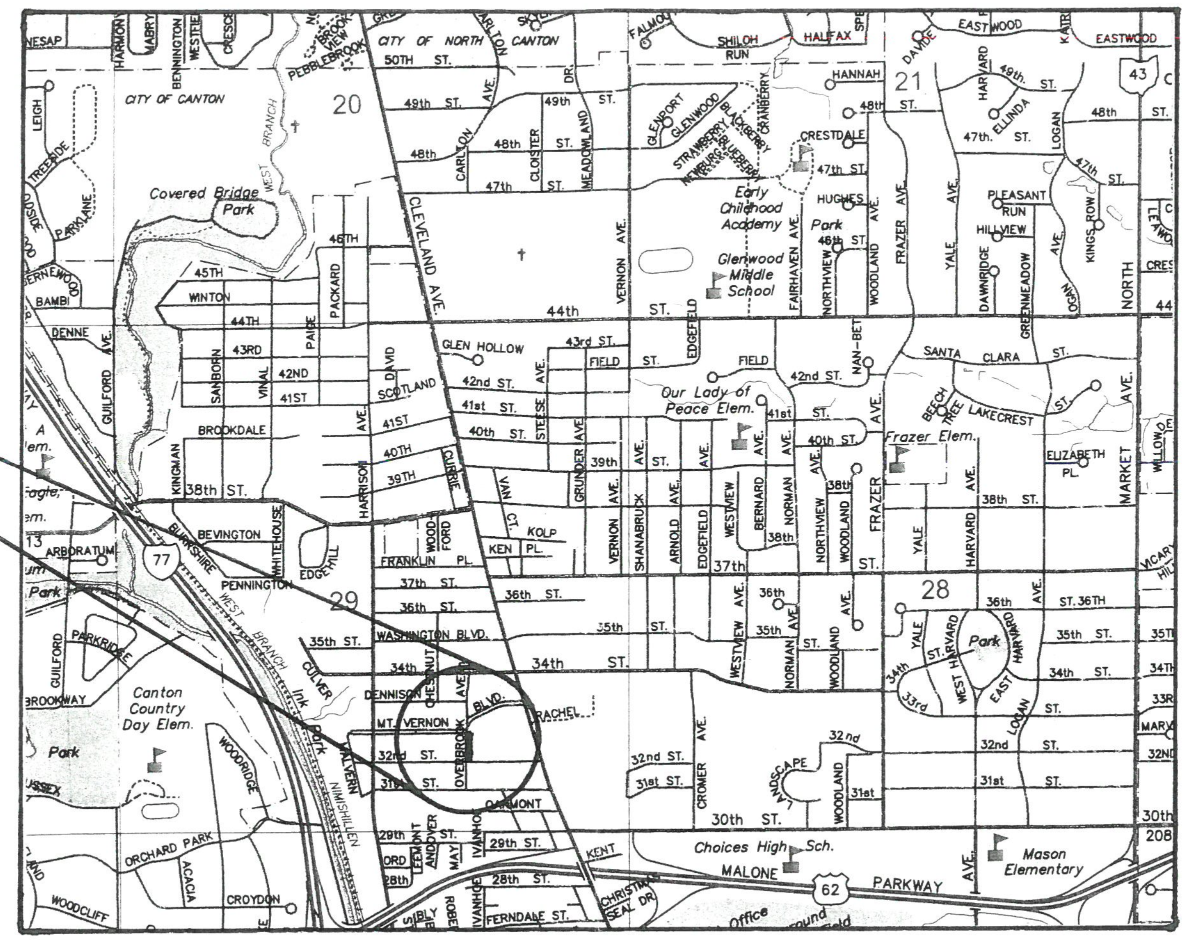
CITY OF CANTON, OHIO

OVERBROOK AVE. NW STORM SEWER REPAIR PROJECT

G.P. 1217

PROJECT LOCATION



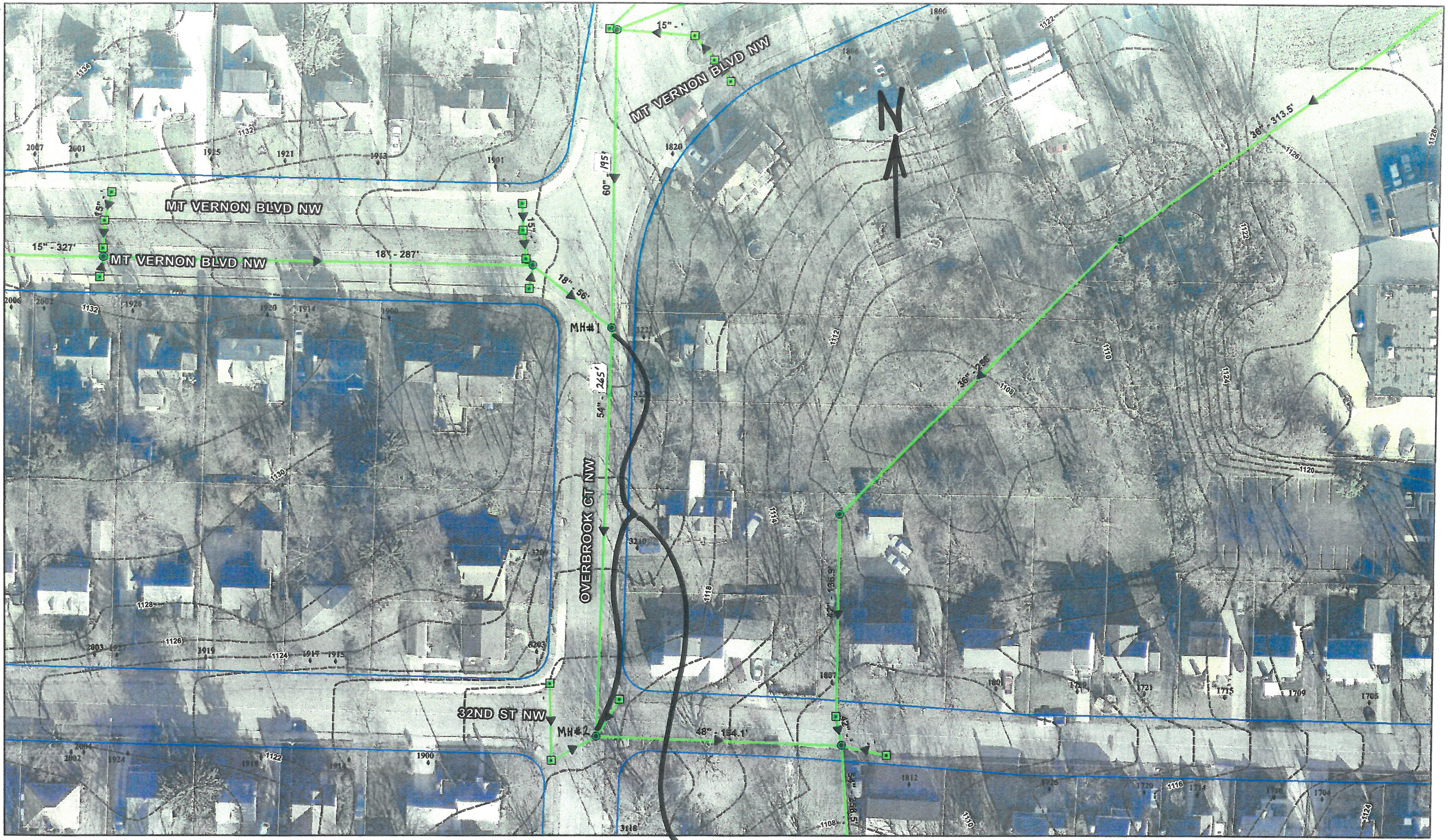
THIS PROJECT REQUIRES THE INSTALLATION OF CURED-IN-PLACE PIPE (CIPP) LINER FOR A 54"-DIAMETER HOST CORRUGATED METAL PIPE (CMP) STORM SEWER. THIS PROJECT MUST SATISFY THE TECHNICAL SPECIFICATIONS FOR CURED-IN-PLACE-PIPE FOR MAINLINE RENEWAL AS REQUIRED BY THE CITY ENGINEER.

Plans prepared by:
City of Canton Engineering Department
Daniel J. Moeglin, PE, SI – City Engineer
2436 30th St. NE
Canton, OH 44705

