):

Thickness, (t)
Flexural Modulus in Hoop Direction (FMH)
Tensile Strength in Axial Direction (TSA)
Tensile Strength in Hoop Direction (TSH)

Thickness (t)

The thickness measurement shall be in accordance with TS 7.60.36 Liner Wall Thickness and Tolerance.

Flexural Modulus in Hoop Direction (FMH)

Flexural modulus in the hoop direction (FMH) means the flexural modulus tested in the liner's hoop direction.

The FMH testing shall be in accordance with ISO 11296, which requires curved specimens cut from the cylindrical sample.

In situations where a full cylindrical sample cannot be obtained and only a flat plate sample is available then, and with the permission of the CA, the FMH shall be determined by testing specimens from the flat plate sample where the specimens are cut from the orientation of the flat plate sample that corresponds with the hoop direction of the liner. This testing shall be in accordance with the ASTM D790.

In situations where hoop direction specimens from the flat plate sample are not available, and with the permission of the CA, specimens cut from the orientation of the flat plate sample that corresponds with the axial direction of the liner may be used. This testing shall be in accordance with the ASTM D790. Test results from axial direction testing shall be transformed to FMH by the use of an axial to hoop transformation factor (AHTF), which is acceptable to the CA. The axial to hoop transformation factor (AHTF) shall have been obtained from sufficient testing of flat plate samples whereby testing was done both in the axial and hoop direction. The transformation factors shall be acceptable to the Contract Administrator.

Tensile Strength in Axial Direction (TSA)

Tensile strength in the axial direction (TSA) means the tensile strength tested in the liner's axial direction.

The TSA testing shall be in accordance with ASTM D638. The test specimens shall be taken from the axial direction of the full cylindrical sample or in the direction of a flat plate sample that correspond with the axial direction of the liner.

Tensile Strength in Hoop Direction (TSH)

Tensile strength in the hoop direction (TSH) means the tensile strength tested in the liner's hoop direction.

When the field sample is suitable, the TSH testing shall be in accordance with ASTM D2290 whereby test specimens shall be rings taken from the full cylindrical sample. When the sample is not suitable for ASTM D2290 testing, the TSH shall be determined by testing in accordance with ASTM D638 on specimens from a flat plate sample in conjunction with a Multiplier Factor (MF). Refer further below regarding the MF.

ASTM D2290 testing is suitable for liner samples that do not have longitudinal folds, ridges, fins or other surface non-uniformities. A liner product with a characteristic longitudinal fold is normally not suitable for ASTM D2290 testing. A liner product not designed to have a fold is normally suitable for ASTM D2290 unless the field sample to be tested has longitudinal anomalies (such as fins or ridges) that make the sample not suitable for ASTM D2290 testing.

When ASTM D2290 testing is used, the TSH shall be the result of the test and shall be considered the effective TSH for comparison with the TSH used in the design (before any long-term retention factor is applied in the design). When sample test results indicate that a design reconciliation is needed the TSH used in the design reconciliation shall be the effective TSH.

When ASTM D638 testing is used, the test specimens shall be cut from the flat plate sample so that the specimens are taken in the liner's hoop direction of the sample. The TSH obtained from the D638 testing shall be adjusted by a Multiplier Factor (MF) to obtain the effective TSH. Refer further below regarding the MF. The MF used shall be acceptable to the Contract Administrator. The effective TSH shall be compared with the TSH used in the liner design (before any long-term retention factor is applied in the design). When sample test results indicate that a design reconciliation is needed, the TSH used in the design reconciliation shall be the effective TSH.

The MF shall be determined by type testing of the liner product. The type testing to generate the MF is done by the liner manufacturer to qualify the product and is independent of the testing required by TS 7.60. This type testing is not required to be done on liner sample(s) from the Contract liner installations. The type testing to generate the MF involves a combination of ASTM D1599 and D638 type testing and is described further below.

The MF shall be generated from type testing by the liner manufacturer as follows:

1) A minimum of one ASTM D1599 test and a minimum of one ASTM D638 test shall be done by the liner manufacturer (or at a testing agency used by the manufacturer) and the samples shall be manufactured from the same materials at the same time. The D1599 test requires a full cylindrical sample for short-term burst testing and the D638 test requires a flat plat sample for TSH testing. The D1599 test cylindrical sample shall be representative of the typical routinely installed liner including representative longitudinal folds and other typical anomalies. The D638 specimens are cut from the flat plate sample in the direction that corresponds with the hoop direction of the liner cylindrical sample.

2) From the ASTM D1599 test result, the tensile TSH corresponding to the burst pressure shall be calculated using the Barlow formula and the geometric parameters of the cylindrical sample (inside diameter and wall thickness). Note that ASTM F1216 Equation X1.7 is simply a rearrangement of the Barlow formula for the lining situation where the outside diameter is constant and the inside diameter varies with the wall thickness.

3) The TSH calculated from the D1599 test is compared to the TSH yielded by the D638 test and a Multiplier Factor (MF) is determined. The MF equals the TSH calculated from the D1599 test divided by the TSH yielded by the D638 test. That is $MF = TSH_{D1599} / TSH_{D638}$. If the TSH calculated from the D1599 test is less than the TSH yielded from the D638 test then the MF will be <1.

4) An MF shall be determined for each family of liner products and for each liner diameter for which the effective TSH is required and for which the effective TSH cannot be determined by ASTM D2290 testing.

5) The MF is applied to ASTM D638 results from samples from actual liner installation to obtain the effective TSH for the liner installations.

The test results for unit properties shall meet or exceed the values used in design. The test results for thickness shall meet or exceed the design thickness subject to TS 7.60.36.

