



**CONSTRUCTION SPECIFICATION FOR THE REHABILITATION OF  
CONCRETE, METAL AND MASONRY CULVERTS, STORMSEWERS, AND  
ASSOCIATED STRUCTURES WITH POLYURETHANE SPRAY-ON LINER**

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This specification covers the requirements for protecting and rehabilitating existing concrete, metal, and masonry pipe culvert, stormsewer, box culvert, and associated structures by monolithic spray-on lining application of a high-build, rigid, and solvent-free polyurethane coating to eliminate infiltration, provide corrosion protection, repair voids, and provide complete structural integrity.

**469.02 REFERENCES**

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

**Ontario Provincial Standard Specifications, Construction**

OPSS 409	Closed-Circuit Television (CCTV) Inspection of Pipelines
OPSS 411	Cleaning and Flushing of Culverts, Pipe Sewers, Catchbasins, Maintenance Holes, Ditch Inlets, and Oil-Grit Separators
OPSS 490	Site Preparation
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 517	Dewatering
OPSS 539	Temporary Protection Systems
OPSS 919	Formwork and Falsework
OPSS 929	Abrasive Blast Cleaning - Concrete Construction

## Ontario Provincial Standard Specifications, Material

OPSS 1301 Cementing Materials  
OPSS 1302 Water  
OPSS 1306 Burlap

## Ontario Ministry of Transportation Publications

MTO Forms:

PH-CC-701 Request to Proceed  
PH-CC-702 Notice to Proceed

## CSA Standards

S6-19 Canadian Highway Bridge Design Code

## American Society for Testing and Materials (ASTM):

C109/C109M-21 Test Method for Compressive Strength of Hydraulic Cement Mortars  
C579-18 Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing, and Polymer Concrete  
C1216/C1216M-23 Test Method for Adhesion and Cohesion of One-Part Elastomeric Solvent Release Sealants  
C882/C882M-20 Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear  
D543-21 Practices for Evaluating the Resistance of Plastics to Chemical Reagents  
D638-22 Test Method for Tensile Properties of Plastics  
D695-15 Test Method for Compressive Properties of Rigid Plastics  
D790-17 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials  
D2240-15(2021) Test Method for Rubber Property - Durometer Hardness, Type D  
D2584-18 Test Method for Ignition Loss of Cured Reinforced Resins  
D2990-17 Test Method for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastic  
D4541-22 Test Method for Pull-off Adhesion Strength of Coatings Using Portable Adhesion Testers  
D5365-18 Test Method for Long-Term Ring-Bending Strain of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe  
D7234-22 Test Method for Pull-off Strength of Coatings on Concrete Using Portable Pull-off Adhesion Testers  
F1216-22 (Including Appendix XI-X7): Design Parameters for Buried Structures (structural rehabilitation) Utilizing the External Buckling Equation for Thickness Determination

## National Association of Corrosion Engineers (NACE International):

The published standards of National Association of Corrosion Engineers (NACE International)

## The Society for Protective Coatings (SSPC):

The published standards of the Society of Protective Coatings

## 469.03 DEFINITIONS

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

**Applicator** means a manufacturer-certified product application company for the construction of the Polyurethane Liner as per the manufacturer's requirements and to its satisfaction.

**Associated Structures** mean a manhole, catch basin, ditch inlet, or valve chamber.

**Box Culvert** means existing culvert constructed of precast reinforced concrete box units rectangular in cross-section.

**Design Engineer** means the Engineer retained by the Contractor who produces the design and Working Drawings and other engineering documents required of the Contractor.

**Design Checking Engineer** means a separate Engineer from the design Engineer retained by the Contractor who checks the design and Working Drawings and other engineering documents prepared by the design Engineer required of the Contractor.

**Host Pipe** means existing original pipe culvert or sewer requiring rehabilitation.

**Liner** means a material which acts as a lining inside the host pipe, box culvert, or associated structures.

**Manufacturer's Site Representative** means a technical representative who is specialized and experienced in spray-on structural polyurethane liner for host pipe and box culvert and who will be present on site during the host pipe preparation and spray-on lining application work.

**Polyurethane** means a plastic composite material, made up of one or more polymer resins joined by urethane links. Strong and mouldable, polyurethanes are an extremely versatile polymer used in many applications.

**Polyurethane Liner** means a polyurethane material acting as a protective lining against corrosion and structural deficiencies inside the host pipe, box culvert, or associated structures.