September 16, 2015

STATE OF OHIO
DANIEL J. MOEGLIN
E-62373
REGISTERED PROFESSIONAL ENGINEER

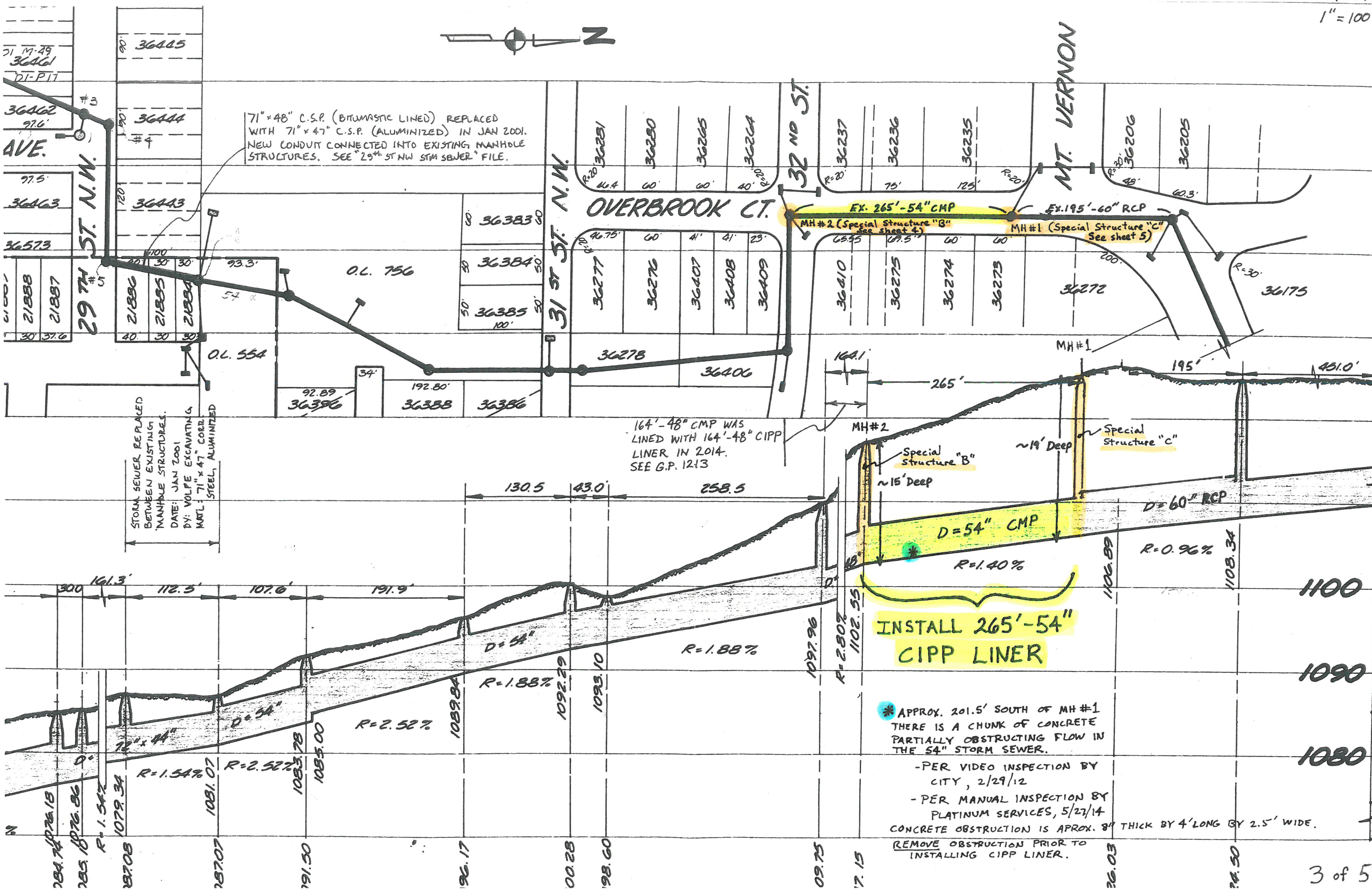
9/17/15

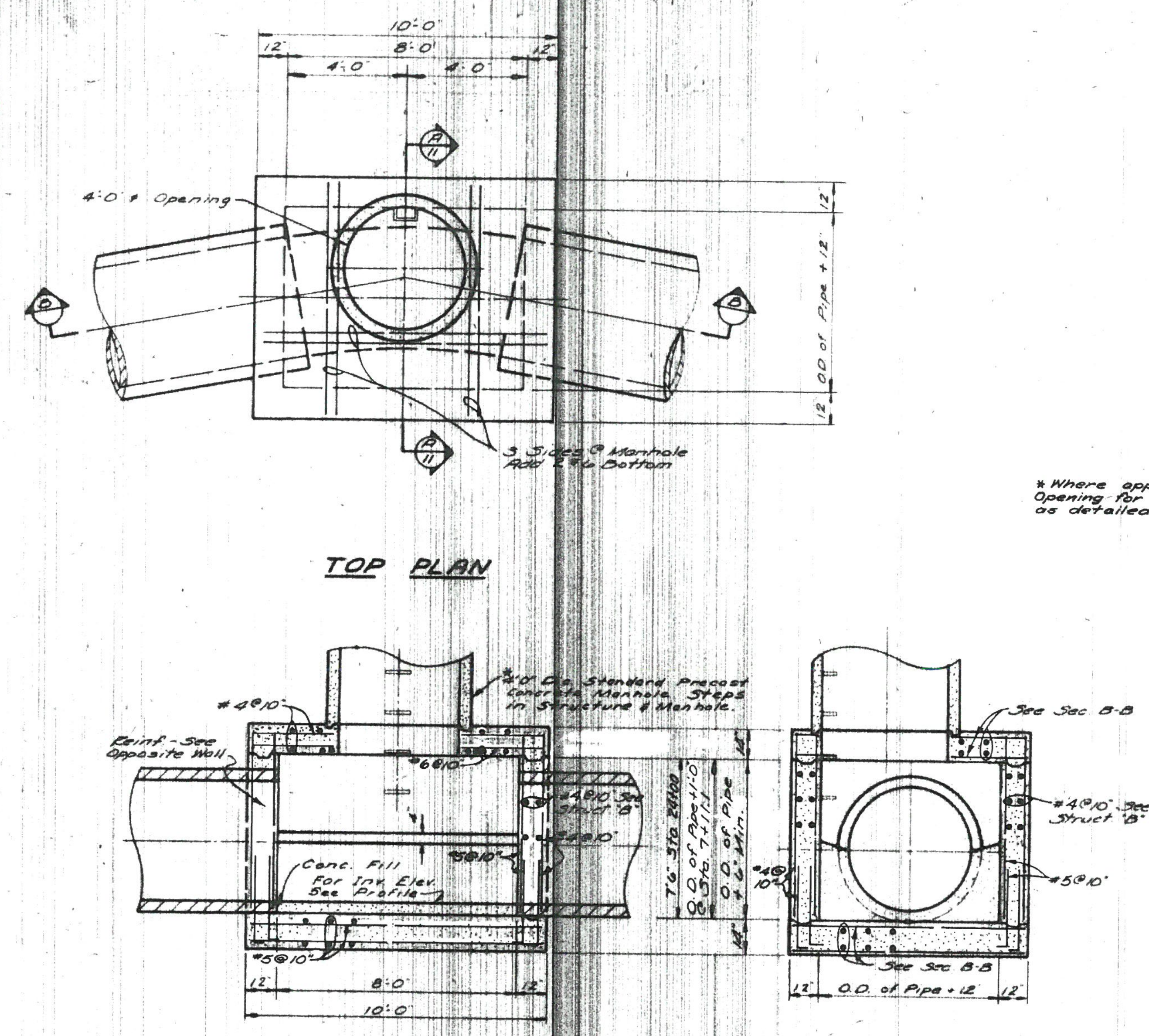


INSTALL 265'-54" CIPP LINER

0 50 100 Feet
1 inch = 60 feet
1:720

N W E S


71" × 48" C.S.P. (BITUMASTIC LINED) REPLACED WITH 71" × 47" C.S.P. (ALUMINIZED) IN JAN 2001. NEW CONDUIT CONNECTED INTO EXISTING MANHOLE STRUCTURES. SEE "29th ST NW STM SEWER" FILE.
AVE.
29TH ST. N.W.
31 ST ST. N.W.
32 ND ST.
MT. VERNON
OVERBROOK CT.
O.L. 756
O.L. 554
EX. 265'-54" CMP
Ex. 195'-60" RCP
MH #2 (Special Structure "B" see sheet 4)
MH #1 (Special Structure "C" See sheet 5)
STORM SEWER REPLACED BETWEEN EXISTING MANHOLE STRUCTURES. DATE: JAN 2001 BY: VOLPE EXCAVATING MAT'L: 71" × 47" CORR STEEL, ALUMINIZED
164'-48" CMP WAS LINED WITH 164'-48" CIPP LINER IN 2014. SEE G.P. 1213
MH#2
MH#1
Special Structure "B"
~15' Deep
~19' Deep
Special Structure "C"
D=54" CMP
D=60" RCP
R=1.40%
R=0.96%
R=1.88%
R=2.52%
R=1.54%
D=54"
72" × 44"
INSTALL 265'-54" CIPP LINER
1100
1090
1080
* APPROX. 201.5' SOUTH OF MH #1 THERE IS A CHUNK OF CONCRETE PARTIALLY OBSTRUCTING FLOW IN THE 54" STORM SEWER.
- PER VIDEO INSPECTION BY CITY, 2/29/12
- PER MANUAL INSPECTION BY PLATINUM SERVICES, 5/27/14
CONCRETE OBSTRUCTION IS APROX. 8" THICK BY 4' LONG BY 2.5' WIDE.
REMOVE OBSTRUCTION PRIOR TO INSTALLING CIPP LINER.



TOP PLAN

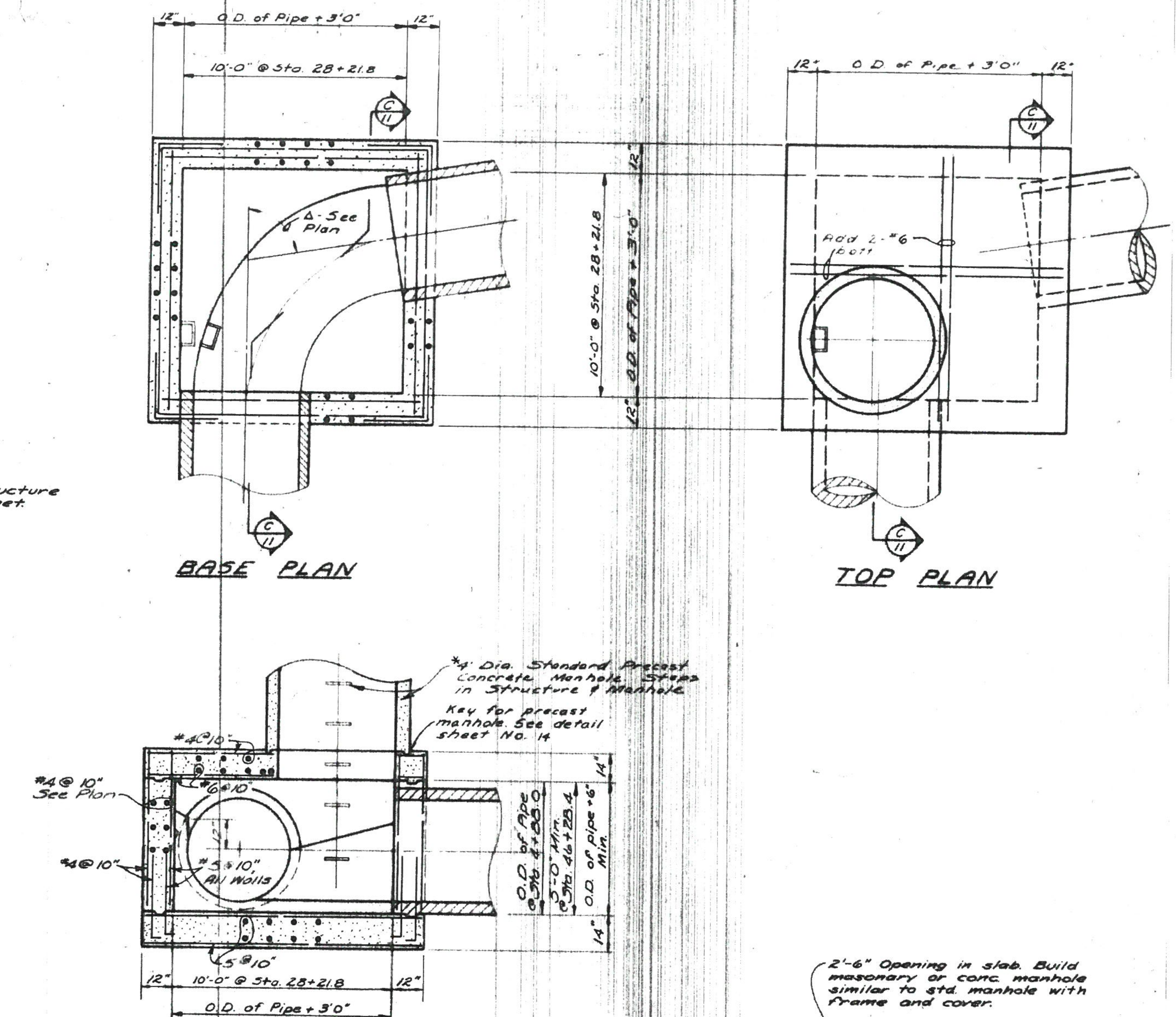
SECTION B-B

SECTION A-A

SPECIAL STRUCTURE TYPE "A"

Scale 3/8" = 1'-0"

* Where applicable use Opening for Shallow Structure as detailed on this sheet.