TS 7.60.38 Reconciliation of Sample Test Results

When sample test results for flexural modulus, tensile strength and thickness are at variance with required values, a Design Reconciliation made by using test properties in place of original design property assumptions (all other parameters remaining the same) may show that, despite the variance, the required liner performance has been achieved with a different combination of properties. The Contract Administrator has the right to allow, accept, reject or perform any Design Reconciliation.

Design Reconciliation shall not be acceptable when the sample test result flexural modulus, flexural strength or tensile strength does not meet the minimum values prescribed by the ASTM F1216-16. Also refer TS 7.60.29.

TS 7.60.39 CCTV Inspection of Completed Liner – V3

On completion of the lining of a watermain section, including all reinstatements of services, a CCTV inspection, called the V3, shall be done and recorded. The CCTV recording and reports shall be submitted to the Contract Administrator for approval. The Contract Administrator shall use the V3 CCTV submission as part of its process for approving the watermain liner installation.

Upon completion of V3, the Contractor shall remediate all defects and deficiencies as indicated in Appendix B: CIPP Defect Classification and Remediation or to the satisfaction of the Contract Administrator.

TS 7.60.40 Close Up of Watermain after Lining Complete

Upon completion of the CIPP liner, the openings in the watermain shall be closed as soon as possible using approved PVC watermain pipe and approved couplings. When using PVC pipe, approved restrainers shall be used to carry out the work. When PVC pipe used at fittings and change in direction of watermain shall be restrained with pipe restrainers according to Chapter 6, *Material Specifications* from the *Design Criteria for Sewers and Watermains* manual and installed in according to manufacturer's instructions.

Cathodic protection, jumper wires and tracer wires shall be installed as required before back fill of the close up location.

Close up of the watermain shall be done within 24 hours following CIPP lining of the watermain.

TS 7.60.41 Disinfection

Disinfection shall be according to TS 7.30 – *Procedure for Disinfecting Watermains*.

TS 7.60.42 Removal of Bypass and Temporary Services

After the tests on all water samples have been approved, the watermain shall be flushed, water service connections restored, excavations backfilled, the watermain returned to service and the temporary service lines removed.

The Contractor will be permitted to reuse temporary bypass service connections previously disinfected without re-disinfecting provided that precautions are taken, to avoid the potential for contamination, that include: immediately capping each end of the temporary bypass service prior to storage and reuse; and storing the temporary service lines in a manner that will lessen the likelihood of contamination.

Prior to the reconnection of the previously disinfected temporary service connection, the connection ends of the service pipe must be submerged in a 5 per cent sodium hypochlorite solution. The service pipe must then be flushed, the outside hose bib and "Y" connector sprayed with a 5 per cent sodium hypochlorite solution before final hook up of the temporary service pipe to provide service.

The Contractor shall satisfactorily restore the permanent property connections and leave streets, sidewalks and adjacent property in a neat and orderly condition. Any valves, corporation stops or other appurtenances that have been damaged due to cleaning and lining operations shall be replaced by the Contractor.

TS 7.60.43 Payment

Payment at the Contract Price shall be full compensation for all Labour, Equipment and Material to do the Work.

TS 7.60.44 List of Appendices

Appendix A: Water Services Statement

Appendix B: Defect Classification and Remediation Requirements

Appendix C: Hydrostatic Leak Test Record

Appendix D: Anticipated Changes to TS 7.60 for 2023 and 2024

TS 7.60

APPENDIX A

Water Services Statement (WSS)

Number of Pages: 1

WATER SERVICES STATEMENT (WSS)

Contract #:	Contractor's Name:	Street Name:
Pipe Material:	Pipe Internal Diameter:	Pipe Measurement (m):
Preliminary CCTV Inspection (V1) Date:		Post Cleaning & Preparation CCTV Inspection (V2) Date:
Start Pit #:		Finish Pit #:
V1 Comments:		
V2 Comments:		
V1 Camera Operator's Name:		V2 Camera Operator's Name:

W/S ON LEFT SIDE OF MAIN	W/S ON RIGHT SIDE OF MAIN	HOUSE #	DISTANCE FROM START PIT (M)	CLOCK POSITION	ESTIMATED W/S DIAMETER	ACTUAL W/S DIAMETER	UPGRADED W/S	MAIN STOP VISUALLY PLUGGED (YES/NO)	GRINDED W/S	NON-PROTRUDING W/S	W/S DRILLED	W/S BLOW BACK	W/S IN THE FOLD	W/S PLUGGED WITH RESIN	DRILLING REMARKS	REMARKS

Notes: _____

_____

TS 7.60

APPENDIX B

Standard Operating Procedure: CIPP Defect Classification

Number of Pages: 21

STANDARD OPERATING PROCEDURE: CIPP DEFECT CLASSIFICATION

OCTOBER 2018

Version 1.1

CIPP Defect Classification

1 Purpose

The City of Toronto has contracted contractors to perform construction services and consultants to perform contract administration services on the Trenchless Rehabilitation (CIPP System) of Existing Watermains projects throughout the City of Toronto. As part of these services, the contractors and consultants are responsible for tracking and controlling the quality of the installed liner by identifying and removing defects. Deficiencies are identified by reviewing the CCTV videos created after the existing pipes have been lined. This procedure identifies the various deficiencies that have been most commonly encountered, as well as the root causes behind them and recommendations of how to deal with them.

2 References

ASTM D2290	2016	Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe
ASTM D2412	2011	Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading

3 Responsibilities

- Consultant Liner Quality Controller (CLQC): Responsible for reviewing CCTV Videos, identifying deficiencies, and preparing reports to be submitted to the CQAM.
- Contractor Quality Assurance Manager (FQAM): Responsible for reviewing the report provided by the CLQC and providing responses to each of the identified deficiencies.

