

**SECTION 02770
PIPE LINING**

PART 1 - GENERAL

1.1 WORK INCLUDED

- A. Contractor shall provide all materials, equipment, labor and supervision for the installation and testing of pipe lining. The pipe lining will be installed in pipes made of various materials.
- B. Related Sections:
 - 1. Section 02150, Bypass Pumping.
 - 2. Section 02651, Television Inspection.
 - 3. Section 02760, Cleaning of Sewers.
 - 4. Section 03602, Sliplining Grout - Structural

1.2 QUALITY ASSURANCE

- A. Reference Standards: Comply with applicable provisions and recommendations of the following:
 - 1. ASTM D2321, Practice for Underground Installation of Flexible Thermoplastic Pipe for Sewers and Other Gravity Flow Applications.
 - 2. ASTM 3035, Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on a Controlled Outside Diameter.
 - 3. ASTM D 3350, Standard Specification for Polyethylene Plastics Pipe and Fittings Materials.
 - 4. ASTM F 585, Practice for Insertion of Flexible Polyethylene Pipe into Existing Sewers.
 - 5. ASTM F 714, Specification for Polyethylene (PE) plastic pipe (SDR-PR) Based on Outside Diameter.
 - 6. ASTM F 1417, Standard Test Method for Installation Acceptance of Plastic Gravity Sewer Lines Using Low Pressure Air
 - 7. PPI Handbook of Polyethylene Pipe.
 - 8. AASHTO Standard Specification for Highway Bridges.
 - 9. ASTM D543 - Test Method for Resistance of Plastics to Chemical Reagents.
 - 10. Standards of American Water Works Association, AWWA.
 - 11. Standards of American National Standards Institute, ANSI.
 - 12. ASTM D2990 - Long-term Flexural and Tensile Modulus of Elasticity.
 - 13. ASTM D1784 - Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds
 - 14. ASTM D2152 - Test Method for Degree of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion
 - 15. ASTM D2241 - Poly (Vinyl Chloride) (PVC) Plastic Pipe (SDR-PR)

- B. Contractor shall be licensed and/or certified by the manufacturer of the sliplining system and shall meet other experience requirements as listed. Only commercially proven products and installers with substantial track records will be approved. Products and installers seeking approval must document an ability to meet the following criteria to be deemed commercially proven:
1. For a product to be considered commercially proven, a minimum of 1,000,000 linear feet or 4,000 manhole-to-manhole line sections of successful wastewater collection system installations in the U.S. must be documented to the satisfaction of the Owner to assure commercial viability. Of that, 50,000 LF must be 26-inches and larger.
 2. For an Installer to be considered as commercially proven, the installer must satisfy all insurance, financial, and bonding requirements of the Owner, and must have had at least 5 (five) years active experience in the commercial installation of the product. Acceptable documentation of these minimum installations must be submitted to the Owner.
 3. Sewer rehabilitation products submitted for approval must provide third party test results supporting the long term performance and structural strength of the product and such data shall be satisfactory to the Owner. No product will be approved without independent third party testing verification.
 4. The Contractor's Superintendent who will perform the work under this Section must have at least 3 years of experience and have successfully installed at least 300,000 linear feet of the proposed product, of which at least 5,000 linear feet must be 36-inch or greater.
- C. The Contractor shall be capable of providing all crews and equipment as needed to complete the work when directed without undue delay.
- D. Though the process may be licensed, no change of material, design values, or procedures may be made during the course of the Work without the prior written approval of the Engineer.
- E. The Contractor shall use sliplining materials provided by a single manufacturer. The supplier shall be responsible for conforming to all test requirements specified herein as applicable. In addition, all liners to be installed under this Contract may be inspected at the plant for compliance with these specifications by an independent testing laboratory provided by the Owner, at its own expense. The Contractor shall require the manufacturer's cooperation in these inspections. The cost of plant inspection will be the responsibility of the Owner.
- F. At the time of manufacture, each lot of liner shall be inspected for defects and tested in accordance with applicable ASTM standards. At the time of delivery, the liner shall be homogeneous throughout, uniform in color, free of cracks, holes, foreign materials, blisters, or deleterious faults.
- G. Care shall be taken in shipping, handling and storage to avoid damaging the liner. Extra care shall be taken during cold weather construction. Any liner damaged in shipment shall be replaced as directed by the Engineer.
- H. While stored, the sliplining materials shall be adequately supported and protected. The sliplining materials shall be stored in a manner as recommended by the manufacturer and as approved by the Engineer.