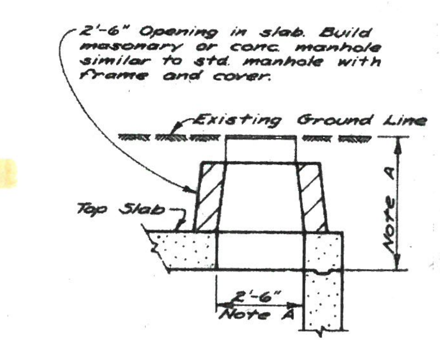
BASE PLAN

TOP PLAN

SECTION C-C

SPECIAL STRUCTURE TYPE "B"

Scale 3/8" = 1'-0"



Note A: Slab opening to be 2'-6" when inside top slab distance to ground line is 4'-8" or less. Slab opening to be 2'-0" when inside top slab distance to ground line is 2'-6" or less.

TYPICAL ENTRANCE OPENING FOR SHALLOW STRUCTURES

No Scale

STRUCTURAL NOTES

1. Cast catch basin leads & proposed storm drains in place where required. See plan sheets for sizes and elevations.
2. Minimum concrete cover over reinforcing bars shall be 2 inches for walls and slabs and 3 inches for concrete poured against earth, unless noted.
3. Manhole frames and covers & manhole steps to be included in price of structure.
4. All exposed concrete corners shall be chamfered 3/4 inches, unless noted.
5. Provide 1 #5 bar in each reinforcing plane around all openings 4'0" or longer than the opening, unless noted.
6. Precast concrete manhole sections to be included in price of structure.
7. Catch basin leads and proposed connecting storm drains not necessarily shown in special structures. See plan & profile views.

NO.	REVISION DATA	DATE	BY	APP'D

FLOYD G. BROWNE AND ASSOCIATES LIMITED
CONSULTING ENGINEER
MARION, OHIO

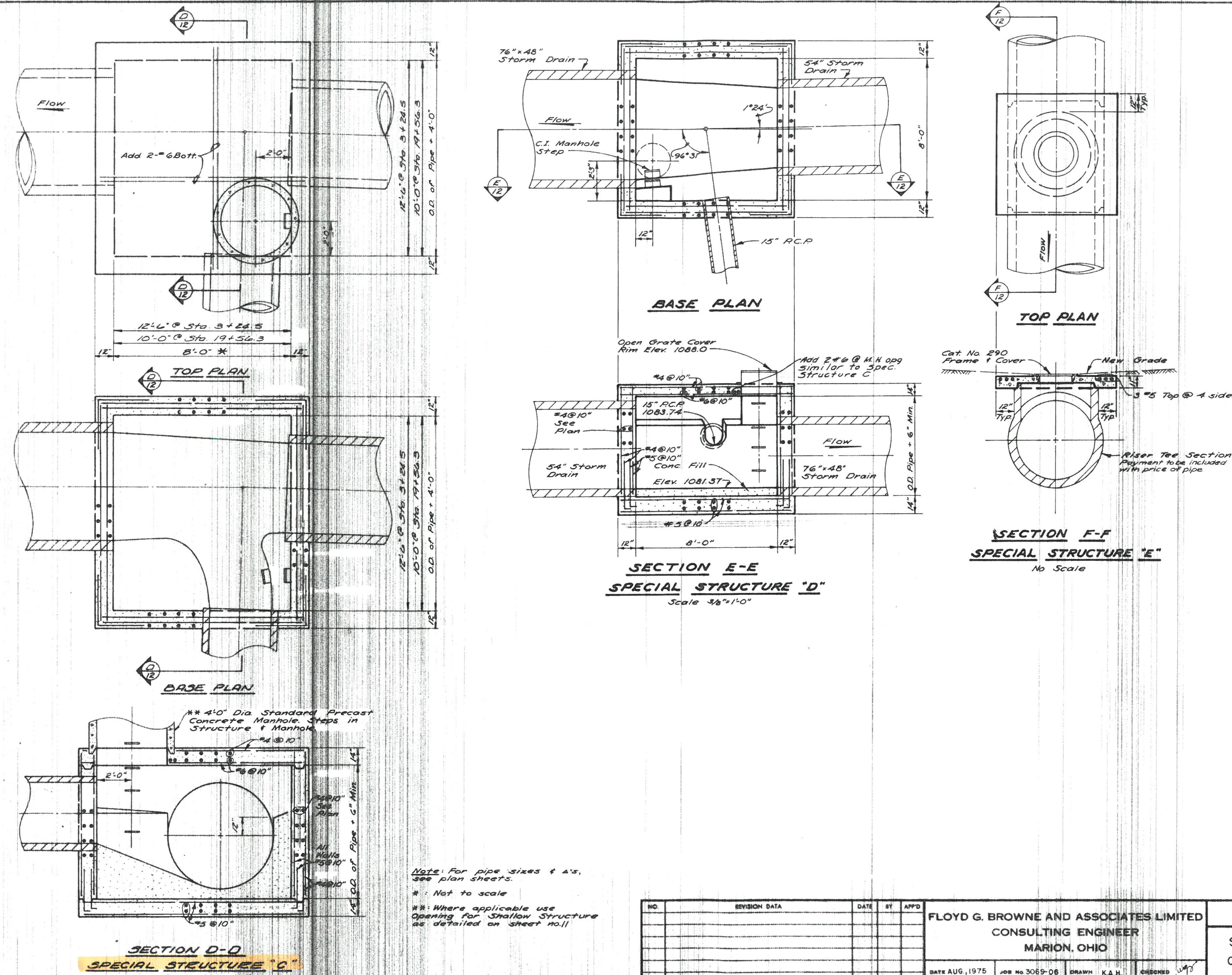
DATE AUG., 1975	JOB No. 3069-06	DRAWN K.A.H.	CHECKED WOP
SCALE AS SHOWN	DWG. No. E 75041	TRACED M.A.L.	APPROVED HAL

CANTON, OHIO

STORM DRAINAGE IMPROVEMENTS

CONTRACT NO. 6 - GENERAL PROJECT 810

SPECIAL STRUCTURES



Note: For pipe sizes & Δ's, see plan sheets.

*: Not to scale

**: Where applicable use opening for Shallow Structure as detailed on sheet no. 11

NO.	REVISION DATA	DATE	BY	APP'D

FLOYD G. BROWNE AND ASSOCIATES LIMITED
CONSULTING ENGINEER
MARION, OHIO

DATE AUG., 1975	JOB No. 3069-06	DRAWN K.A.H.	CHECKED
SCALE AS SHOWN	DWG. No. E T5042	TRACED D. K. G.	APPROVED

CANTON, OHIO

STORM DRAINAGE IMPROVEMENTS
CONTRACT NO. 6 — GENERAL PROJECT 810
SPECIAL STRUCTURES

BRUNING 44-160

NOTES:

1. **BEDDING:**

MATERIALS SHALL BE AASHTO M 43 NO. 56, 57, OR 67 CRUSHED STONE. NO ALTERNATES UNLESS APPROVED BY THE CITY ENGINEER. PRIVATE UTILITIES MAY TYPICALLY PROVIDE ALTERNATIVE BEDDING MATERIAL AS APPROVED BY THE CITY ENGINEER.

BEDDING WIDTH TABLE

PIPE TYPE	MIN. WIDTH, TYP.	MAX. WIDTH, TYP.
NON-RIGID PIPE (PVC, HDPE, CMP, ALUMINUM)	**PIPE I.D. x 1.25 + 1'-0"**	**PIPE O.D. + 2'-0"**
RIGID PIPE (CONC., VIT. CLAY, DUCTILE IRON)	**PIPE I.D. x 1.33**	PIPE O.D. + 2'-0"

CENTER PIPE HORIZONTALLY WITHIN BEDDING AREA. ANY DEVIATION TO TYPICAL BEDDING REQUIREMENTS ARE SUBJECT TO THE DISCRETION OF THE CITY ENGINEER.

THE BEDDING LIMITS SHOWN APPLY IN ALL CASES *EXCEPT* FOR WHEN PIPE MANUFACTURER SPECIFIES A BEDDING WIDTH DIFFERENT FROM THAT SHOWN AND THE CITY ENGINEER PERMITS SAME.

2. **BACKFILL:**

BACKFILL WITHIN THE PUBLIC STREET R/W:

MATERIALS SHALL BE ODOT 703.11, TYPE '1' GRANULAR MATERIAL (304, 411, or 617 AGGREGATE GRADATION) OR TYPE '2' GRANULAR MATERIAL, OR ODOT 613, LOW STRENGTH MORTAR; DEVIATIONS FROM THIS ARE AS FOLLOWS:

A) NO FOUNDRY SAND OR SLAG IS PERMITTED.