4 Definitions

CCTV = Closed-Circuit Television
CIPP = Cast In Place Pipe

5 Defect Classification

The following section covers the individual classes of deficiencies that have been encountered throughout the Trenchless Rehabilitation (CIPP System) of Existing Watermains projects. Each class of deficiency has a root cause and a general description for that class, followed by examples of varying severity or sub-classes of that deficiency type:

5.1 Liner Fold

5.1.1 General Root Cause

The longitudinal folds in the liner are caused by the slight over-sizing of the liner diameter compared to the host pipe diameter. The extra liner material bunches together into the longitudinal fold. The over-sizing of the liner is a property of this type of liner and is done to ensure a tight fit to the host pipe.

5.1.2 General Defect Description

A generally thin and short longitudinal fold which runs the length of all liners installed.

5.1.3 Examples

5.1.3.1 Example 1 – Benign

Root Cause: Standard fold due to slight over-sizing of the liner to ensure tight fit.
Description: Thin and short longitudinal fold which runs the length of the installed liner.
Recommendation: Standard feature of the liner. To be left as is.

5.1.3.2 Example 2 – Moderate

Root Cause: Large fold caused by the liner passing through a section of pipe with reduced diameter compared to the diameter of the host pipe the liner was sized for.

Description: Thin and tall longitudinal fold which runs the length of the reduced diameter host pipe section. Fold height is greater than 25% of the diameter of the liner. The thin and tall fold provides a location of stress concentration that can reduce the pressure class of the liner far beyond the effect of a standard fold. Fold height is also sufficient to cause issues with CCTVing, swabbing, and cleaning.
Recommendation: Dig and replace at the moment but further testing could validate leaving as it is depending on the severity (see Section 6 Testing).

5.2 Clustered Protrusions

5.2.1 General Root Cause

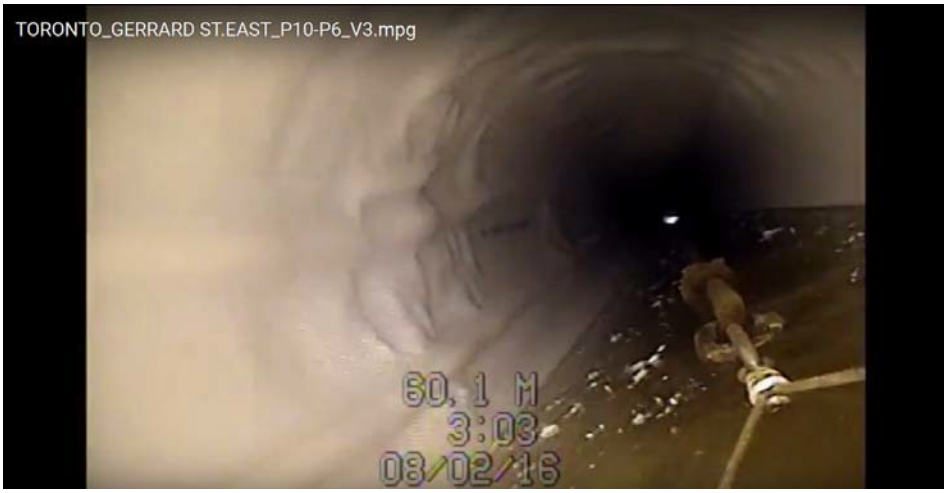
This class of defect is caused by imperfections inside the host main that are unable to be removed during cleaning.

5.2.2 General Defect Description

As the host pipe is lined the liner takes on the shape of the host pipe, therefore any imperfections within the host pipe manifest as imperfections in the liner. The CIPP liner is designed to wrap around any such imperfections and they end up as rounded bumps throughout that section of the liner. In these sections the liner thickness is generally unchanged by the host pipe imperfection beneath, the whole of the lump is generally due to the host pipe.

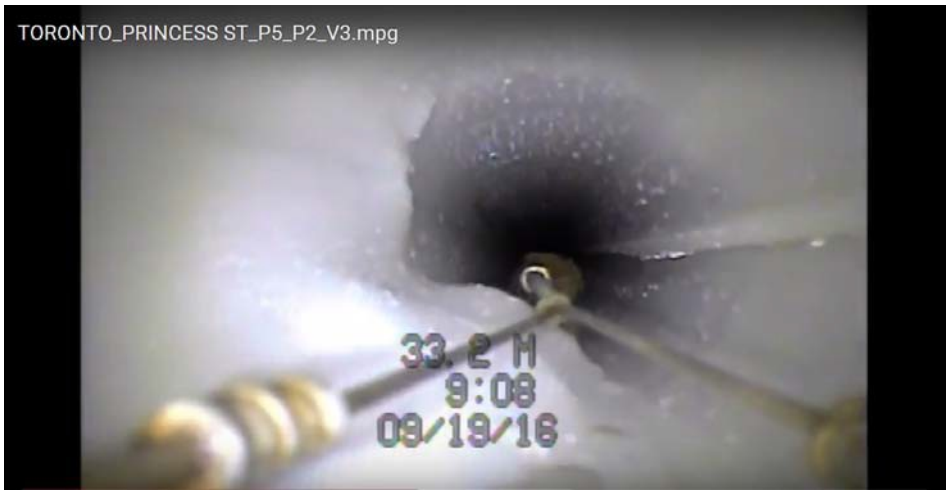
5.2.3 Examples

5.2.3.1 Example 1 - Benign



Root Cause: Tightly bonded cement or hard tuberculation that is resistant to pressure flushers and scrappers. Increase in number of passes or even pressure could lead to host pipe being subjected to blow holes.
Description: Short sections of small bumps in the liner. Often seen in groups, but do not protrude significantly into the liner.
Recommendation: To be left as is.