**Resin** means an organic polymer, solid or liquid; usually thermoplastic or thermosetting.

**Spray-On Lining** means a method for applying a lining of cement mortar, polymer, or resin by rotating a sprayhead which is winched through the existing pipe culvert, sewer, or box culvert or applying a lining of cement mortar, polymer, or resin by hand spraying.

## **469.04 DESIGN AND SUBMISSION REQUIREMENTS**

### **469.04.01 Design Requirements**

The engineering design of the polyurethane liner shall be in accordance with the applicable ASTM standards and as specified in the Contract Documents with the following criteria:

- a) Design conditions shall assume fully deteriorated condition of the host pipe, box culvert, or associated structures.
- b) Parameters for design shall be according to Table 1.

### **469.04.02 Submission Requirements**

#### **469.04.02.01 Working Drawings**

Three copies of written procedures and Working Drawings showing the design calculations for the wall thickness of the polyurethane liner in the host pipe shall be submitted to the Contract Administrator a minimum of 2 weeks or as per the Contract Documents, prior to commencement of the polyurethane liner application. Prior to making a submission, the seal and signature of a design Engineer and design checking Engineer shall be affixed on the written procedures and Working Drawings verifying the drawings are consistent with the Contract Documents. The written procedures and Working Drawings shall include the following:

- a) The Working Area layout;
- b) A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;

- c) A traffic control plan;
- d) A safety plan including the company safety manual and emergency procedures;
- e) The requirement or restriction for man entry into the host pipe to perform polyurethane liner operations shall be specified;
- f) Material mixture and installation procedures for repairs and/or filling voids;
- g) A work plan including all materials and methods for any repairs necessary to the host pipe, box culvert, and associated structures prior to the polyurethane liner application, including all materials and methods for CSP surface, joint, and perforation restorations and repairs; and for stopping and plugging ground water infiltration into the host pipe, box culvert, and associated structures;
- h) Allowable host pipe or box culvert surface and ambient temperatures, and humidity levels to start the polyurethane liner application, during the curing period and before allowing the water flow back to the lined host pipe or box culvert. Control measures to deal with adverse conditions of temperature, wind and rain, especially at the host pipe or box culvert's open ends;
- i) Method to verify applied thickness of the finished product during the installation of the polyurethane liner at the plastic and hardened states;
- j) Dewatering or temporary flow by-pass plan, when specified in the Contract Documents;
- k) A containment and contingency plan in conformance with the Contract Documents for the following potential conditions:
  - i. Improper placement of the polyurethane liner.
  - ii. Damage to the host pipe or box culvert.
  - iii. The liner's failure to achieve structural integrity.
  - iv. Potential environmental impacts, emergency containment and clean-up procedures.

**469.04.02.02 Product Data**

A minimum of 2 weeks prior to commencement of the polyurethane liner installation or as per the Contract Documents, the following shall be submitted to the Contract Administrator:

- a) Technical data sheet on each product used, including ASTM test results indicating the product conforms to and is suitable for its intended use per these specifications.
- b) Safety Data Sheets (SDS) for each product used.
- c) Project specific guidelines and recommendations including handling, storage requirements, on-site quality control recommendations, and a list of all materials to be used.

**469.04.02.03 Certifications**

The following shall be submitted to the Contract Administrator:

- a) Certification from the manufacturer that the supplied product meets the product technical & package specifications and is designed to withstand all conditions specific to the site where the materials will be installed and is suitable for the specified application.
- b) A letter of certification that the equipment to be used for applying the products has been manufactured or approved by the protective coating/polyurethane manufacturer and applicator personnel have been trained and certified for proper use of the equipment. Certification letter shall be dated within 6 months of the bid date.
- c) Third party independently certified laboratory testing:

- i. Verifying the short-term modulus of elasticity used in the work, minimum of 5,068 MPa (7,35,000 psi).
- ii. Verifying long-term flexural modulus of elasticity, minimum of 3,647 MPa (5,29,200 psi). The third-party testing will verify the long-term reduction factor (creep analysis) of a minimum of 28%. This long-term reduction factor verification shall be conducted utilizing ASTM D2990.

d) Applicator's job history and reference certificates.

e) Proof of any necessary federal, provincial, or local permits or licenses necessary for the work.

#### **469.04.02.04                      Applicator's Qualifications**

A certified statement from the manufacturer shall be submitted that states the applicator performing the work has been trained and approved in the handling, mixing and application of the products to be used. Certification letter shall be dated within 6 months of the bid date.