- I. For testing purposes, a production lot shall consist of all liner having the same marking number. It shall include any and all items produced during any given work shift and must be so identified as opposed to previous or ensuing production.
- J. All sliplining work shall be fully guaranteed by the Contractor and manufacturer for a period of one year from the date of acceptance. During this period, all serious defects discovered by the Owner shall be removed and replaced in a satisfactory manner at no cost to the Owner. The Owner may conduct an independent television inspection, at its own expense, of the lining work at any time prior to the completion of the guarantee period.
- K. The Engineer may at any time direct the manufacturer and the Contractor to obtain compound samples and prepare test specimens in accordance with the applicable ASTM standards. The Contractor shall provide certified test results of the short-term properties, including wall thickness, flexural strength and flexural modulus of the cured lining material from a flat plate sample, conforming to Article 3.6.A of this Section. Samples shall be prepared and tested by an independent laboratory approved by the Engineer. The cured liner samples shall be tested for flexural strength and flexural modulus properties in accordance with ASTM F1216, ASTM D790, ASTM M638 and ASTM D2990. The samples shall meet or exceed the physical properties stated in this specification. Conformance certification shall be submitted to the Engineer for approval as part of the acceptance requirements.
- L. The newly installed liner shall be designed for a minimum 50-year service life under continuous loading conditions. Design of the liner shall be based on the condition of the existing pipe as classified by the Engineer. The liner design is the responsibility of the Contractor. The liner shall be designed by a registered professional engineer in the State of Ohio and shall have sufficient wall thickness to withstand the anticipated external pressures and loads which will be imposed after installation. The design of the liner shall include considerations for ring bending, deflection, combined loading, buckling, and ovality. Calculations which determine wall thickness requirements of the liner shall be submitted to the Engineer for information only, to assure that the requirements of the specifications have been complied with. Designs shall be based on the use of standard flexible pipe equations, as defined in ASTM and shall account for the effects of ovality. A safety factor of at least two shall be utilized. The short-term modulus of elasticity shall be reduced by 50 percent in the calculations. Where ovalities exceed 10 percent, alternate design methodologies shall be used and shall show design meets structural requirements.

1.3 DESCRIPTION

- A. The process shall consist of inserting a plastic pipe into an existing sewer, holding the pipe in place and grouting the annular space between the host pipe and the liner.
- B. The liner pipe shall be designed for and a structurally sound pipe with a uniformly smooth interior providing hydraulic flow equal to or greater than the existing sewer in original condition.

1.4 SUBMITTALS

- A. Submittals shall conform to the requirements of Section 01300, Submittals.

- B. Product Data: Provide data indicating pipe and pipe accessories.
- C. Manufacturer's Installation Instructions: Indicate special procedures required to install Products specified.
- D. Manufacturer's Certificate: Certify that products meet or exceed specified requirements.

PART 2 - PRODUCTS

2.1 MATERIALS

A. High Density Polyethylene (HDPE) Pipe

- 1. Be manufactured of high-density polyethylene resin in accordance with ASTM D3350-06 with a cell classification of 345464C.
- 2. Have a material designation of PE 3408 by the Plastic Pipe Institute.
- 3. Meet stiffness range as shown in ASTM F714, Appendix X1, Table X1.1
- 4. Have physical properties in accordance with polyethylene material standard ASTM D3350-06 with cell classification 345464C as follows:
 - a. Density: 0.955 gms/cubic centimeters per ASTM D1505.
 - b. Flexural Modulus: Minimum 135,000 psi per ASTM D790.
 - c. Tensile Strength: Minimum 3,200 psi per ASTM D638.
 - d. PENT > 100 hours at 80 degrees C, 2.4 Mpa per ASTM F1473.
 - e. HDB@ 23 degrees C: 1,600 psi per ASTM D2837.
 - f. UV Stabilizer: Minimum 2% carbon black per ASTM D 1603.
- 5. Liner pipe for host pipe 24-inch ID and larger shall be DR 32.5
- 6. Liner pipe for host pipe 20-inch and smaller shall be DR 17
- 7. Liner pipe shall be smooth and non-porous with a Manning friction coefficient "n" of 0.009 or a Hazen Williams friction coefficient "C" of 150.