5.2.3.2 Example 2 - Severe



Root Cause: Lead deposit at the base of the pipe due to improper pouring of lead when joining pipe together. The lead could not be removed by cleaning.
Description: Large raised uneven bumps that results in a significantly distorted liner. The bumps protrude significantly, and noticeably reduce the cross-sectional area of the liner. The ridges can cause stress concentrations that may reduce the pressure class of the liner. The cross-sectional geometry of the liner is far from circular.
Recommendation: Dig and replace this section pre- or post-lining depending on the severity.

5.2.3.3 Example 3 – Severe

Root Cause: Unlike the other clustered protrusion defects above, there were no imperfections inside the host main here. These protrusions were instead caused by bunching up of the inner liner while the outer liner exhibits a larger than normal fold. It is not known what caused the bunching up of the inner liner.
Description: Large raised uneven bumps that results in a localized distortion of the liner as well as a larger fold in this region, while the remainder of the liner looks pristine. The ridges and larger fold can cause stress concentrations that may reduce the pressure class of the liner.
Recommendation: Dig and replace this section.

5.3 Circumferential Folding

5.3.1 General Root Cause

This class of defect is caused by errors in the liner material distribution during the installation of the liner.

5.3.2 General Defect Description

Any twisting or accumulation of liner material during the installation of the liner can result in circumferential folds after the epoxy is cured. Unlike axial folds which travel parallel to the installation direction of the liner, these types of folds are perpendicular to the installation direction. Although this type of fold does not impact the tight fit of the liner, it is not desired in order to obtain a tight fit.

5.3.3 Examples

5.3.3.1 Example 1 – Benign Type 1

Root Cause: Helical fold due to the rotation of liner during insertion. This could also be influenced by swab movement during the forming stages.
Description: Non-continuous perpendicular fold, which does not significantly reduce the circumferential area of the liner. Can consist of several folds in sequence but no single fold is of impactful size.
Recommendation: To be left as is.

5.3.3.2 Example 2 – Benign Type 2

Root Cause: “Accordion” effect due to accumulation of material during the forming stages.
Description: Continuous perpendicular fold which runs the full circumference of the liner. Folds are quite small in height and do not noticeably reduce the circumferential area of the liner.
Recommendation: Depending on the level of wrinkle (substantiated with existing or future test works (see Section 6 Testing)) can be left as is or removed.

5.3.3.3 Example 3 - Severe

Root Cause: “Accordion” effect due to accumulation of material during the forming stages.
Description: Continuous perpendicular fold which runs the full circumference of the liner. Significantly reduces the circumferential area and therefore the hydraulic carrying capacity.
Recommendation: Dig and replace.

5.3.3.4 Example 4 – Severe

Root Cause: “Accordion” effect due to accumulation of material during the forming stages. Liner not property stretched out after being threaded through host pipe
Description: Cluster of continuous perpendicular folds which runs the full circumference of the liner and which are also folding in on each other. Significantly reduces the circumferential area and therefore the hydraulic carrying capacity. Also significantly reduces the pressure rating of the liner at this section.
Recommendation: Dig and replace.

5.4 Axial Lumps

5.4.1 General Root Cause

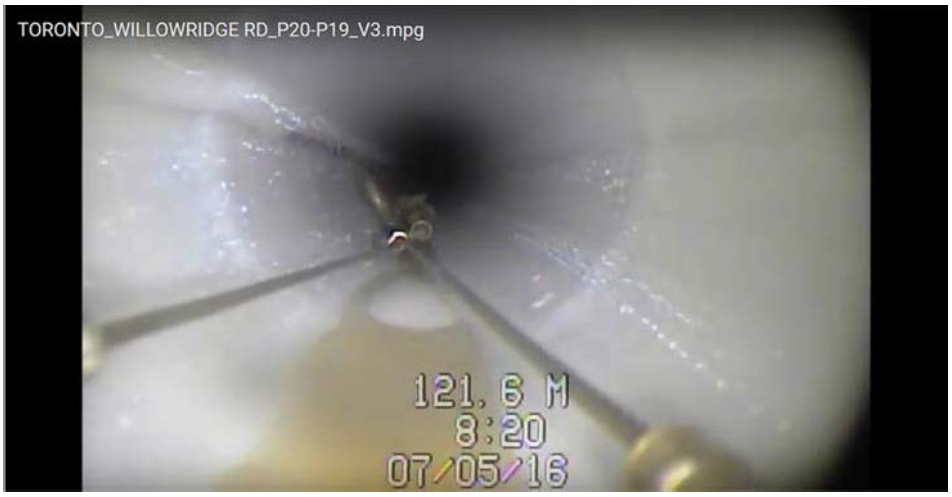
This class of defect is caused due to external pressure (water or air) during the forming of the liner. This generally occurs at large offsets in the host pipe joints or near valves.

5.4.2 General Defect Description

The external pressure during the lining process forces the liner inwards resulting in an elongated smooth lump in the liner. These lumps have a characteristic ovoid shape but can occur in a large range of widths and lengths. The interior of the lump can be fully epoxy or an air pocket, it is nearly impossible to determine which without excavating the lump.