#### **469.04.02.05                      Manufacturer's Site Representative**

The manufacturer shall assign a site representative for this project. The name and resume of the site representative shall be submitted to the Contract Administrator 3 weeks prior to start of the work. The manufacturer's site representative shall:

- a) Be on-site during the host pipe surface repair, restoration, and preparation operations.
- b) Issue a certification to the Contract Administrator that the host pipe and box culvert cleaning, surface repair, water infiltration stoppage, drying and preparation are done to the manufacturer's satisfaction, and the host pipe, box culvert, and associated structures are ready to receive the Polyurethane Liner coating.
- c) Be on-site right before and during the lining installation operations.
- d) Issue a final certification that the Polyurethane Liner installation work has been done in conformance with the Contract Documents and the manufacturer's requirements and standards without any hidden or exposed deficiencies that require replacement or repairs of part of or all the work.

#### **469.05    MATERIALS**

The materials utilized anywhere in the Work shall be fully styrene free and non-VOC.

#### **469.05.01    Polyurethane Liner**

The polyurethane liner material shall be compatible with the thermal and chemical conditions of the host pipe, box culvert, and associated structures. If the manufacturer requires data related to weather, temperature, and pH of water at the site, the Contractor shall be responsible for acquiring the data and supplying it to the manufacturer.

The polyurethane liner material shall be used to form the sprayed structurally enhanced monolithic liner, covering all interior surfaces of the host pipe, box culvert, or associated structures. The finished liner shall be 100% solids polyurethane and according to Table 2. The physical requirements must be verified by an independent, certified, third-party testing laboratory and must be submitted with the bid package.

The reduction factor for long-term (50 year) value of the flexural modulus of elasticity, according to 468.04.02.03, will be utilized to calculate the thickness of the structural polyurethane liner. The initial flexural modulus of elasticity (short-term) of the submitted resin material will be utilized with the long-term deformation percentage as determined by ASTM D2990 in the design equations outlined in ASTM F1216-22, Appendix X1-X7 (Circular Geometries) or Flat Wall Beam Analysis for walled structures. No adhesion to the substrate is assumed in structural calculations. The value of the long-term flexural modulus of elasticity of the proposed product will be certified by an independent, certified, third-party testing lab, independent of the manufacturer and submitted with the bid package. All design submittals will include this certified third-party DMA testing (ASTM D2990) value in their respective design calculations for each structure being rehabilitated.

#### **469.05.02                    Thickness of Polyurethane Liner**

The minimum value for coating thickness for corrosion protection for non-structural rehabilitation shall be 3.17 mm (3,170 microns or 125 mils) and structural rehabilitation shall be a minimum of 6.35 mm (6,350 microns or 250 mils) or the design thickness determined by the proper design protocol.

Wall thickness design calculations for each structure to be rehabilitated utilizing the specified polyurethane resin technology systems must be submitted with all qualified bids, along with supporting formulas that document that version of formula used. Additionally, product specific strength values, including the short-term flexural modulus and the long-term flexural modulus strength, must be substantiated by third-party testing which will be submitted with all qualified bids.

#### **469.05.03                    Delivery of Materials**

Polyurethane liner materials shall be delivered in the manufacturer's original, unopened, and undamaged packages. Each package shall clearly identify manufacturer, brand name, contents, lot number, and best before or expiry date, if applicable.

When the delivered quality of certified polyurethane liner product is deemed to be unacceptable by the Contract Administrator, the product shall be rejected.

#### **469.05.04                    Storage of Materials**

Materials shall be kept dry, protected from weather, and stored under protective cover to protect from damage. Material from defective, punctured, or damaged containers shall not be used. Each container shall be labeled with a batch or lot number and with an expiration or use-by date.

Materials shall be stored at temperatures recommended by the polyurethane liner manufacturer i.e., between 10°C (50°F) and 32°C (90°F). Do not store near flame, heat, or strong oxidants.

#### **469.05.05                    Handling of Materials**

Polyurethane Liner materials shall be handled according to their SDS.

### **469.06                        EQUIPMENT**

#### **469.06.01                    Spray-Applying Equipment for Polyurethane Liner**

The work consists of hand spray application or centrifugally spin-casting the specified polyurethane liner material to the inside of the host pipe, existing box culvert, or associated structure. The necessary equipment and application methods to apply the liner materials shall be only as approved by the manufacturer. Material shall be mixed in accordance with manufacturer's specifications and pumped to the appropriate application device.