B. Fusible Polyvinyl Chloride (FPVC) Pipe

- 1. Fusible polyvinylchloride pipe shall conform to ASTM D3034 or ASTM F679.
- 2. Fusible polyvinylchloride pipe may instead conform to AWWA C900 or AWWA C905, and/or ASTM D2241 or ASTM D1785 for IPS standard dimensionality, if applicable. Testing shall be in accordance with AWWA standards for any of these pipe types.
- 3. Rework material shall be allowed per ASTM D3034, ASTM F679, AWWA C900 or AWWA C905 standards.
- 4. Fusible polyvinylchloride pipe shall be extruded with plain ends. The ends shall be square to the pipe and free of any bevel or chamfer. There shall be no bell or gasket of any kind incorporated into the pipe.
- 5. Fusible polyvinylchloride pipe shall be manufactured in a standard 20', 30' or 40' nominal length.
- 6. Fusible polyvinylchloride pipe shall be green in color for wastewater use.

7. Pipe generally shall be marked per AWWA C900 or AWWA C905, and shall include as a minimum:
 - a. Nominal pipe size
 - b. PVC
 - c. Dimension Ratio, Standard Dimension Ratio or Schedule (omit for ASTM D3034 or ASTM F679 pipe)
 - d. Extrusion production-record code
 - e. Trademark or trade name
 - f. Cell Classification 12454 and/or PVC material code 1120 may also be included.
8. Pipe shall be homogeneous throughout and be free of visible cracks, holes, foreign material, blisters, or other visible deleterious faults.
9. Liner pipe for host pipe 24-inch ID and larger shall be DR 32.5
10. Liner pipe for host pipe 20-inch and smaller shall be DR 17
11. Liner pipe shall be smooth and non-porous with a Manning friction coefficient “n” of 0.009 or a Hazen Williams friction coefficient “C” of 150.

2.2 JOINTING

A. Fusion Joints

1. Fusible joints shall be assembled in the field with butt-fused joints.
2. Contractor shall follow the pipe supplier’s guidelines for this procedure.
3. Pipe shall be handled in a safe and non-destructive manner before, during, and after the fusion process and in accordance with this specification and pipe supplier’s guidelines.
4. Pipe shall be fused by qualified fusion technicians, as documented by the pipe supplier.
5. Each fusion joint shall be recorded and logged by an electronic monitoring device (data logger) affixed to the fusion machine.
6. Only appropriately sized and outfitted fusion machines that have been approved by the pipe supplier shall be used for the fusion process.
7. Fusion machines shall incorporate the following properties, including the following elements:
 - a. HEAT PLATE - Heat plates shall be in good condition with no deep gouges or scratches. Plates shall be clean and free of any debris or contamination. Heater controls shall function properly, cord and plug shall be in good condition. The appropriately sized heat plate shall be capable of maintaining a uniform and consistent heat profile and temperature for the size of pipe being fused, per the pipe supplier’s guidelines.
 - b. CARRIAGE – Carriage shall travel smoothly with no binding at less than 50 psi. Jaws shall be in good condition with proper inserts for the pipe size being fused. Insert pins shall be installed with no interference to

- c. carriage travel.
 - c. GENERAL MACHINE - Overview of machine body shall yield no obvious defects, missing parts, or potential safety issues during fusion.
 - d. DATA LOGGING DEVICE - The current version of the pipe supplier's recommended and compatible software shall be used. Datalogging device operations and maintenance manual shall be with the unit at all times. If fusing for extended periods of time, an independent 110V power source shall be available to extend battery life.
8. Other equipment specifically required for the fusion process shall include the following:
- a. Pipe rollers shall be used for support of pipe to either side of the machine.
 - b. A weather protection canopy that allows full machine motion of the heat plate, fusion assembly and carriage shall be provided for fusion in inclement and /or windy weather.
 - c. Fusion machine operations and maintenance manual shall be kept with the fusion machine at all times.
 - d. Facing blades specifically designed for cutting fusible polyvinylchloride pipe shall be used.
9. Joint Recording
- a. Each fusion joint shall be recorded and logged by an electronic monitoring device (data logger) connected to the fusion machine.
 - b. The fusion data logging and joint report shall be generated by software developed specifically for the butt-fusion of thermoplastic pipe.
 - c. The software shall register and/or record the parameters required by the pipe supplier and these specifications.
 - d. Data not logged by the data logger shall be logged manually and be included in the Fusion Technician's joint report.