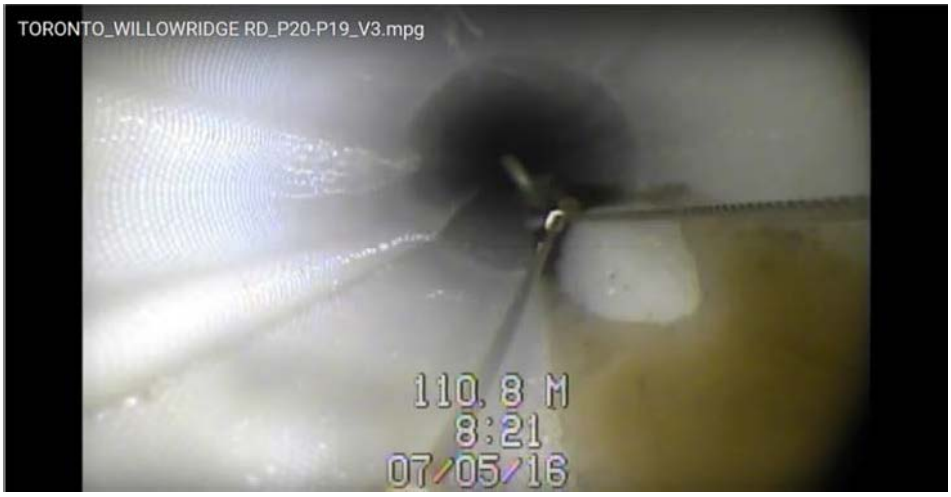
5.4.3 Examples

5.4.3.1 Example 1 - Benign



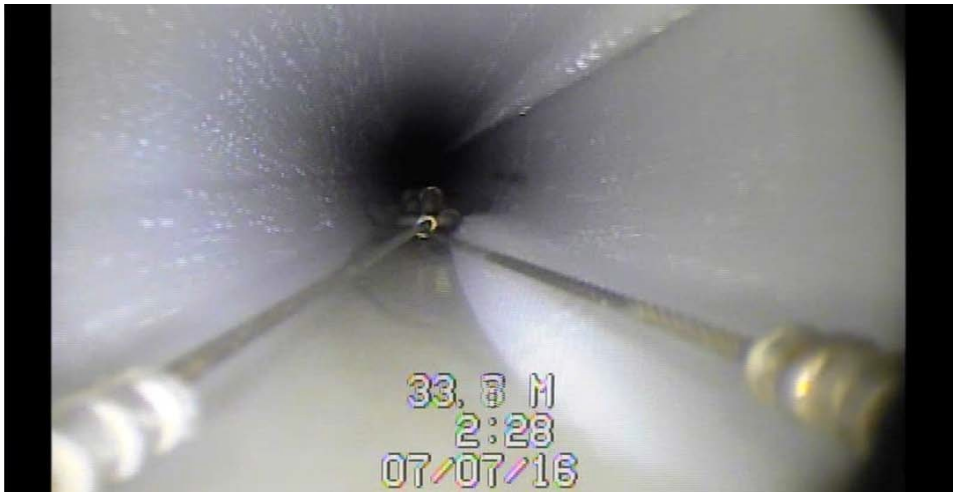
Root Cause: Bump due to external pressure (water or air) during the forming of the liner.
Description: Small size ovoid lump along the bottom of the liner. Width at the lump base is <10% of the circumference of the liner. Height of the lump is <10% of the diameter of the liner. Lump poses no problem to the liner.
Recommendation: To be left as is.

5.4.3.2 Example 2 – Moderate Type 1



Root Cause: Bump due to external pressure (water or air) during the forming of the liner.
Description: Medium size ovoid lump along the bottom of the liner. Width at the lump base is 15%-25% of the circumference of the liner. Height of the lump is 15%-25% of the diameter of the liner. Lump may pose a problem to the liner by reducing hydraulic carrying capacity and providing a stress concentration point that can reduce the pressure class of the liner.
Recommendation: Dig and replace at the moment but further testing could validate leaving as it is depending on the severity (see Section 6 Testing).

5.4.3.3 Example 3 – Moderate Type 2

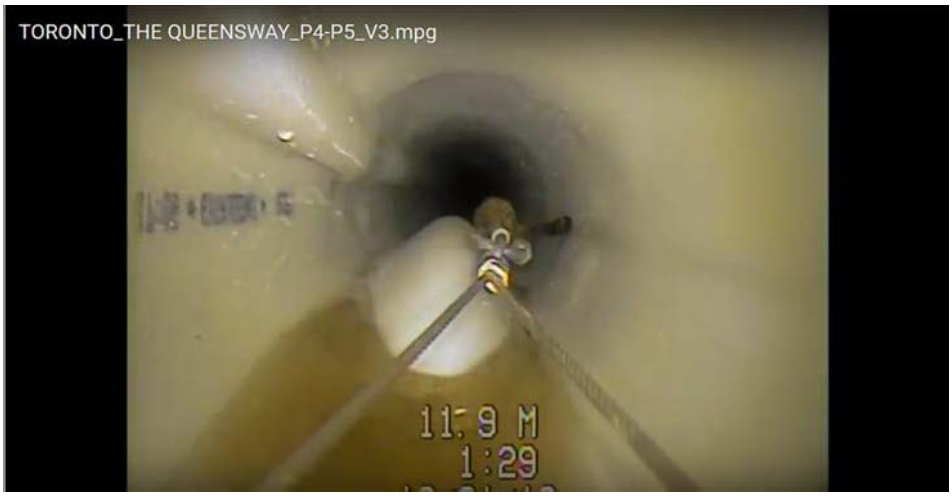


Root Cause: Bump due to external pressure (water or air) during the forming of the liner.
Description: Medium size ovoid lump along the bottom of the liner. Width at the lump base is 15%-25% of the circumference of the liner. Height of the lump is 15%-25% of the diameter of the liner. Lumps size is on the low end of medium but is far longer than typical. Lump may pose a problem to the liner by reducing hydraulic carrying capacity and providing a stress concentration point that can reduce the pressure class of the liner.
Recommendation: Dig and replace at the moment but further testing could validate leaving as it is depending on the severity (see Section 6 Testing).