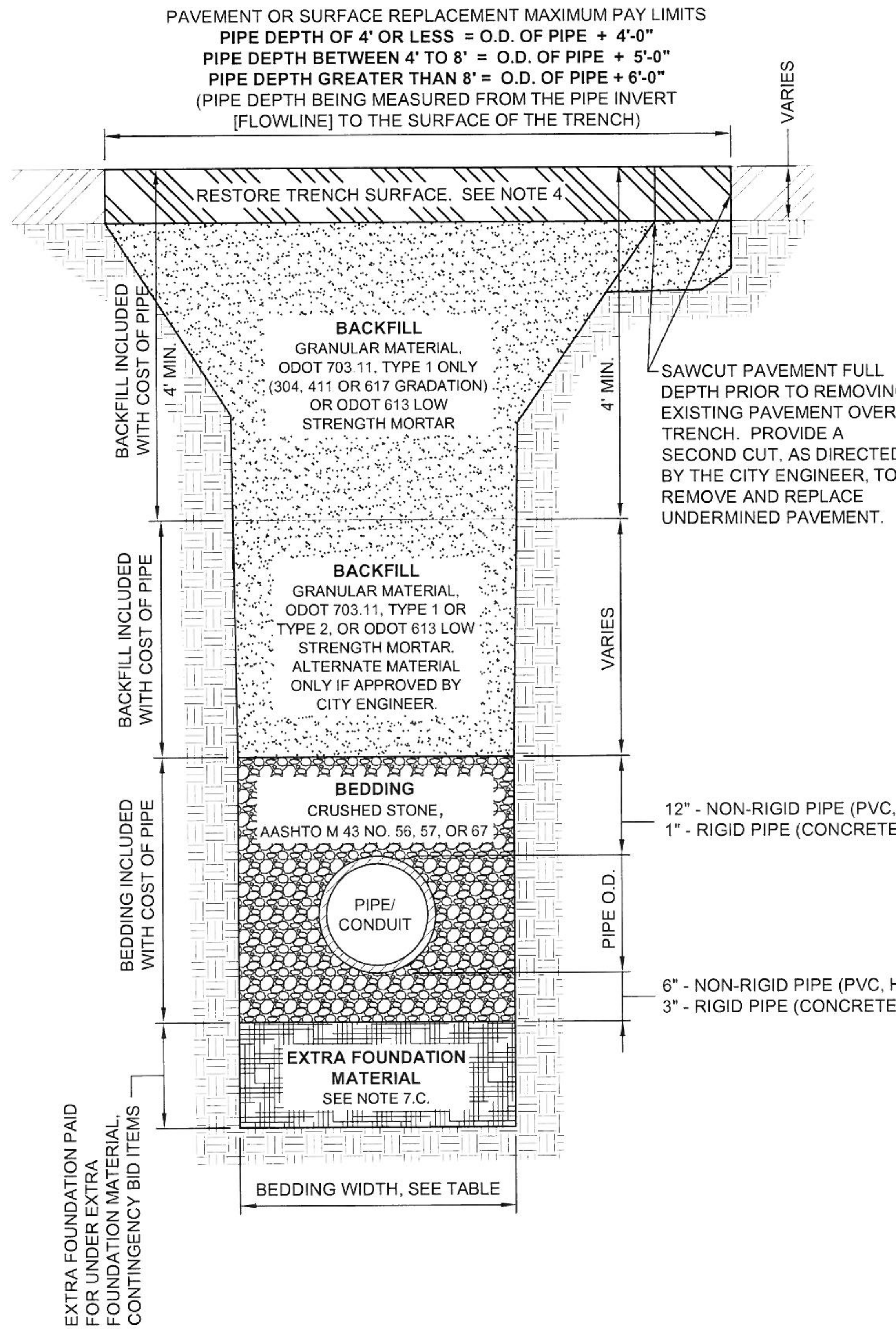
B) ALTERNATE GRANULAR MATERIAL SHALL BE PERMITTED ONLY WITH THE SUPPLEMENTAL APPROVAL OF THE CITY ENGINEER. TO PETITION FOR SUCH SUPPLEMENTAL APPROVAL, THE DEVELOPER/CONTRACTOR SHALL SUBMIT IN WRITING THE FOLLOWING:
   * SOURCE OF THE ALTERNATE BACKFILL MATERIAL.
   * GRADATION REPORT IN ACCORDANCE WITH AASHTO T II AND T 27.
   * PROCTOR CURVE ANALYSIS IN ACCORDANCE WITH ASTM D 698.
   * PROPOSED COMPACTION METHOD.

   THE CITY ENGINEER RESERVES THE RIGHT TO REFUSE ANY ALTERNATE BACKFILL MATERIAL, REGARDLESS OF APPROVAL OF SIMILAR MATERIAL ON A PREVIOUS PROJECT.

   THE CITY ENGINEER FURTHER RESERVES THE RIGHT TO REFUSE ANY ALTERNATE BACKFILL MATERIAL THE CITY FINDS NOT CONSISTENT WITH THE APPROVED SOURCE, GRADATION REPORT, PROCTOR REPORT, OR COMPACTION METHOD.

C) ODOT 703.11, TYPE 2, OR ALTERNATE MATERIALS ARE NOT PERMITTED WITHIN 4 FEET OF THE TRENCH SURFACE, UNLESS OTHERWISE APPROVED BY THE CITY ENGINEER.

BACKFILL OUTSIDE OF THE PUBLIC STREET R/W:
FOLLOW MATERIAL AND METHODS FOR BACKFILL IN ACCORDANCE WITH ODOT 603.



NOTES: (CONTINUED)

3. **COMPACTION:**

ALL BACKFILL SHALL BE PLACED IN LAYERS NOT TO EXCEED 12-INCHES LOOSE DEPTH AND COMPACTED BY APPROVED MECHANICAL MEANS. JETTING IS NOT APPROVED WITHOUT THE CITY ENGINEER'S APPROVAL. BUCKET COMPACTION MUST BE SUPPLEMENTED WITH VIBRATION OR TAMPING EQUIPMENT AS DIRECTED. ANY MODIFICATIONS TO THESE REQUIREMENTS MUST BE APPROVED BY THE CITY ENGINEER.

4. **SURFACE:**

TRENCHES SHALL BE TOPPED WITH 4" OF ODOT 304 LIMESTONE OR ASPHALT GRINDINGS WITHIN EXISTING STREET PAVEMENTS WHEN THE STREET WILL BE OPENED TO VEHICULAR TRAFFIC PRIOR TO PAVEMENT REPLACEMENT. THE TRENCH TOPPING MATERIAL SHALL BE ROLLED OR OTHERWISE COMPLETED FLUSH WITH THE ADJOINING PAVEMENT.

STREET RESTORATION:
CONCRETE OR ASPHALT STREET PAVEMENT SHALL BE REPLACED IN ACCORDANCE WITH **CITY STD. DWG. NO. 32**. BRICK OR ASPHALT-BRICK COMPOSITE STREET PAVEMENT SHALL BE REPLACED IN ACCORDANCE WITH **CITY STD. DWG. NO. 31**.

SIDEWALK, CURB, AND DRIVEWAY RESTORATION:
DRIVEWAY SURFACES SHALL BE REPLACED IN ACCORDANCE WITH THE **CURRENT EDITION OF THE CITY OF CANTON SPECIFICATIONS FOR THE CONSTRUCTION, REPAIR, AND REPLACEMENT OF SIDEWALKS, CURBS, AND DRIVEWAYS**; AND CITY STD. DWG. NOS. 28 THRU 33.

LAWN RESTORATION:
LAWN SURFACES SHALL BE REPLACED WITH A MINIMUM OF 4" TOPSOIL, SEEDED, AND MULCHED. SEED MIX SHALL CONFORM TO ADJOINING LAWN GRASS.

5. **CONSTRUCTION METHODS** FOR BEDDING AND BACKFILL SHALL CONFORM WITH ODOT 603, UNLESS STATED OTHERWISE HEREIN.

6. **ODOT REFERENCES** ARE FROM THE CURRENT ODOT CONSTRUCTION AND MATERIAL SPECIFICATIONS. ANY DISCREPANCIES SHALL BE SUBJECT TO THE CITY ENGINEER'S DISCRETION.

EST. 1805 CANTON, OHIO

OFFICE OF THE CITY ENGINEER
CANTON, OHIO
DANIEL J. MOEGLIN, P.E., CITY ENGINEER
2436 30th St. NE 44705 330-489-3381 www.cantonohio.gov/engineering

APPROVED DATE: JAN 2012

APPROVED BY: CDB, RMB, SLH

DRAWING FILE NAME: ce_19.dwg

REVISIONS

DESCRIPTION	DATE	BY
REVISIONS TO NOTES 7 & 8	6/4/2012	CDB
REVISIONS TO NOTES 7	6/10/2013	CDB

STANDARD DRAWING NO. 19
UTILITY TRENCH REQUIREMENTS

NOTES: (CONTINUED)

7. **PAY LIMITS FOR CITY PROJECTS**

A) **BEDDING AND BACKFILL** IS INCLUDED WITH THE COST OF PIPE UNLESS DIRECTED TO BID OTHERWISE.

B) **PAVEMENT RESTORATION** IS INCLUDED WITH THE COST OF PIPE UNLESS A SEPARATE PAY ITEM IS PROVIDED, WHEREBY THE WIDTH MEASUREMENT OVER THE TRENCH FOR PAVEMENT RESTORATION SHALL NOT EXCEED THE OUTSIDE DIAMETER (O.D.) OF PIPE PLUS A SET MEASUREMENT DEPENDENT ON DEPTH OF PIPE. AREA MEASUREMENTS AT MANHOLE AND CATCH BASIN STRUCTURES SHALL NOT EXCEED THE AREA OF THE BASE OF THE STRUCTURE + 3'-0" OFFSET AREA AROUND THE STRUCTURE'S BASE.

C) **EXTRA FOUNDATION MATERIAL**: THE CONTRACTOR SHALL BE PAID FOR OVER-EXCAVATION AND BEDDING FOUNDATION MATERIAL UNDER THE CONTINGENCY BID ITEMS FOR EXTRA FOUNDATION MATERIAL.

WHEN IN THE OPINION OF THE CITY ENGINEER, SOFT/UNSTABLE MATERIALS ARE ENCOUNTERED WHICH ARE UNSUITABLE FOR BEDDING FOUNDATION, SAID MATERIAL SHALL BE REMOVED BY THE CONTRACTOR TO THE DEPTH DIRECTED BY THE ENGINEER AND REPLACED WITH SUITABLE MATERIAL.

FOR CITY PROJECTS, THE PAYABLE WIDTH OF THE EXTRA FOUNDATION MATERIAL SHALL NOT EXCEED THE LESSER OF THE APPLICABLE MINIMUM OR MAXIMUM TYPICAL BEDDING WIDTH, AS NOTED ON SHEET 1 OF STD. DWG. NO. 19.

FOR PRIVATE WORK, ALL COSTS ARE AT THE OWNER'S EXPENSE.