B. Buttress Lock Joints

- 1. "Buttress-Loc" pipe allows short lengths of pipe to be assemble inside a manhole effectively converting short lengths of plastic pipe into continuous pipelines.
- 2. Each length is screwed together with a chain wrench that when fully tightened, automatically self seals.
- 3. Completed joint shall exhibit very high pull out strength without changing the OD or the ID of the liner pipe.
- 4. Liner pipe shall be advanced into the host pipe as the joints are completed.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Review survey television inspection tapes of the sewer line to plan rehabilitation work. Contractor shall be responsible for determining the location of all active sanitary services prior to lining.
- B. The work of pipeline cleaning shall conform to the requirements of Section 02760, Cleaning of Sewers.
- C. Contractor shall provide for continuous sewage flow around the section of sewer that is to be lined in accordance with Section 02150, Bypass Pumping.
- D. Inspect and confirm the inside diameter, alignment and condition of the pipeline. Contractor shall confirm the data and information collected from this inspection to verify the size of the liner and refine the installation techniques. If unknown physical conditions in the work area are uncovered during the investigation that materially differ from those ordinarily encountered, the Contractor shall notify the Engineer.
- E. Inform the Engineer of work schedules for sliplining installation.
- F. Conduct operations in accordance with applicable OSHA standards, including those safety requirements involving work on an elevated platform and entry into a confined space. Make suitable precautions to eliminate hazards to personnel near construction activities when pressurized air is being used.

3.2 PRE-INSTALLATION CLEANING AND TV INSPECTION

- A. Contractor shall clean the pipeline in accordance with Section 02760, Cleaning of Sewers, prior to lining the existing pipe.
- B. Contractor shall conduct TV Inspection, prior to lining in accordance with Section 02651, Television Inspection.

3.3 OBSTRUCTION REMOVAL, POINT REPAIR AND SAG ELIMINATION

- A. Necessary point repairs to facilitate lining shall be the responsibility of the Owner. Contractor shall notify the Owner immediately after the pre-installation cleaning and TV inspection where point repairs are necessary to facilitate installation of the liner.
- B. Notify the Engineer if the pre-installation video inspection reveals an obstruction in the line segment (such as heavy solids, dropped joints, protruding service connections or collapsed pipe) that cannot be removed by conventional sewer cleaning equipment and if the obstruction will prevent completion of the inversion.

3.4 BYPASS PUMPING

- A. Bypass pumping systems shall be in accordance with Section 02150, Bypass Pumping.

3.5 INSTALLATION PROCEDURES

- A. General
 - 1. Liner shall be installed by pulling or pushing.
 - 2. Precautions shall be taken to protect the liner from scratches or gouges.

3. Liner shall be protected from rough edges of the host pipe.
4. Liner shall be equipped with suitable spacers to allow installation and ensure proper placement of the liner pipe in the host pipe.
5. Liner shall be allowed to relax and come to thermal equilibrium before sealing the annular space between the liner and the host pipe.
6. Liner shall extend into manhole.

B. Excavation And Access Pits

1. Access pit length shall be determined by the material and jointing method selected by the Contractor.
2. The minimum bending radius for the pipe as recommended by the supplier shall be maintained.
3. Sheet piling, shoring and bracing requirements shall be in accordance with these specifications and applicable jurisdictional standards.
4. Confined space requirements shall be in accordance with OSHA regulations.
5. Access pit excavations shall be performed at all points where the slipline pipe will be inserted into the existing pipeline.
6. When possible, access pit excavations shall coincide with host pipe lateral connection points or other appurtenance installations.

C. Pulling Equipment

1. The pulling mechanism shall be properly connected to the end of the pipe via a pulling head or arrangement approved by the pipe supplier.
2. The maximum pulling tension on the pipe shall not exceed the pipe supplier's safe pulling force as submitted for this project.

D. Pushing Equipment

1. An end protector plate shall be attached for hydraulically pushing or winching completed sections further into the sewer from manhole to manhole.
2. Routine shall be carried out until the entire pipe insertion is finished.

E. Pipe Care

1. The pipe shall be handled with care to minimize the possibility of it being cut, kinked, gouged, or otherwise damaged. The use of cables or hooks will not be permitted.
2. Sections of the pipe damaged, cut, or gouged shall be repaired by cutting out the section of damaged pipe and rejoining.

3.6 **FIELD QUALITY CONTROL**

- A. Field acceptance of the liner shall be based on the Engineer's evaluation of the installation including TV video and a review of certified test data for the installed pipe samples.