Prior to proceeding with the lining, a letter from the manufacturer shall be submitted to the Contract Administrator indicating that the applicator's plans, means, methods and application calibrated equipment satisfy the requirement for application of the lining. Copies of the plans, means, methods and description of application equipment shall be attached to the letter for information purposes.

### **469.07                        CONSTRUCTION**

#### **469.07.01                    Site Preparation**

Site preparation shall be according to OPSS 490.

#### **469.07.02                    Preservation and Protection of Existing Facilities**

Preservation and protection of existing facilities shall be according to OPSS 491.

#### **469.07.03                    Dewatering**

When required, flow diversion, unwatering/dewatering, shall be installed to fulfill the Contract requirements. Dewatering when required shall be according to OPSS 517.

The Environment Canada weather forecast shall be monitored prior to commencement of lining operations. Where the anticipated weather conditions are such that anticipated host pipe/box culvert flows may exceed the installed bypass pumping capacity or may cause potential site flooding, commencement of construction shall be delayed until favourable weather is forecast

#### **469.07.04                    Temporary Protection Systems**

The construction of all protection systems shall be according to OPSS 539.

#### **469.07.05                    Cleaning of Host Pipe, Box Culvert, or Associated Structures**

Host pipe, box culvert, or associated structures cleaning shall be according to OPSS 411.

#### **469.07.06                    Preparation of Host Pipe, Box Culvert, or Associated Structures**

Prior to the polyurethane liner application, the host pipe, box culvert, or associated structures shall be inspected using visual observations or when specified CCTV/zoom camera where personnel entry is impracticable. CCTV inspection shall be according to OPSS 409.

All contaminants including oils, grease, incompatible existing coatings, waxes, form release, curing compounds, efflorescence, sealers, salts, or other contaminants shall be removed.

All concrete or metal that is not sound or has been damaged by chemical exposure shall be removed to a sound surface or replaced.

Surface preparation method(s) shall be based upon the conditions of the substrate, service environment and the requirements of the polyurethane liner coating to be applied.

##### **469.07.06.01                Surface Preparation**

Achieving a repaired, clean, and dry surface prior to the lining application is critical for successful polyurethane liner application and long-term performance. Surfaces to receive polyurethane liner coating shall be:

- a) Cleaned and abraded to produce a sound surface with profile to meet the relative standard profile and porosity to provide a strong bond between the polyurethane liner coating and the substrate. Generally, this can be achieved with a high-pressure water cleaning using equipment capable of a minimum 4,500 psi at 4.5 gpm with a turbo head jet nozzle. Other methods such as high-pressure water jetting (refer to SSPC-SP 13/NACE No.6), abrasive blasting, shotblasting, grinding, scarifying or acid etching may also be used. Whichever method(s) are used, they shall be performed in a manner that provides a uniform, sound clean neutralized surface that is not excessively damaged.
- b) Dry to the touch and or with no visible dampness. This is to insure maximum adhesion to the substrate and no foaming defects in the polyurethane liner. If required, drying may be accomplished by a minimum of 20 minutes of a heated, indirect forced air blower. The drying shall be to the specification dictated by the polyurethane liner manufacturer and its trained applicator.
- c) Prepared with a series of grooves cut into the substrate at a spacing and depth determined by the manufacturer to “key” or lock the protective coating to the substrate, when utilizing flat wall beam analysis design. All coating termination edges shall be “locked” into the substrate with a termination groove “key” cut into the substrate. The “key” shall be a minimum ¼”w x ¼”d and cut at a 45 degree angle.

- d) Temperature of the surface to be coated should be maintained between 21 °C (70 °F) and 44 °C (110 °F) during polyurethane liner application. Prior to and during application, care should be taken to avoid exposure of direct sunlight or other intense heat source to the structure being coated.
- e) In the case of new concrete infrastructure, installation of the polyurethane protective coating shall not commence until the concrete substrate has properly cured in accordance with these specifications.

**469.07.06.02                    Pre-Lining Repairs**

Any open joints and voids in the embedment or invert shall be sealed with approved repair material prior to the lining of the host pipe, box culvert, or associated structures. No leaks may be present prior to commencing and during work. If additional repair procedures are required to restore the host pipe for lining, for example invert reconstruction, a repair plan shall be submitted to the Contract Administrator prior to proceeding.

Repair materials shall meet the specifications herein. The materials shall be trowel or spray applied, utilizing proper equipment on to specified surfaces. The material thickness shall be specified by the design Engineer according to Owner's requirements and manufacturer's recommendations.