EXTRA FOUNDATION MATERIAL, OPTION A, B, C, & D, MAY BE USED IN ANY COMBINATION AS DIRECTED BY THE CITY ENGINEER:

OPTION A: CRUSHED STONE, AASHTO M 43 NO. 1 AND/OR 2

OPTION B: CRUSHED STONE, AASHTO M 43 NO. 56, 57, OR 67

OPTION C: ODOT 703.11, TYPE 1 (304, 411 OR 617 GRADATION)

OPTION D: TENSAR GEOGRID T1100, OR APPROVED EQUAL

EXTRA FOUNDATION MATERIAL, CONTINGENCY BID ITEMS

ITEM	QTY.	UNIT	DESCRIPTION
603		C.Y.	EXTRA FOUNDATION, OPTION A (#1,#2 STONE)
603		C.Y.	EXTRA FOUNDATION, OPTION B (#56,57,67 STONE)
603		C.Y.	EXTRA FOUNDATION, OPTION C (304,411,617)
603		S.F.	EXTRA FOUNDATION, OPTION D (GEOGRID)

NOTES: (CONTINUED)

8. **EXCAVATION OF ROCK OR BURIED/ABANDONED CONCRETE STRUCTURE REMOVAL**

EXCAVATION FOR NEW MANHOLES AND CATCH BASINS, UNLESS OTHERWISE SPECIFIED OR SHOWN ON CONSTRUCTION PLANS, SHALL BE MEASURED BETWEEN VERTICAL PLANES ONE (1) FOOT BEYOND THE OUTSIDE EDGE OF THE FOUNDATION OF THE STRUCTURES ON ALL SIDES, AND PARALLEL THERETO, AND FROM THE SURFACE OF THE ROCK TO THE BOTTOM OF THE ROCK OR THE NEAT LINES OF THE BOTTOM OF THE STRUCTURES PLUS THE DEPTH OF THE BASE MATERIAL, USE THE MEASUREMENT WHICH IS LESSER.

EXCAVATION FOR NEW PIPES, UNLESS OTHERWISE SPECIFIED OR SHOWN ON CONSTRUCTION PLANS, SHALL BE MEASURED BETWEEN TRENCH WALLS (NOT TO EXCEED PIPE O.D. + 18", AND FROM THE SURFACE OF THE ROCK TO THE BOTTOM OF THE ROCK OR THE BOTTOM OF THE PIPE BEDDING, USE THE MEASUREMENT WHICH IS LESSER.

EXCAVATION OF BURIED AND ABANDONED CONCRETE STRUCTURES SHALL BE MEASURED IN THE SAME MANNER AS ROCK REMOVAL.

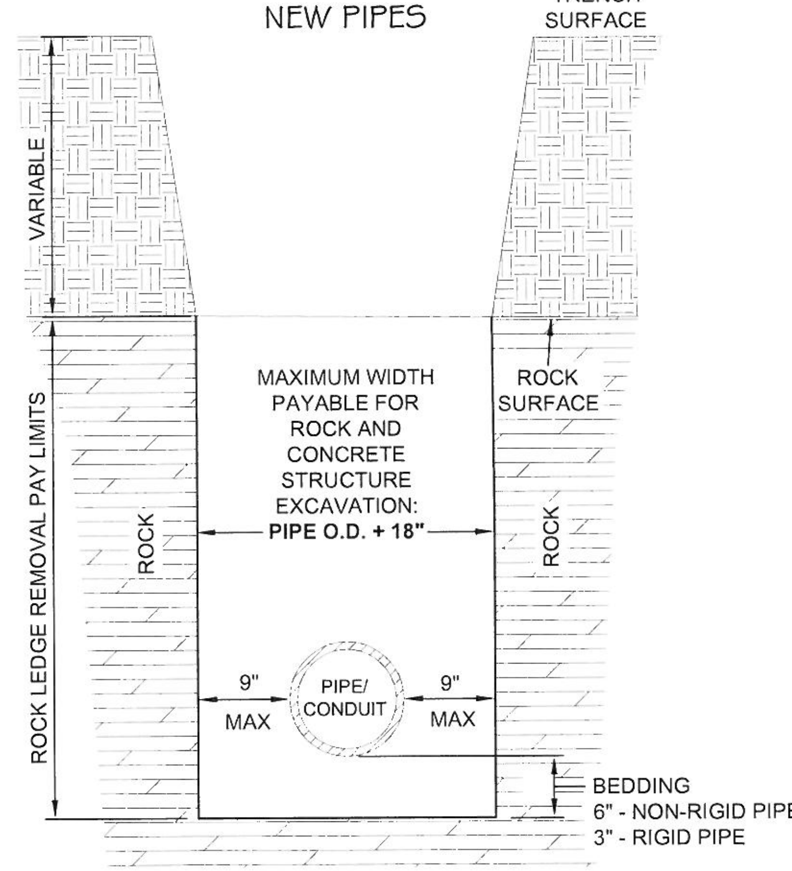
FOR CITY PROJECTS, THE CONTRACTOR SHALL BE PAID FOR ROCK REMOVAL AND CONCRETE STRUCTURE REMOVAL UNDER THE CONTINGENCY BID ITEMS FOR ROCK OR CONCRETE STRUCTURE REMOVAL. IF A CONTINGENCY BID ITEM IS NOT INCLUDED IN THE BID PROPOSAL, THE CONTACTOR MAY SUBMIT A PROPOSAL (PRIOR TO WORK BEING STARTED) TO THE CITY ENGINEER FOR REVIEW AND APPROVAL.

FOR PRIVATE WORK, ALL COSTS ARE AT THE OWNER'S EXPENSE.

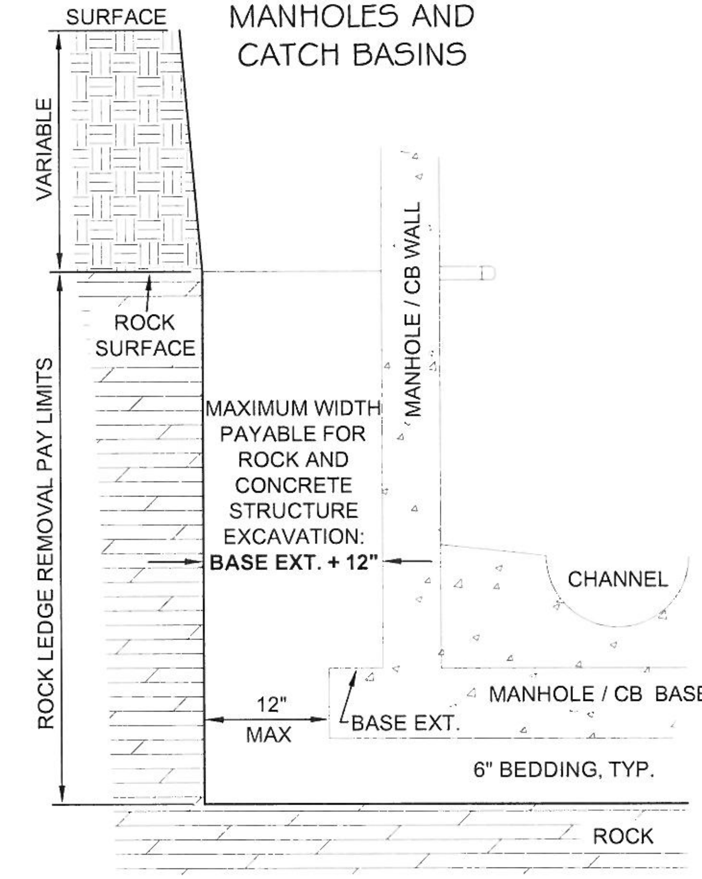
ROCK AND BURIED & ABANDONED CONCRETE STRUCTURE REMOVAL, CONTINGENCY BID ITEMS

ITEM	QTY.	UNIT	DESCRIPTION
603		C.Y.	ROCK REMOVAL
603		C.Y.	CONCRETE STRUCTURE REMOVAL

ROCK EXCAVATION NEW PIPES



ROCK EXCAVATION MANHOLES AND CATCH BASINS



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APPROVED DATE: JAN 2012

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DESCRIPTION	DATE	BY
REVISIONS TO NOTES 7 & 8	6/4/2012	CDB
REVISIONS TO NOTES 7	6/10/2013	CDB

STANDARD DRAWING NO. 19

UTILITY TRENCH REQUIREMENTS

SHEET 2 OF 2

Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube[1, 2]

This standard is issued under the fixed designation F 1216; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice describes the procedures for the reconstruction of pipelines and conduits (4 to 108-in. diameter) by the installation of a resin-impregnated, flexible tube which is inverted into the existing conduit by use of a hydrostatic head or air pressure. The resin is cured by circulating hot water or introducing controlled steam within the tube. When cured, the finished pipe will be continuous and tight-fitting. This reconstruction process can be used in a variety of gravity and pressure applications such as sanitary sewers, storm sewers, process piping, electrical conduits, and ventilation systems.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements, see 7.4.2.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D 543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents
D 638 Test Method for Tensile Properties of Plastics
D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D 903 Test Method for Peel or Stripping Strength of Adhesive Bonds
D 1600 Terminology for Abbreviated Terms Relating to Plastics
D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
D 3839 Guide for Underground Installation of "Fiberglass" (Glass-FiberReinforced Thermosetting-Resin) Pipe
D 5813 Specification for Cured-In-Place Thermosetting Resin Sewer Piping Systems
E 797 Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method
F 412 Terminology Relating to Plastic Piping Systems

2.2 *AWWA Standard:*

Manual on Cleaning and Lining Water Mains, M 28 [4]

2.3 *NASSCO Standard:*

Recommended Specifications for Sewer Collection System Rehabilitation [5]

3. Terminology

3.1 Definitions are in accordance with Terminology F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise specified.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cured-in-place pipe (CIPP)*—a hollow cylinder containing a nonwoven or a woven material, or a combination of nonwoven and woven material surrounded by a cured thermosetting resin. Plastic coatings may be included. This pipe is formed within an existing pipe. Therefore, it takes the shape of and fits tightly to the existing pipe.

3.2.2 *inversion*—the process of turning the resin-impregnated tube inside out by the use of water pressure or air pressure.

3.2.3 *lift*—a portion of the CIPP that has cured in a position such that it has pulled away from the existing pipe wall.

4. Significance and Use

4.1 This practice is for use by designers and specifiers, regulatory agencies, owners, and inspection organizations who

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[1] This practice is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.67 on Trenchless Plastic Pipeline Technology.

Current edition approved March 1, 2009. Published March 2009. Originally approved in 1989. Last previous edition approved 2008 as F 1216 – 08.

[2] The following report has been published on one of the processes: Driver, F. T., and Olson, M. R., " *Demonstration of Sewer Relining by the Insituform Process, Northbrook, Illinois*," EPA-600/2-83-064, Environmental Protection Agency, 1983. Interested parties can obtain copies from the Environmental Protection Agency or from a local technical library.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Water Works Association (AWWA), 6666 W. Quincy Ave., Denver, CO 80235, http://www.awwa.org.