1. Groundwater infiltration of the liner shall be zero.
 2. There shall be no evidence of splits, cracks, breaks, lifts, kinks, delaminations or crazing in the liner.
 3. If any defective liner is discovered after it has been installed, it shall be removed and replaced with either a sound liner or a new pipe at no additional cost to the Owner.
- B. Repair failed lining or lining deemed unacceptable as a result of post-installation television inspection or test reports for structural values, thickness, or other defects. Obtain approval of the Engineer for method of repair, which may require field or workshop demonstration.

3.7 SEALING AT MANHOLES

- A. Form a tight seal between the sliplining and the manhole wall at the pipe penetration.
- B. Liner pipe shall be allowed to relax and come to thermal equilibrium for 24 hours prior to sealing.
- C. Do not leave any annular gaps.
- D. Seal the annular space to permanently block the flow of water into the manhole between the liner and the host pipe.
- E. Finish off the seal with an approved non-shrink grout or cementitious liner material placed around the pipe opening from inside the manhole in a band at least 4-inches wide.

3.8 POST-TELEVISING OF COMPLETED WORK

- A. Provide a video tape showing completed work in accordance with Section 02651, Television Inspection.
- B. All defects discovered during the television inspection shall be corrected by the Contractor before the Work under the Contract will be considered for substantial completion. After the defects are corrected, the sewer shall be video taped again.
- C. The post-rehabilitation television inspection tape shall be submitted to the Engineer in sufficient time to allow the Engineer to review the video tape prior to substantial completion.

3.9 FINAL CLEANUP

- A. Upon completion of rehabilitation work and testing, Contractor shall clean and restore the entire project area affected by the Work.
- B. All excess material and debris not incorporated into the permanent installation shall be disposed of in accordance with local regulations.
- C. Sidewalks, driveways and street surfaces shall be cleaned and returned to a condition similar to that before the work started.

END OF SECTION

02770-9

SECTION 03602
SLIPLINING GROUT - STRUCTURAL

PART 1 – GENERAL

1.1 DESCRIPTION

Contractor shall provide all materials, labor and equipment necessary to completely fill the annular space between the slipliner pipe and the host pipe with high-strength (> 3000 psi) cementitious grout.

1.2 QUALITY ASSURANCE

- A. ASTM C138 Test Method for Unit Weight, Yield and Air Content (Gravimetric) of Concrete
- B. ASTM C939 Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
- C. ASTM C942 Standard Test Method for Compressive Strength of Grout for Preplaced-Aggregate Concrete in the Laboratory
- D. ASTM C1090 Standard Test Method for Measuring Changes in Height of Cylindrical Specimens from Hydraulic-Cement Grout

1.3 DESCRIPTION

- A. Contractor shall seal the annular space between the liner and host pipes with cementitious structural grout as shown and specified.

1.4 SUBMITTALS

- A. Submittals shall conform to the requirements of Section 01300, Submittals.
- B. CONTRACTOR shall provide six (6) bound copies of the following information to the ENGINEER for review and approval prior to construction:
 - 1. Qualifications and experience of grout mix applicator and Project Superintendent and support personnel.
 - 2. Grout mix design and trial mix tests, with set time, compressive strength, viscosity, and density test results.
 - 3. Initial set time of the grout.
 - 4. The 24 hour and 28 day minimum grout compressive strengths.
 - 5. The grout working time before a 15% change in density or viscosity occurs.
 - 6. The proposed grouting methods and procedures.
 - 7. Method for waste grout recovery.
 - 8. Estimated grout volume for each pipe.
 - 9. The maximum injection pressures proposed as well as maximum allowable grout injection pressures as provided by the pipe manufacturer (as applicable).
 - 10. Proposed grout stage volumes (if grouting is to be performed in stages)

11. Bulkhead designs and locations including vent and injection port location and proposed materials to be used in bulkhead construction. In addition the lengths of each port shall be shown.
12. Method of flow control during grouting
13. Detailed plans depicting the method of blocking the liner pipe down to the invert for a period of time long enough to allow the grout to set when buoyant uplift is a factor.
14. Written confirmation that the CONTRACTOR has coordinated grouting procedures with the grout installer and the liner pipe manufacturer.
15. For each different type of grout or variations in procedure of installation, a complete package shall be submitted. The submittal shall include each of the above items and the locations of conditions to which it applies.