5.4.3.4 Example 4 – Moderate Type 3

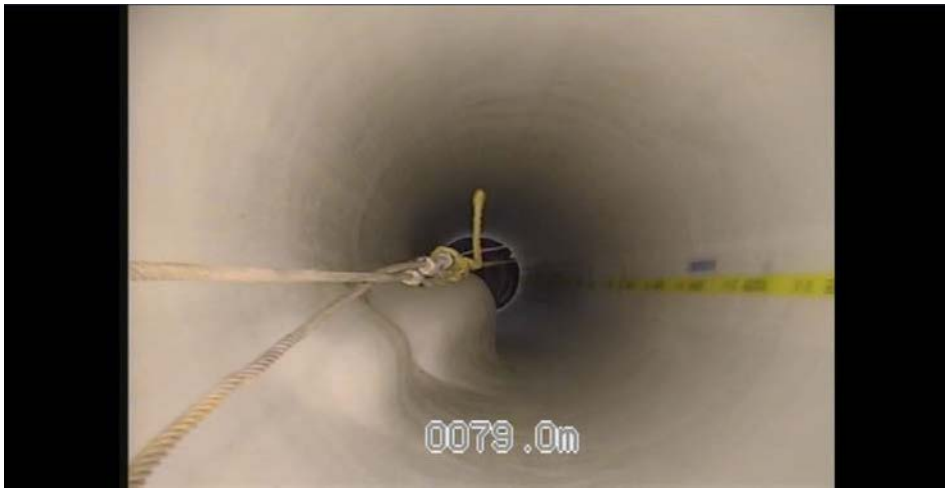
Root Cause: Different than standard lumps, its shape is caused by instantaneous depressurization or rapidly pushed up air during lining due to an adjacent valve.
Description: Tall-thin medium size ovoid lump along the side of the liner. Width at the lump base is ~15% of the circumference of the liner. Height of the lump is ~25% of the diameter of the liner. Lump may pose a problem to the liner by reducing hydraulic carrying capacity and providing a stress concentration point that can reduce the pressure class of the liner.
Recommendation: Dig and replace at the moment but further testing could validate leaving as it is depending on the severity (see Section 6 Testing).

5.4.3.5 Example 5 - Severe



Root Cause: Bump due to external pressure (water or air) during the forming of the liner.
Description: Large size ovoid lump along the bottom of the liner. Width at the lump base is 15%-25% of the circumference of the liner. Height of the lump is >30% of the diameter of the liner. Lump poses a problem to the liner by reducing hydraulic carrying capacity and providing a stress concentration point that can reduce the pressure class of the liner.
Recommendation: Dig and replace.

5.4.3.6 Example 6 - Severe



Root Cause: Multiple lumps due to external pressure (water or air) during the forming of the liner.
Description: Large size ovoid lump with smaller sister lump along the bottom of the liner. Width at large lump base is 15%-25% of the circumference of the liner. Height of the lump is >30% of the diameter of the liner. Lump poses a problem to the liner by reducing hydraulic carrying capacity and providing a stress concentration point that can reduce the pressure class of the liner.
Recommendation: Dig and replace.

5.5 Liner Collapse

5.5.1 General Root Cause

This class of defect is rare and is caused by water flowing in behind the liner from a hole in the host pipe or from a service connection that was not properly closed before or during the curing process. The weight of the water pushes down on the liner before it can cure and causes it to collapse. The liner then cures hard in this collapsed state.

5.5.2 General Defect Description

Very large sag or lump in the liner that usually runs for several meters. Generally, CCTV equipment will not be able to bypass the collapsed section of the liner and the section must also be CCTV'd in the opposite direction to determine the extent of the collapse.

5.5.3 Examples

5.5.3.1 Example 1 - Severe

Root Cause: Liner collapse caused by mater meter being turned on at adjacent home with service open. Water ran back through the line and behind the liner causing it to collapse.
Description: Very large sag in top of the liner that ran for 3-4m.
Recommendation: Dig and replace.

5.5.3.2 Example 2 – Severe

Root Cause: This section was below two water services, assumption is that there was a leak overnight through the lining day which accumulated water at the base of this section and was then lined over.
Description: Very large lump with large base on the bottom of the liner.
Recommendation: Dig and replace.

5.6 Premature Curing

5.6.1 General Root Cause

This class of defect is extremely rare and is caused by premature curing of epoxy due to localized higher than normal temperatures of epoxy. These higher temperatures can develop during hot weather if the liner is improperly kept cool during the layout stage prior to installation.

5.6.2 General Defect Description

Defect appears as numerous hard-looking irregular stacked lumps and protrusions.

5.6.3 Example

Root Cause: Excessive epoxy consumption and higher than normal temperature exacerbates the curing effect of the epoxy and can caused this defect.
Description: Defect appears as a clustered bumps type of defect, but every bump is the size of a large protrusion. This type of defect can occur continuously throughout a long section of the liner. Pressure class and hydraulic capacity of this section is severely reduced.
Recommendation: Dig and replace entire section of the liner containing this defect.

5.7 Uncured Liner

5.7.1 General Root Cause

Water present in the host pipe mixing with and washing away the epoxy at a localized section of the liner.