[5] Available from the National Association of Sewer Service Companies, 101 Wymore Rd., Suite 501, Altamonte, FL 32714.

***A Summary of Changes section appears at the end of this standard.**

are involved in the rehabilitation of conduits through the use of a resin-impregnated tube inverted through the existing conduit. As for any practice, modifications may be required for specific job conditions.

5. Materials

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

5.2 *Resin*—A general purpose, unsaturated, styrene-based, thermoset resin and catalyst system or an epoxy resin and hardener that is compatible with the inversion process should be used. The resin must be able to cure in the presence of water and the initiation temperature for cure should be less than 180°F (82.2°C). The CIPP system can be expected to have as a minimum the initial structural properties given in Table 1. These physical strength properties should be determined in accordance with Section 8.

6. Design Considerations

6.1 *General Guidelines*—The design thickness of the CIPP is largely a function of the condition of the existing pipe. Design equations and details are given in Appendix X1.

7. Installation

7.1 *Cleaning and Inspection*:

7.1.1 Prior to entering access areas such as manholes, and performing inspection or cleaning operations, an evaluation of the atmosphere to determine the presence of toxic or flammable vapors or lack of oxygen must be undertaken in accordance with local, state, or federal safety regulations.

7.1.2 *Cleaning of Pipeline*—All internal debris should be removed from the original pipeline. Gravity pipes should be cleaned with hydraulically powered equipment, high-velocity jet cleaners, or mechanically powered equipment (see NASSCO Recommended Specifications for Sewer Collection System Rehabilitation). Pressure pipelines should be cleaned with cable-attached devices or fluid-propelled devices as shown in AWWA Manual on Cleaning and Lining Water Mains, M 28.

7.1.3 *Inspection of Pipelines*—Inspection of pipelines should be performed by experienced personnel trained in locating breaks, obstacles, and service connections by closed-circuit television or man entry. The interior of the pipeline should be carefully inspected to determine the location of any conditions that may prevent proper installation of the impregnated tube, such as protruding service taps, collapsed or crushed pipe, and reductions in the cross-sectional area of more than 40 %. These conditions should be noted so that they can be corrected.

7.1.4 *Line Obstructions*—The original pipeline should be clear of obstructions such as solids, dropped joints, protruding service connections, crushed or collapsed pipe, and reductions in the cross-sectional area of more than 40 % that will prevent the insertion of the resin-impregnated tube. If inspection reveals an obstruction that cannot be removed by conventional sewer cleaning equipment, then a point repair excavation should be made to uncover and remove or repair the obstruction.

7.2 *Resin Impregnation*—The tube should be vacuum-impregnated with resin (wet-out) under controlled conditions. The volume of resin used should be sufficient to fill all voids in the tube material at nominal thickness and diameter. The volume should be adjusted by adding 5 to 10 % excess resin for the change in resin volume due to polymerization and to allow for any migration of resin into the cracks and joints in the original pipe.

7.3 *Bypassing*—If bypassing of the flow is required around the sections of pipe designated for reconstruction, the bypass should be made by plugging the line at a point upstream of the pipe to be reconstructed and pumping the flow to a downstream point or adjacent system. The pump and bypass lines should be of adequate capacity and size to handle the flow. Services within this reach will be temporarily out of service.

7.3.1 Public advisory services will be required to notify all parties whose service laterals will be out of commission and to advise against water usage until the mainline is back in service.

7.4 *Inversion*:

7.4.1 *Using Hydrostatic Head*—The wet-out tube should be inserted through an existing manhole or other approved access by means of an inversion process and the application of a hydrostatic head sufficient to fully extend it to the next designated manhole or termination point. The tube should be inserted into the vertical inversion standpipe with the impermeable plastic membrane side out. At the lower end of the inversion standpipe, the tube should be turned inside out and attached to the standpipe so that a leakproof seal is created. The inversion head should be adjusted to be of sufficient height to cause the impregnated tube to invert from point of inversion to point of termination and hold the tube tight to the pipe wall, producing dimples at side connections. Care should be taken during the inversion so as not to over-stress the felt fiber.

TABLE 1 CIPP Initial Structural Properties[A]

Property	Test Method	Minimum Value psi	Minimum Value (MPa)
Flexural strength	D 790	4 500	(31)
Flexural modulus	D 790	250 000	(1 724)
Tensile strength (for pressure pipes only)	D 638	3 000	(21)

[A]The values in Table 1 are for field inspection. The purchaser should consult the manufacturer for the long-term structural properties.

7.4.1.1 An alternative method of installation is a top inversion. In this case, the tube is attached to a top ring and is inverted to form a standpipe from the tube itself or another method accepted by the engineer.

NOTE 1—The tube manufacturer should provide information on the maximum allowable tensile stress for the tube.

7.4.2 *Using Air Pressure*—The wet-out tube should be inserted through an existing manhole or other approved access by means of an inversion process and the application of air pressure sufficient to fully extend it to the next designated manhole or termination point. The tube should be connected by an attachment at the upper end of the guide chute so that a leakproof seal is created and with the impermeable plastic membranes side out. As the tube enters the guide chute, the tube should be turned inside out. The inversion air pressure should be adjusted to be of sufficient pressure to cause the impregnated tube to invert from point of inversion to point of termination and hold the tube tight to the pipe wall, producing dimples at side connections. Care should be taken during the inversion so as not to overstress the woven and nonwoven materials.

NOTE 2—**Warning:** Suitable precautions should be taken to eliminate hazards to personnel in the proximity of the construction when pressurized air is being use.

7.4.3 *Required Pressures*—Before the inversion begins, the tube manufacturer shall provide the minimum pressure required to hold the tube tight against the existing conduit, and the maximum allowable pressure so as not to damage the tube. Once the inversion has started, the pressure shall be maintained between the minimum and maximum pressures until the inversion has been completed.

7.5 *Lubricant*—The use of a lubricant during inversion is recommended to reduce friction during inversion. This lubricant should be poured into the inversion water in the downtube or applied directly to the tube. The lubricant used should be a nontoxic, oil-based product that has no detrimental effects on the tube or boiler and pump system, will not support the growth of bacteria, and will not adversely affect the fluid to be transported.

7.6 *Curing*:

7.6.1 *Using Circulating Heated Water*— After inversion is completed, a suitable heat source and water recirculation equipment are required to circulate heated water throughout the pipe. The equipment should be capable of delivering hot water throughout the section to uniformly raise the water temperature above the temperature required to effect a cure of the resin. Water temperature in the line during the cure period should be as recommended by the resin manufacturer.

7.6.1.1 The heat source should be fitted with suitable monitors to gage the temperature of the incoming and outgoing water supply. Another such gage should be placed between the impregnated tube and the pipe invert at the termination to determine the temperatures during cure.

7.6.1.2 Initial cure will occur during temperature heat-up and is completed when exposed portions of the new pipe appear to be hard and sound and the remote temperature sensor indicates that the temperature is of a magnitude to realize an exotherm or cure in the resin. After initial cure is reached, the temperature should be raised to the post-cure temperature recommended by the resin manufacturer. The post-cure temperature should be held for a period as recommended by the resin manufacturer, during which time the recirculation of the water and cycling of the boiler to maintain the temperature continues. The curing of the CIPP must take into account the existing pipe material, the resin system, and ground conditions (temperature, moisture level, and thermal conductivity of soil).

7.6.2 *Using Steam*—After inversion is completed, suitable steam-generating equipment is required to distribute steam throughout the pipe. The equipment should be capable of delivering steam throughout the section to uniformly raise the temperature within the pipe above the temperature required to effect a cure of the resin. The temperature in the line during the cure period should be as recommended by the resin manufacturer.

7.6.2.1 The steam-generating equipment should be fitted with a suitable monitor to gage the temperature of the outgoing steam. The temperature of the resin being cured should be monitored by placing gages between the impregnated tube and the existing pipe at both ends to determine the temperature during cure.

7.6.2.2 Initial cure will occur during temperature heat-up and is completed when exposed portions of the new pipe appear to be hard and sound and the remote temperature sensor indicates that the temperature is of a magnitude to realize an exotherm or cure in the resin. After initial cure is reached, the temperature should be raised to post-cure temperatures recommended by the resin manufacturer. The post-cure temperature should be held for a period as recommended by the resin manufacturer, during which time the distribution and control of steam to maintain the temperature continues. The curing of the CIPP must take into account the existing pipe material, the resin system, and ground conditions (temperature, moisture level, and thermal conductivity of soil).

7.6.3 *Required Pressures*—As required by the purchase agreement, the estimated maximum and minimum pressure required to hold the flexible tube tight against the existing conduit during the curing process should be provided by the seller and shall be increased to include consideration of the external ground water, if present. Once the cure has started and dimpling for laterals is completed, the required pressures should be maintained until the cure has been completed. For water or steam, the pressure should be maintained within the estimated maximum and minimum pressure during the curing process. If the steam pressure or hydrostatic head drops below the recommended minimum during the cure, the CIPP should be inspected for lifts or delaminations and evaluated for its ability to fully meet the applicable requirements of 7.8 and Section 8.

7.7 *Cool-Down*:

7.7.1 *Using Cool Water After Heated Water Cure*—The new pipe should be cooled to a temperature below 100°F (38°C) before relieving the static head in the inversion standpipe. Cool-down may be accomplished by the introduction of cool water into the inversion standpipe to replace water being drained from a small hole made in the downstream end. Care should be taken in the release of the static head so that a vacuum will not be developed that could damage the newly installed pipe.

7.7.2 *Using Cool Water After Steam Cure*— The new pipe should be cooled to a temperature below 113°F (45°C) before relieving the internal pressure within the section. Cool-down may be accomplished by the introduction of cool water into the section to replace the mixture of air and steam being drained from a small hole made in the downstream end. Care should be taken in the release of the air pressure so that a vacuum will not be developed that could damage the newly installed pipe.

7.8 *Workmanship*—The finished pipe should be continuous over the entire length of an inversion run and be free of dry spots, lifts, and delaminations. If these conditions are present, remove and replace the CIPP in these areas.

7.8.1 If the CIPP does not fit tightly against the original pipe at its termination point(s), the space between the pipes should be sealed by filling with a resin mixture compatible with the CIPP.

7.9 *Service Connections*—After the new pipe has been cured in place, the existing active service connections should be reconnected. This should generally be done without excavation, and in the case of non-man entry pipes, from the interior of the pipeline by means of a television camera and a remote-control cutting device.