Cementitious patching and repair materials should not be used unless their manufacturer provides information as to its compatibility and procedures for top-coating with the approved polyurethane liner coating. If using approved cementitious repair materials, such shall be troweled to provide a smooth surface with an average profile equivalent to coarse 60 grit sandpaper or a minimum profile to optimally receive the polyurethane liner coating. No bugholes or honeycomb surfaces should remain after the final trowel procedure of the repair mortar. The repair materials shall be permitted to cure according to manufacturer recommendations. Curing compounds should not be used unless approved for compatibility with the specified polyurethane liner coating.

Areas where structural steel has been exposed or removed shall be repaired in accordance with the design Engineer's recommendations and approved by the Contract Administrator.

After high pressure water blasting and leak repair is performed, all surfaces shall be inspected for remaining laitance prior to polyurethane liner application. Any evidence of remaining contamination or laitance shall be removed by additional abrasive blast, shotblast or other approved method. If repair materials are used, refer to these specifications for surface preparation. Areas to be coated must also be prepared in accordance with these specifications after receiving a cementitious repair mortar and prior to application of the approved polyurethane liner coating.

Any active flows shall be dammed, plugged, or diverted as required to ensure that the liquid flow is maintained below the surfaces to be coated. Flows shall be totally plugged and/or diverted when coating the invert. All extraneous flows into the buried infrastructure at or above the area coated shall be plugged and/or diverted until the coating has set hard to the touch. As an option, hot air may be added to accelerate set time of the coating.

Infiltration shall be stopped by using a material which is compatible with the specified repair mortar and is suitable for top-coating with the specified polyurethane liner. All products used to stop active infiltration shall be approved by the Contract Administrator and used in accordance with the manufacturer's recommendations.

**469.07.06.03                    Prior to Application of Polyurethane Liner**

At the completion of the cleaning, surface repair and infiltration stoppage operations of host pipe, box culvert, or associated structures to be lined and a minimum of 2 Business Days prior to the planned commencement of the application of polyurethane liner, MTO form PH-CC-701, Request to Proceed shall be submitted to the Contract Administrator.

The MTO form PH-CC-701, Request to Proceed shall be accompanied by a signed letter by the manufacturer's site representative stating that the host pipe, box culvert surface, or associated structure's preparation has been completed in accordance with the manufacturer's requirements and to their satisfaction, and that the host pipe, box culvert, or associated structure is ready for the spray applying of the lining.



The application of polyurethane liner shall not proceed until MTO form PH-CC-702, Notice to Proceed has been received from the Contract Administrator.

No polyurethane liner installation shall start until all materials and products used in the host pipe, box culvert, or associated structure's repairs and to stop water infiltration have been cured as per their manufacturer's instructions.

#### **469.07.07 Application of Polyurethane Liner**

Lining operations shall not start when the host pipe, existing box culvert, or associated structure's surface temperature is less than 21 °C, ambient temperature is less than 10 °C, air humidity is more than 60%, or when it is likely that these limits will not be met throughout the duration of the spray application of the liner of the complete culvert. The ready-to-be-lined host pipe, box culvert, or associated structure will require external source of heating to meet these requirements. Special protection measures to shield host pipe or box culvert open ends from adverse weather conditions will also be required.

Prior to application of polyurethane liner, it shall be demonstrated to the Contract Administrator that the substrate temperatures meet the above requirements by measuring the substrate temperatures throughout its length, using a contact thermometer, and recording them.

The air in contact with the lined surfaces shall be maintained at temperatures equal to or greater than 10 °C for a minimum of 24 hours after the application of lining. Appropriate type of heaters, protection or other equipment might be used when moisture or temperature is a concern.

Lining operations shall not be allowed during weather conditions that may adversely affect the quality of the work. This includes, but is not limited to, high wind, causing improper and uneven application of product, or rain and wind, causing the host pipe, box culvert, or associated structure's surface to become wet or humid ahead of or during the application process.

The diameter, profile, length and all other dimensions of all host pipes, box culvert, or associated structures to be rehabilitated shall be accurately measure for planning all construction activities and choosing appropriate equipment.

Specified surfaces shall be coated by spray application of a solvent-free, 100% solids, rigid structural lining as further described herein. Application procedures shall conform to the recommendations of the polyurethane liner manufacturer, including material handling, mixing, environmental controls during application, safety, and spray equipment.

The spray equipment shall be specifically designed to accurately ratio and apply the specified polyurethane liner coating materials and shall be regularly maintained and in proper working order.