5.7.2 General Defect Description

Small lump stained reddish-orange behind the translucent non-structural surface layer of the liner, the staining may flow down to the bottom of the liner. The reddish-orange colour is cause by the rusty water behind the liner soaking into the felt. When cut out this defect is found to not have been cured and has no structural strength.

5.7.3 Example

Recommendation: Dig and replace section of the liner containing this defect, check for voids behind any folds in the vicinity of this defect as it is possible for the epoxy to be washed away for a long distance behind the fold.

5.8 Bend Folding

5.8.1 General Root Cause

The folds in this defect are caused by “sleeving” across bend due to the difference in radius of each side of the bend.

5.8.2 General Defect Description

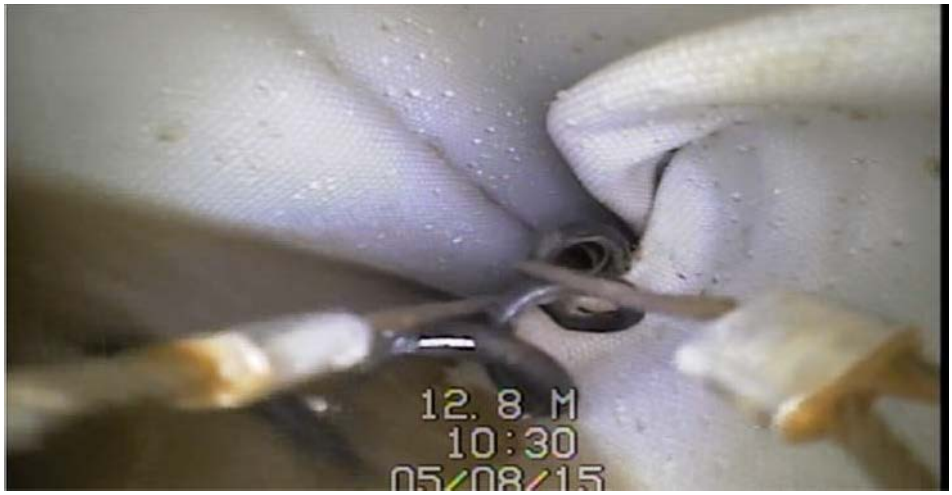
“Sleeving” across bends is generally acceptable. The “sleeving” results in a combination of short circumferential folds together with the standard axial fold on the short radius side of the bend. The degree of folding depends largely on the bend angle and orientation of the bend.

5.8.3 Examples

5.8.3.1 Example 1 - Benign

Root Cause: “Sleeving” across bend due to a 45-degree bend.
Description: Non-liner defect. Some short circumferential folds, but to be expected and does not cause a detrimental effect to the liner.
Recommendation: To be left as is.

5.8.3.2 Example 2 - Severe



Root Cause: “Sleeving” across bend due to a greater than 45-degree bend.
Description: Folding poses a problem to the liner by reducing hydraulic carrying capacity and providing areas of stress concentration that reduce the pressure class of the liner.
Recommendation: Dig and replace.

5.9 Operator Induced Error (Epoxy Plugged Service)

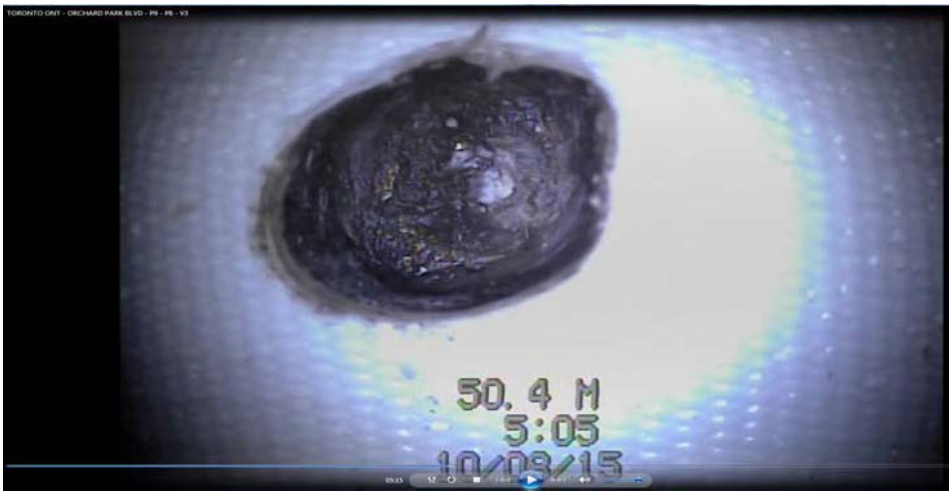
5.9.1 General Root Cause

Epoxy plugged services occur when either a service connection is missed during the plugging process or the service plug is inserted incorrectly and allows epoxy to migrate into the service and plug it. The plugged service must be rectified by external reinstatement prior to putting the watermain into service.

5.9.2 General Defect Description

Defect appears as a partially drilled out water service that is blocked by epoxy. The epoxy may appear dark yellow to black, or whitish is it has been partially shredded and stressed during the drilling process. A plugged service can be differentiated from a fully drilled service by the reflection of light off the glossy epoxy.

5.9.3 Examples



Root Cause: Epoxy plugged services due to missed or incorrectly installed plugs.
Description: Migration of epoxy into the service line rendering the water service inoperable.

Recommendation: Service is to be reinstated externally.

5.10 Operator Induced Error (Miss-Drill)

5.10.1 General Root Cause

Miss-Drilling while attempting to drill out plugs placed in service connections. Operator misdiagnoses the location of service protrusion and proceeds to drill through resulting in a miss-drill. Liner integrity is breached in most cases.