8. Inspection Practices

8.1 For each inversion length designated by the owner in the Contract documents or purchase order, the preparation of a CIPP sample is required, using one of the following two methods, depending on the size of the host pipe.

8.1.1 For pipe sizes of 18 in. or less, the sample should be cut from a section of cured CIPP at an intermediate manhole or at the termination point that has been inverted through a like diameter pipe which has been held in place by a suitable heat sink, such as sandbags.

8.1.2 In medium and large-diameter applications and areas with limited access, the sample should be fabricated from material taken from the tube and the resin/catalyst system used and cured in a clamped mold placed in the downtube when circulating heated water is used and in the silencer when steam is used. This method can also be used for sizes 18 in. or less, in situations where preparing samples in accordance with 8.1.1 can not be obtained due to physical constrains, if approved by the owner.

8.1.3 The samples for each of these cases should be large enough to provide a minimum of three specimens and a recommended five specimens for flexural testing and also for tensile testing, if applicable. The following test procedures should be followed after the sample is cured and removed.

8.1.3.1 *Short-Term Flexural (Bending) Properties*—The initial tangent flexural modulus of elasticity and flexural stress should be measured for gravity and pressure pipe applications in accordance with Test Methods D 790 and should meet the requirements of Table 1.

8.1.3.2 *Tensile Properties*—The tensile strength should be measured for pressure pipe applications in accordance with Test Method D 638 and must meet the requirements of Table 1.

8.2 *Gravity Pipe Leakage Testing*—If required by the owner in the contract documents or purchase order, gravity pipes should be tested using an exfiltration test method where the CIPP is plugged at both ends and filled with water. This test should take place after the CIPP has cooled down to ambient temperature. This test is limited to pipe lengths with no service laterals and diameters of 36 in. or less. The allowable water exfiltration for any length of pipe between termination points should not exceed 50 U.S. gallons per inch of internal pipe diameter per mile per day, providing that all air has been bled from the line. During exfiltration testing, the maximum internal pipe pressure at the lowest end should not exceed 10 ft (3.0 m) of water or 4.3 psi (29.7 kPA) and the water level inside of the inversion standpipe should be 2 ft (0.6 m) higher than the top of the pipe or 2 ft higher than the groundwater level, whichever is greater. The leakage quantity should be gaged by the water level in a temporary standpipe placed in the upstream plug. The test should be conducted for a minimum of one hour.

NOTE 3—It is impractical to test pipes above 36-in. diameter for leakage due to the technology available in the pipe rehabilitation industry. Post inspection of larger pipes will detect major leaks or blockages.

8.3 *Pressure Pipe Testing*—If required by the owner in the contract documents or purchase order, pressure pipes should be subjected to a hydrostatic pressure test. A recommended pressure and leakage test would be at twice the known working pressure or at the working pressure plus 50 psi, whichever is less. Hold this pressure for a period of two to three hours to allow for stabilization of the CIPP. After this period, the pressure test will begin for a minimum of one hour. The allowable leakage during the pressure test should be 20 U.S. gallons per inch of internal pipe diameter per mile per day, providing that all air has been evacuated from the line prior to testing and the CIPP has cooled down to ambient temperature.

NOTE 4—The allowable leakage for gravity and pressure pipe testing is a function of water loss at the end seals and trapped air in the pipe.

8.4 *Delamination Test*—If required by the owner in the contract documents or purchase order, a delamination test should be performed on each inversion length specified. The CIPP samples should be prepared in accordance with 8.1.2, except that a portion of the tube material in the sample should be dry and isolated from the resin in order to separate tube layers for testing. (Consult the tube manufacturer for further information.) Delamination testing shall be in accordance with Test Method D 903, with the following exceptions:

8.4.1 The rate of travel of the power-actuated grip shall be 1 in. (25 mm)/min.

8.4.2 Five test specimens shall be tested for each inversion specified.

8.4.3 The thickness of the test specimen shall be minimized, but should be sufficient to adequately test delamination of nonhomogeneous CIPP layers.

8.5 The peel or stripping strength between any nonhomogeneous layers of the CIPP laminate should be a minimum of 10 lb/in. (178.60 g/mm) of width for typical CIPP applications.

NOTE 5—The purchaser may designate the dissimilar layers between which the delamination test will be conducted.

NOTE 6—For additional details on conducting the delamination test, contact the CIPP contractor.

8.6 *CIPP Wall Thickness*—The method of obtaining CIPP wall thickness measurements should be determined in a manner consistent with 8.1.2 of Specification D 5813. Thickness measurements should be made in accordance with Practice D 3567 for samples prepared in accordance with 8.1. Make a minimum of eight measurements at evenly spaced intervals around the circumference of the pipe to ensure that minimum and maximum thicknesses have been determined. Deduct from the measured values the thickness of any plastic coatings or CIPP layers not included in the structural design of the CIPP. The average thickness should be calculated using all measured values and shall meet or exceed minimum design thickness as agreed upon between purchaser and seller. The minimum wall thickness at any point shall not be less than 87.5% of the specified design thickness as agreed upon between purchase and seller.

8.6.1 *Ultrasonic Testing of Wall Thickness*—An alternative method to 8.6 for measuring the wall thickness may be performed within the installed CIPP at either end of the pipe by the ultrasonic pulse echo method as described in Practice E 797. A minimum of eight (8) evenly spaced measurements should be made around the internal circumference of the installed CIPP within the host pipe at a distance of 12 to 18 in. from the end of the pipe. For pipe diameters of fifteen (15) in. or greater, a minimum of sixteen (16) evenly spaced measurements shall be recorded. The ultrasonic method to be used is the flaw detector with A-scan display and direct thickness readout as defined in 6.1.2 of E 797. A calibration block shall be manufactured from the identical materials used in the installed CIPP to calibrate sound velocity through the liner. Calibration of the transducer shall be performed daily in accordance with the equipment manufacturer's recommendations. The average thickness should be calculated using all measured values and shall meet or exceed minimum design thickness as agreed upon between purchaser and seller. The minimum wall thickness at any point shall not be less than 87.5 % of the specified design thickness as agreed upon between purchaser and seller.

8.7 *Inspection and Acceptance*—The installation may be inspected visually if appropriate, or by closed-circuit television if visual inspection cannot be accomplished. Variations from true line and grade may be inherent because of the conditions of the original piping. No infiltration of groundwater should be observed. All service entrances should be accounted for and be unobstructed.

APPENDIXES

(Nonmandatory Information)

X1. DESIGN CONSIDERATIONS

X1.1 *Terminology*:

X1.1.1 *partially deteriorated pipe*—the original pipe can support the soil and surcharge loads throughout the design life of the rehabilitated pipe. The soil adjacent to the existing pipe must provide adequate side support. The pipe may have longitudinal cracks and up to 10.0% distortion of the diameter. If the distortion of the diameter is greater than 10.0%, alternative design methods are required (see Note 1).

X1.1.2 *fully deteriorated pipe*—the original pipe is not structurally sound and cannot support soil and live loads or is expected to reach this condition over the design life of the rehabilitated pipe. This condition is evident when sections of the original pipe are missing, the pipe has lost its original shape, or the pipe has corroded due to the effects of the fluid, atmosphere, soil, or applied loads.

X1.2 *Gravity Pipe*:

X1.2.1 *Partially Deteriorated Gravity Pipe Condition*—The CIPP is designed to support the hydraulic loads due to groundwater, since the soil and surcharge loads can be supported by the original pipe. The groundwater level should be determined by the purchaser and the thickness of the CIPP should be sufficient to withstand this hydrostatic pressure without collapsing. The following equation may be used to determine the thickness required:

$$P = \frac{2KE_L}{(1 - \nu^2)} \cdot \frac{1}{(DR - 1)^3} \cdot \frac{C}{N} \qquad \text{(X1.1)}$$

where:

P = groundwater load, psi (MPa), measured from the invert of the pipe

K = enhancement factor of the soil and existing pipe adjacent to the new pipe (a minimum value of 7.0 is recommended where there is full support of the existing pipe),

E_L = long-term (time corrected) modulus of elasticity for CIPP, psi (MPa) (see Note X1.1),

ν = Poisson's ratio (0.3 average),

DR = dimension ratio of CIPP,

C = ovality reduction factor =

$$\left(\left[1 - \frac{\Delta}{100}\right] / \left[1 + \frac{\Delta}{100}\right]^2\right)^3$$

Δ = percentage ovality of original pipe =

$$100 \times \frac{(Mean\ Inside\ Diameter - Minimum\ Inside\ Diameter)}{Mean\ Inside\ Diameter}$$

or

$$100 \times \frac{(Maximum\ Inside\ Diameter - Mean\ Inside\ Diameter)}{Mean\ Inside\ Diameter}$$

and

N = factor of safety.

NOTE X1.1—The choice of value (from manufacturer's literature) of E_L will depend on the estimated duration of the application of the load, P, in relation to the design life of the structure. For example, if the total duration of the load, P, is estimated to be 50 years, either continuously applied, or the sum of intermittent periods of loading, the appropriately conservative choice of value for E_L will be that given for 50 years of continuous loading at the maximum ground or fluid temperature expected to be reached over the life of the structure.

NOTE X1.2—If there is no groundwater above the pipe invert, the CIPP should typically have a maximum SDR of 100, dependent upon design conditions.

X1.2.1.1 If the original pipe is oval, the CIPP design from Eq X1.1 shall have a minimum thickness as calculated by the following formula:

$$1.5\frac{\Delta}{100}\left(1+\frac{\Delta}{100}\right)DR^2 - 0.5\left(1+\frac{\Delta}{100}\right)DR = \frac{\sigma_L}{PN} \tag{X1.2}$$

where:

σ_L = long-term (time corrected) flexural strength for CIPP, psi (MPa) (see Note X1.5).

X1.2.1.2 See Table X1.1 for typical design calculations.