Plural component spray application equipment approved by the polyurethane liner manufacturer shall be used to apply each coat of the polyurethane liner coating.

If necessary, subsequent top-coating or additional coats of the polyurethane liner should occur as soon as the basecoat becomes tack free, no later than the recoat window for the specified products. Additional surface preparation procedures will be required if this recoat window is exceeded as per manufacturer's recommendation.

The ends of the finished polyurethane liner shall be neat and smooth. Terminations at maintenance holes or headwalls shall be flush or extend slightly beyond the maintenance hole wall/headwall.

#### **469.07.08 Curing of Polyurethane Liner**

Manufacturer's recommended schedule shall be followed in curing of the polyurethane liner. The polyurethane liner shall be sufficiently cured to not be subjected to thermal shock or be damaged by water. Any surface water diversion/dewatering requirements must remain active until curing and post-construction inspection is complete.

During the curing period, proper steps shall be taken to deal with any adverse climate conditions. The polyurethane liner shall be cured as instructed by the manufacturer considering the weather condition during construction. If ambient temperature goes below 10 °C after application of the polyurethane liner, proper heating, as recommended by the manufacturer, shall be applied to keep the material and substrate warm.

At the completion of the host pipe, box culvert, or associated structure's lining operations and at a minimum of 24 hours prior to the planned commencement of the diverting of the flow water back to the lined host pipe or box culvert, MTO form PH-CC-701, Request to Proceed shall be submitted to the Contract Administrator to divert water flow back to the lined host pipe, box culvert, or associated structure.

The MTO form PH-CC-701, Request to Proceed shall be accompanied by a signed letter by the manufacturer's site representative stating that the lining has been completed in accordance with the manufacturer's requirements and to their satisfaction without any defects or deficiencies that require replacement or repair and that the host pipe, box culvert, or associated structure is ready for diverting flow water back to it.

The diversion of flow water back to the lined host pipe, box culvert, or associated structure shall not proceed until the completed lining has cured and is protected from thermal shock for 24 hours from its completion time and shall not proceed until MTO form PH-CC-702, Notice to Proceed has been received from the Contract Administrator.

#### **469.07.09                      Manufacturer's Certificate of Conformance**

Upon completion of the polyurethane liner work and restoring of flow water of a host pipe, box culvert, or associated structure and prior to the start of the work on other host pipe or box culvert, a Certificate of Conformance signed by the manufacturer's Engineer shall be submitted to the Contract Administrator. The Certificate of Conformance shall state that the installed liner materials and construction have been done according to the manufacturer's requirements and to their satisfaction and as per Contract Documents. The certificate shall state MTO contract number, the structure site number, the name of the structure and the date of lining work completion.

#### **469.07.10                      Supervision**

The project Superintendent shall have received adequate training from the technology supplier and shall have a minimum of 3 years demonstrated experience on projects with similar scope and complexity.

#### **469.07.11                      Environmental Protection and Contingency**

Environmental protection requirements and mitigation measures shall be according to the Contract Documents with the following additions:

- a) Install containment measures to prevent the escape of grout from the host pipe undergoing geopolymer liner procedure.
- b) Reinstate water flow no sooner than 24 hr after installation of the geopolymer liner and as per the manufacturer's recommended schedule.
- c) Capture and properly dispose-off the rinse/first flush water until pH levels are confirmed to be at or below a pH level of 9.

#### **469.07.12                      Electrical Equipment, Fixtures and Systems**

Electrical equipment shall be suitably insulated for noise reduction. Noise produced by electrical equipment must comply with local municipal noise by-laws.

#### **469.07.13                      Quality Control**

##### **469.07.13.01                  Daily Activity Logs**

A daily activity log for each geopolymer liner application shall be completed anytime a work crew is on site. The daily log shall include the following information:

- a) List all personnel on site complete with arrival and departure times;
- b) Reinforcing prior to spray-on operations, if applicable;
- c) Start and end times for application of each spray-on coat and section, including speed of winch and pumping/spraying rate (m<sup>3</sup>/minute);
- d) Atmospheric conditions at the time of spraying including ambient air temperature and temperature inside the host pipe, box culvert, or associated structures;
- e) Mechanical equipment operations data;
- f) Quantity of materials used and area completed including thickness;
- g) Total length of the liner installation;
- h) Curing/drying time; and
- i) Any special conditions are to be noted.

A copy of the daily log shall be submitted to the Contract Administrator within 1 Business Day.