PART 2 - PRODUCTS

- A. Provide cementitious grout consisting of a mixture of cement, water, fly ash or lime and admixtures specifically designed to meet the requirements of this Section.
- B. Use only potable water obtained from a municipal water distribution system and transported, when required, in a clean, dedicated container designed specifically for such.
- C. Admixtures shall be selected by the slip-lining grout manufacturer to meet performance requirements, improve pumpability, control set time and reduce segregation. Admixtures shall not be biodegradable.
- D. The grout shall have a minimum compressive strength of 3000 psi in 28 days when tested in accordance with ASTM C942.
- E. The grouting system shall have sufficient gauges, monitoring devices, and tests to determine the effectiveness of the grouting operation and to ensure compliance with the liner pipe specifications and design parameters.
- F. CONTRACTOR shall develop one or more mix designs to completely fill the annular space based upon, but not restricted to, the following requirements:
 1. Size of annular void
 2. Void (size) of the surrounding soil
 3. Absence or presence of water
 4. Sufficient strength and durability achieve the design requirements presented in the sliplining Specification.
 5. Provide adequate retardation for placement
 6. Provide less than 1 percent shrinkage by volume
 7. Heat of hydration compatible with pipe material in accordance with pipe manufacturer's recommendations
- G. Mixing
 1. The materials shall be mixed in equipment of sufficient size and capacity to

provide the desired amount of grout material for each stage of the grouting operation.

2. System shall mix the grout to a homogeneous consistency and deliver grout to the injection point under a normal range of operating conditions.
3. Equipment shall be capable of mixing the grout at densities required for the approved procedures and shall also be capable of changing mixing parameters as dictated by field conditions at any time during the grouting operation.

H. Pressure Gauges

1. Pressure gauges shall be suitable for use in the grouting environment and have a working range between 1.5 to 2.0 times the design grout pressures, and have accuracy within 0.5% of full range.
2. Provide, at a minimum, one pressure gauge at the point of injection and one pressure gauge at the grout pump.

PART 3 - EXECUTION

3.1 GROUT INJECTION

- A. Notify the ENGINEER at least 24 hours in advance of grouting operations.
- B. Once the slipliner pipe has been installed, construct bulkheads at each end in sequence from upstream to downstream. Following construction of the bulkheads, the CONTRACTOR shall fill the annular space between the slipliner pipe and the host pipe along its entire length with cementitious grout by injecting grout from one end of the pipe segment, allowing it to flow toward the other end.
- C. Equip slipliner pipes with temporary weirs as necessary to fill the pipes with water to prevent flotation during grouting operations.
- D. Remove or control standing or running water in annular spaces to maintain the correct water ratio of the grout mixture.
- E. Limit pressure on the annular space to prevent damage to the liner. The gauged grout pressure at the pipe shall not exceed that of the pipe manufacturer's recommendation or 5 psi, whichever is smaller. Regardless of the pressure, the CONTRACTOR shall be solely responsible for any damage or distortion to slipliner pipe due to grouting.
- F. The drilling of additional injection holes from the surface or through the liner pipe to facilitate grouting is prohibited.
- G. Injection of grout shall continue until all of the following conditions have been achieved unless otherwise approved by the ENGINEER:
 1. The estimated volume of grout has been injected
 2. The exhausted grout recovered at each vent is not less than 85% of the density of the freshly injected grout
 3. The exhausted grout at each vent is not less than 85% of the original viscosity of the freshly injected grout, and

4. The grout installer, and/or Field Engineer recommends ceasing grouting operations
- H. No hardened grout is permitted in the liner pipe invert after completion of grouting operations.

3.2 **TESTING**

- A. Provide all personnel and equipment necessary to measure density in accordance with ASTM C138 or by another method as approved by the ENGINEER not less than two times per hour in the field during grouting operations.
- B. Provide all personnel and equipment necessary to measure viscosity in accordance with ASTM C939 not less than two times per hour in the field during grouting placement. The apparent viscosity shall not exceed 35 seconds unless otherwise approved by the ENGINEER.
- C. Compressive Strength
 1. Collect, transport, cure, test and report samples in accordance with ASTM C942.
 2. Contrary to ASTM C942, collect and test specimens based on the more restrictive of the following criteria:
 - a. One (1) specimen (consisting of one, 3-gang mold) for each grouting event for each pipe collected at approximately the mid-point of the grouting operation.
 - b. One (1) specimen (consisting of one, 3-gang mold) for each 500 cubic feet of grout placed for each pipe.
 3. Test all specimens for compressive strength at 28 days. Additional specimens and tests may be performed at the CONTRACTOR'S discretion.
 4. CONTRACTOR shall engage the services of an independent, ASTM/AASHTO accredited testing laboratory to collect and test specimens associated with the strength requirements of this Section.

END OF SECTION