5.10.2 General Defect Description

Defect appears as a significant ovoid tear in the liner, will generally result in being able to see the exposed pipe behind the epoxy. A void may also be visible as a dark spot behind the liner at the miss-drill location.

5.10.3 Examples

Root Cause: Miss-Drilling.
Description: Breach of liner integrity around the actual service protrusion.
Recommendation: Dig and replace. Service is to be reinstated externally.

5.11 Operator Induced Error (Liner Tear)

5.11.1 General Root Cause

Tearing of liner due to abrasive action. This type of operator induced error is rare. Unintentional consequences of winching of the robotic equipment inside lined pipe resulting in a tearing or fraying of liner usually near bends.

5.11.2 General Defect Description

This class of defect appears as a linear frayed tear at a fold or protrusion in this pipe. Depending on the degree of the tear it may be possible to also see exposed epoxy.

5.11.3 Examples

5.11.3.1 Example 1 – Liner Tear in Protrusion

Root Cause: Abrasive action of winching mechanism while pulling CCTV camera equipment.

Description: Breach of liner integrity at frayed tear located on a protrusion at the bottom of the liner.
Recommendation: Dig and replace.

5.11.3.2 Example 2 - Liner Tear in Fold

Root Cause: Commonly occurs when there are multiple bends in a run as well as large axial folds at the bends. The bends cause tension in the CCTV winching rope resulting in contact between the fold and the rope. This action causes tearing or fraying of the liner fold at the bends.
Description: Appears as a linear frayed tear at a fold, the CCTV winching rope can be seen passing through a bite created in the fold.
Recommendation: Dig and replace.

5.12 Operator Induced Error (Puncture)

5.12.1 General Root Cause

Damage to the liner's non-structural surface layer prior to pulling the liner through the host pipe.

5.12.2 General Description

Visible hole in the liner's non-structural surface layer with epoxy smearing on the liner surface around the hole.

5.12.3 Example – Severe

Recommendation: Dig and replace area of the liner containing this defect plus 0.5m on either side.

5.13 Operator Induced Error (Protrusions)

5.13.1 General Root Cause

During lining host pipe features such as existing substandard services that have not been grinded down or foreign objects such as corks, swab pieces, etc… may be lined over accidentally and result in protrusions.

5.13.2 General Description

These protrusions generally appear as isolated bumps in the liner wall which are of non-ovoid or non-smooth shapes. It can be difficult to uncover the exact root cause that results in a specific type of protrusion, but it is possible to identify the cause in the pre-lining video.

5.13.3 Examples

5.13.3.1 Example 1 – Benign Type 1

Root Cause: Lining over an existing substandard service that has not been grinded down.
Description: Cylindrical protrusion at the top of the liner, the protrusion appears isolated as the rest of the liner is smooth.
Recommendation: To be left as is.

5.13.3.2 Example 2 – Benign Type 2

Root Cause: Lining over a foreign object such as a cork, swab piece, etc… This defect cannot have been caused by a substandard service as it is located on the bottom of the liner.
Description: Irregular non-ovoid protrusion on bottom of liner, the protrusion appears isolated as the rest of the liner is smooth.
Recommendation: To be left as is.

6 Testing

The defect classification system outlined in Section 5 Defect Classification relies significantly on visual inspection, experience with viewing past defect examples, and past precedent. There are several types of defects, specifically Axial Lumps and Circumferential Folding, where further material property testing would be very useful to determine the exact effects of defects on the performance of the liner. Examples of such material testing are ASTM D2290 for the hoop tensile strength and ASTM D2412 for the external loading characteristics; further tests are possible depending on the type of defect. These tests would be performed on liner coupon samples containing defects of various levels of severity, as well as on control samples of coupons without defects. This would provide an empirical way to discover the impact of such defects on the liner.

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APPENDIX C

Hydrostatic Leak Test Record

Number of Pages: 1

TORONTO
Engineering & Construction Services

HYDROSTATIC LEAK TEST RECORD
(FOR BURIED WATER & WASTEWATER PRESSURE PIPING)

Date of Test:		
Test No.:		Retest: Yes ☐ No ☐
Project:		Project No.:
Contractor:		Inspector: (Print Name)
Pipeline Identification:		
Location of Test:		
Test From: (Station)	To: (Station)	Test Fluid:
Test Specification:		

For _____ metres, pipe diameter of _____ makeup water = _____ litres

(length) (mm)

First Test: ☐ Subsequent Test: ☐

Allowable Leakage (L) Test Computation:

Refer to OPSS 441.07.24.03 which states the allowable leakage of 0.082 litres per millimetre of pipe diameter per kilometre of pipe for a 2-hour test period.

Remarks:

Contractor Certification:

Signature

Title

Inspector:

Signature

Title

TS 7.60

APPENDIX D

Anticipated Changes to TS 7.60 for 2023 and 2024

Number of Pages: 1

TS 7.60: APPENDIX D

Anticipated Changes to TS 7.60 for 2023 and 2024

Anticipated changes for 2023 construction year:

1. Leaks caused by deterioration of the host pipe at couplings and regressed saddle service taps will no longer be excluded as deficiencies.

Anticipated change for 2024 construction year:

1. Permanent end seals and couplings of watermain shall not rely on host pipe.

2. Mechanical seals shall be required for service connections 25 mm and less. The practice of only drilling out the liner to instate services will no longer be accepted.

3. Contractors shall provide, as part of their bid submission, ASTM D2990 50-year tensile rupture strength in hoop and axial direction for each class of liner being proposed

Sept 30, 2022