#### **469.07.13.02                    Equipment Calibration Reports**

All applicable equipment calibrations must be maintained on site by the Superintendent and available for inspection upon request by the Owner.

#### **469.07.13.03                    Sampling of Polyurethane Liner**

During the lining operation of each host pipe, box culvert, or associated structure, the applicator shall prepare three test coupons per day of lining operations. Preparation of samples shall be carried out by covering flat, smooth, and precision machined (to minimize edge effects) steel plates with the liner material. The size of the plates shall suit sample size requirements of the relevant ASTM test method and the plate surface shall be coated with non-stick material. The plates will be coated with the liner material using the same application methods and equipment as used in the work. The prepared samples shall be marked with the host pipe/box culvert cell, name, and site number. Once the plate samples are cured, they shall be cut into the required plaques for flexural and tensile tests as specified by ASTM D790 and D638 standards. The manufacturer's representative shall have half the samples tested at a third-party laboratory and shall submit the test results and report to the Contract Administrator. Samples not tested shall be provided to the Contract Administrator.

#### **469.07.14                        Management of Excess Materials**

Management of excess materials shall be according to the Contract Documents.

### **469.08                            QUALITY ASSURANCE**

#### **469.08.01                        Polyurethane Material**

##### **469.08.01.01                    General**

The Contractor shall initiate and enforce quality control procedures consistent with applicable ASTM, and NACE, SSPC standards, and the polyurethane liner manufacturer's recommendations. The finished polyurethane liner shall be continuous over the entire length of the liner installation without any breaks, separation, or joints. The ends of the finished liner shall be neat and smooth.

All QA sampling and testing such as thickness, high voltage spark test, and adhesion test etc. of the material shall be in accordance with applicable NACE and ASTM test methods (D790, D2584, D4787, D4541, D7234 etc.), and the manufacturer's specifications and design recommendations to confirm compliance with the requirements specified in the Contract Documents.

The Contractor shall furnish to the Contract Administrator required samples in a clean bag, tagged with necessary project details. Samples shall be taken into custody by the Contract Administrator immediately and delivered to the MTO QA laboratory or an independent testing laboratory retained by the Contract Administrator. In the case of testing at site, the independent testing laboratory shall carry out the required testing as per the applicable ASTM, NACE, and SSPC standards.

Appropriate heating/cooling procedures must be adhered to during the installation phase to reduce the risk of compromising the structural integrity of the installed product.

#### **469.08.01.02 Liner Adhesion**

The Contractor shall test the adhesion of the completed lining to the culvert surface by a holiday detector device, a pull test, or any other means at random locations of the completed lining work as selected by the Contract Administrator.

If lack of adherence is detected at some areas of the polyurethane liner, the work is considered unacceptable. The Contractor shall submit to the Contract Administrator a proposed method of repair or replacement, approved by the manufacturer, for review and approval.

#### **469.08.01.03 Thickness of Polyurethane Liner**

The Contractor shall install small indicator stainless steel tabs/metal screws on the specified surfaces receiving polyurethane liner coating at random locations of crown, invert, and sides of the host pipe, box culvert, or associated structure, and along its length to verify that the proper plastic and dried liner material thickness is achieved. The location of these indicator tabs/screws will be selected by the Contract Administrator; however, the location of sets of tabs shall be no more than 5 m apart along the length of the host pipe and box culvert and each set shall consist of three tabs around the circumference of the host pipe and box culvert. Tabs to be installed on the crest of the corrugation of the CSP. These are positioned to be "just" below the specified thickness and are left in place when sprayed over. The Contract Administrator shall verify the height of these tabs/screws from the cleaned CSP surface before lining application so that if they are not exposed after the liner application, then the minimum required polyurethane liner thickness has been achieved.

The liner thickness over the CSP interior peaks shall meet the requirements for liner thickness. If thickness of the installed polyurethane liner anywhere is less than the engineered requirement, the product is considered unacceptable. Contractor shall submit to the Contract Administrator a proposed method of repair or replacement, approved by the manufacturer, for review and approval.

#### **469.08.02 Inspection After Curing**

The completed and cured polyurethane liner shall be inspected as per the manufacturer's inspection protocol guidelines. The inspection shall look for deficiencies such as runs and sags, pinholes, cracking, foaming and debonding, blisters and cissing, overspray, cratering or large pinhole.

The manufacturer's site representative shall evaluate the type, extent and frequency of deficiencies and advise the Contractor and the Contract Administrator of the recommended course of actions of removing and replacing or repairing areas with such deficiencies.

The Contractor shall replace or repair areas identified by the manufacturer's site representative. The Contractor shall also replace areas of the polyurethane liner where debonding is found.

#### **469.08.03 Warranty**

The Contractor shall guarantee the material and workmanship of the lined surfaces against material delamination and all other defects in workmanship and materials for a period of 3 years after the completion of

the lining work at each host pipe, box culvert, or associated structure's site. This is in addition to the manufacturer's standard warranty. Any detected defect or failure during this period shall be repaired by the Contractor within 4 weeks from the date of notification.

In addition to the manufacturer's Certificate of Conformance, submitted according to manufacturer's Certificate of Conformance in subsection 469.07.09, the Contractor shall submit to the Contract Administrator the manufacturer's project and structure specific standard warranty.

**469.08.04                      Closed-Circuit Television (CCTV) Inspection**

Installed polyurethane liner shall be inspected using visual observations or specified CCTV/zoom camera where personnel entry is impracticable. CCTV inspection shall be according to OPSS 409.

In the case of repairs required to restore the host pipe, box culvert, or associated structures for lining, such as joints sealing, invert reconstruction, or additional repairs etc., a post preparation CCTV inspection shall be completed for each structure, when specified in the Contract Documents.

**469.09                              MEASUREMENT FOR PAYMENT**

**469.09.01                      Actual Measurement**

**469.09.01.01                  Polyurethane Liner**

Measurement for payment shall be the length in meters of polyurethane liner placed, as measured along the centerline of the invert, of the host pipe or box culvert.

Measurement for payment for flat wall structures shall be in square metres.

**469.09.02                      Plan Quantity Measurement**

When measurement is by Plan Quantity, such measurement shall be based on the units shown in the clause under Actual Measurement.

**469.10                              BASIS OF PAYMENT**

**469.10.01                      Polyurethane Liner - Item**

Payment at the Contract price for the above tender items shall be full compensation for all labour, Equipment, and Material to do the work.

**TABLE 1  
Design Parameters for Polyurethane Liner**

<b>Parameter</b>	<b>Design Requirement</b>
Structure Condition	Fully Deteriorated
Design Thickness Method	<p>ASTM F1216-22 or Two Way Flat Wall Beam Analysis</p> <p>Assume fully deteriorated condition of the gravity host pipe, box culvert, or associated structures.</p> <p>For non-circular host pipe (such as egg, oval, or other non-round shapes) a design method other than ASTM F1216 X1 shall be used because the F1216 X1 design method is not applicable to host pipes that were not originally circular. The non-circular host pipe design method shall be as specified in the Contract Documents or proposed by the Contractor for approval by the Contract Administrator.</p>
Design Life	50 years
Safety Factor	2.0
Groundwater Depth	Full soil depth, unless otherwise known.
Soil Modulus	6.9 MPa (1000 psi)
Soil Density	20 kN/m <sup>3</sup> (2039 kg/m <sup>3</sup> )
External Earth Load	Minimum depth of 3.0 m to top of pipe or the actual height of cover that exists at the liner location, whichever is greater.
Live Load	Canadian Highway Bridge Design Code (CHBDC S6-14 of 166.6 kN).
Ovality	5% or actual existing culvert ovality, whichever is greater
Design Reduction Factor to Determine Design Value for Long Term Flexural Modulus of Elasticity	0.65

**TABLE 2**  
**Physical Properties of Polyurethane Liner**

<b>Property</b>	<b>Test Method</b>	<b>Requirement</b>
Compressive Strength	ASTM D695	> 124 MPa (18,000 psi)
Tensile Strength	ASTM D638	> 52 MPa (7,450 psi)
Flexural Strength	ASTM D638	> 96 MPa (14,000 psi)
Bond (Concrete)	ASTM D638	> 1.4 MPa (200 psi) Or Substrate Failure
Bond (Steel)	ASTM D4541	> 7 MPa (1,000 psi)
Flexural Modulus (Initial)	ASTM D790	> 5068 MPa (7,35,000 psi)
Flexural Modulus (Long Term)	ASTM D2990	> 3647 MPa (5,29,000 psi)
Elongation	ASTM D638	4% at break
Abrasion (Taber CS17)	ASTM D4060	17.7 mg loss
Hardness, Shore D	ASTM D2240	90
Long term Ring-Bending Strain	ASTM D5365	0.0130
Density		87 ± pcf
Chemical Resistance:	ASTM D543	