X1.2.2 *Fully Deteriorated Gravity Pipe Condition*—The CIPP is designed to support hydraulic, soil, and live loads. The groundwater level, soil type and depth, and live load should be determined by the purchaser, and the following equation should be used to calculate the CIPP thickness required to withstand these loads without collapsing:

$$q_t = \frac{1}{N}[32R_w B' E'_s \cdot C(E_L I/D^3)]^{1/2} \tag{X1.3}$$

where:

q_t = total external pressure on pipe, psi (MPa),
= $0.433H_w + wHR_w/144 + W_s$, (English Units), $0.00981H_w + wHR_w/1000 + W_s$, (Metric Units)

R_w = water buoyancy factor (0.67 min) = $1 - 0.33(H_w/H)$,

w = soil density, lb.ft^3(KN/m^3),

W_s = live load, psi (Mpa),

H_w = height of water above top of pipe, ft (m)

H = height of soil above top of pipe, ft (m),

B' = coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ inch-pound units, $(1/(1 + 4e^{-0.213H})$ SI units

I = moment of inertia of CIPP, in.^{4}/in. (mm^4/mm) = $t^3/12$,

t = thickness of CIPP, in. (mm),

C = ovality reduction factor (see X1.2.1),

N = factor of safety,

E'_s = modulus of soil reaction, psi (MPa) (see Note X1.4),

E_L = long-term modulus of elasticity for CIPP, psi (MPa), and

D = mean inside diameter of original pipe, in. (mm)

X1.2.2.1 The CIPP design from Eq X1.3 should have a minimum thickness as calculated by the following formula:

$$\frac{EI}{D^3} = \frac{E}{12(DR)^3} \geq 0.093\ (inch-pound\ units), \tag{X1.4}$$

or

$$\frac{E}{12(DR)^3} \geq 0.00064\ (SI\ units)$$

where:

E = initial modulus of elasticity, psi (MPa)

NOTE X1.3—For pipelines at depth not subject to construction disturbance, or if the pipeline was originally installed using tunneling method, the soil load may be calculated using a tunnel load analysis. Finite element analysis is an alternative design method for noncircular pipes.

NOTE X1.4—For definition of modulus of soil reaction, see Practice D 3839.

X1.2.2.2 The minimum CIPP design thickness for a fully deteriorated condition should also meet the requirements of Eq X1.1 and X1.2.

X1.3 *Pressure Pipe*:

X1.3.1 *Partially Deteriorated Pressure Condition*—A CIPP installed in an existing underground pipe is designed to support external hydrostatic loads due to groundwater as well as withstand the internal pressure in spanning across any holes in the original pipe wall. The results of Eq X1.1 are compared to those from Eq X1.6 or Eq X1.7, as directed by Eq X1.5, and the largest of the thicknesses is selected. In an above-ground design condition, the CIPP is designed to withstand the internal pressure only by using Eq X1.5-X1.7 as applicable.

X1.3.1.1 If the ratio of the hole in the original pipe wall to the pipe diameter does not exceed the quantity shown in Eq X1.5, then the CIPP is assumed to be a circular flat plate fixed

TABLE X1.1 Maximum Groundwater Loads for Partially Deteriorated Gravity Pipe Condition

Diameter, in. (Inside Diameter of Original Pipe)	Nominal CIPP Thickness, mm	CIPP Thickness, t, in.	Maximum Allowable Groundwater Load[A] (above invert)	
			ft	m
8	6	0.236	40.0	12.2
10	6	0.236	20.1	6.1
12	6	0.236	11.5	3.5
15	9	0.354	20.1	6.1
18	9	0.354	11.5	3.5
18	12	0.472	27.8	8.5
24	12	0.472	11.5	3.5
24	15	0.591	22.8	6.9
30	15	0.591	11.5	3.5
30	18	0.709	20.1	6.1

[A]Assumes K = 7.0, E = 125 000 psi (862 MPa) (50-year strength), ν = 0.30, C = 0.64 (5 % ovality), and N = 2.0

at the edge and subjected to transverse pressure only. In this case, Eq X1.6 is used for design. For holes larger than the d/D value in Eq X1.5, the liner cannot be considered in flat plate loading, but rather in ring tension or hoop stress, and Eq X1.7 is used.

$$\frac{d}{D} \leq 1.83 \left(\frac{t}{D}\right)^{1/2} \tag{X1.5}$$

where:

d = diameter of hole or opening in original pipe wall, in. (mm),
D = mean inside diameter of original pipe, in. (mm), and
t = thickness of CIPP, in. (mm).

$$P = \frac{5.33}{(DR-1)^2}\left(\frac{D}{d}\right)^2 \frac{\sigma_L}{N} \tag{X1.6}$$

where:

DR = dimension ratio of CIPP,
D = mean inside diameter of original pipe, in. (mm),
d = diameter of hole or opening in original pipe wall, in. (mm),
σ_L = long-term (time corrected) flexural strength for CIPP, psi (MPa) (see Note X1.5), and
N = factor of safety.

NOTE X1.5—The choice of value (from manufacturer's literature) of σ_L will depend on the estimated duration of the application of the load, P, in relation to the design life of the structure. For example, if the total duration of the load, P, is estimated to be 50 years, either continuously applied, or the sum of intermittent periods of loading, the appropriately conservative choice of value of σ_L will be that given for 50 years of continuous loading at the maximum ground or fluid temperature expected to be reached over the life of the structure.

X1.3.2 *Fully Deteriorated Pressure Pipe Condition*—A CIPP to be installed in an underground condition is designed to withstand all external loads and the full internal pressure. The design thicknesses are calculated from Eq X1.1, Eq X1.3, Eq X1.4, and Eq X1.7, and the largest thickness is selected. If the pipe is above ground, the CIPP is designed to withstand internal pressure only by using Eq X1.7.

$$P = \frac{2\sigma_{TL}}{(DR-2)\,N} \tag{X1.7}$$

where:

P = internal pressure, psi (MPa),
σ_{TL} = long-term (time corrected) tensile strength for CIPP, psi (MPa) (see Note 12),
DR = dimension ratio of CIPP, and
N = factor of safety.

NOTE X1.6—The choice of value (from manufacturer's literature) of σ_{TL} will depend on the estimated duration of the application of the load, P, in relation to the design life of the structure. For example, if the total duration of the load, P, is estimated to be 50 years, either continuously applied, or the sum of intermittent periods of loading, the appropriately conservative choice of value of σ_{TL} will be that given for 50 years of continuous loading at the maximum ground or fluid temperature expected to be reached over the life of the structure.

X1.4 — *Negative Pressure*—Where the pipe is subject to a vacuum, the CIPP should be designed as a gravity pipe with the external hydrostatic pressure increased by an amount equal to the negative pressure.

NOTE X1.7—Table X1.1 presents maximum groundwater loads for partially deteriorated pipes for selected typical nominal pipe sizes. CIPP is custom made to fit the original pipe and can be fabricated to a variety of sizes from 4 to 96-in. diameter which would be impractical to list here.

X2. CHEMICAL-RESISTANCE TESTS

X2.1 *Scope*:

X2.1.1 This appendix covers the test procedures for chemical-resistance properties of CIPP. Minimum standards are presented for standard domestic sewer applications.

X2.2 *Procedure for Chemical-Resistance Testing*:

X2.2.1 Chemical resistance tests should be completed in accordance with Practices D 543. Exposure should be for a minimum of one month at 73.4°F (23°C). During this period, the CIPP test specimens should lose no more than 20 % of their initial flexural strength and flexural modulus when tested in accordance with Section 8 of this practice.

X2.2.2 Table X2.1 presents a list of chemical solutions that serve as a recommended minimum requirement for the chemical-resistant properties of CIPP in standard domestic sanitary sewer applications.

X2.2.3 For applications other than standard domestic sewage, it is recommended that chemical-resistance tests be conducted with actual samples of the fluid flowing in the pipe. These tests can also be accomplished by depositing CIPP test specimens in the active pipe.

TABLE X2.1 Minimum Chemical Resistance Requirements for Domestic Sanitary Sewer Applications

Chemical Solution	Concentration, %
Tap water (pH 6–9)	100
Nitric acid	5
Phosphoric acid	10
Sulfuric acid	10
Gasoline	100
Vegetable oil	100
Detergent	0.1
Soap	0.1

SUMMARY OF CHANGES

Committee F17 has identified the location of selected changes to this standard since the last issue (F 1216–08) that may impact the use of this standard. (Approved March 1, 2009.)

(*1*) 8.1, 8.1.1 and 8.1.2 were revised.

Committee F17 has identified the location of selected changes to this standard since the last issue (F 1217–07b) that may impact the use of this standard.

(*1*) Added Practices D 3567, E 797, and Specification D 5813 to Section 2, Reference Documents.
(*2*) Added 8.6 and 8.6.1 to include an alternative method of wall thickness measurement by Ultrasonic Methods.
(*3*) Renumbered Inspection and Acceptance from 8.6 to 8.7.

Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[1]

This standard is issued under the fixed designation D790; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 These test methods cover the determination of flexural properties of unreinforced and reinforced plastics, including high-modulus composites and electrical insulating materials in the form of rectangular bars molded directly or cut from sheets, plates, or molded shapes. These test methods are generally applicable to both rigid and semirigid materials. However, flexural strength cannot be determined for those materials that do not break or that do not fail in the outer surface of the test specimen within the 5.0 % strain limit of these test methods. These test methods utilize a three-point loading system applied to a simply supported beam. A four-point loading system method can be found in Test Method D6272.

1.1.1 *Procedure A,* designed principally for materials that break at comparatively small deflections.

1.1.2 *Procedure B,* designed particularly for those materials that undergo large deflections during testing.

1.1.3 Procedure A shall be used for measurement of flexural properties, particularly flexural modulus, unless the material specification states otherwise. Procedure B may be used for measurement of flexural strength only. Tangent modulus data obtained by Procedure A tends to exhibit lower standard deviations than comparable data obtained by means of Procedure B.

1.2 Comparative tests may be run in accordance with either procedure, provided that the procedure is found satisfactory for the material being tested.

1.3 The values stated in SI units are to be regarded as the standard. The values provided in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—These test methods are not technically equivalent to ISO 178.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D883 Terminology Relating to Plastics
D4000 Classification System for Specifying Plastic Materials
D4101 Specification for Polypropylene Injection and Extrusion Materials
D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens
D6272 Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials by Four-Point Bending
E4 Practices for Force Verification of Testing Machines
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *ISO Standard:*[3]

ISO 178 Plastics—Determination of Flexural Properties

3. Terminology

3.1 *Definitions*—Definitions of terms applying to these test methods appear in Terminology D883 and Annex A1 of Test Method D638.

4. Summary of Test Method

4.1 A bar of rectangular cross section rests on two supports and is loaded by means of a loading nose midway between the supports. A support span-to-depth ratio of 16:1 shall be used unless there is reason to suspect that a larger span-to-depth

[1] These test methods are under the jurisdiction of ASTM Committee D20 on Plastics and are the direct responsibility of Subcommittee D20.10 on Mechanical Properties.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

***A Summary of Changes section appears at the end of this standard**

ratio may be required, as may be the case for certain laminated materials (see Section 7 and Note 7 for guidance).

4.2 The specimen is deflected until rupture occurs in the outer surface of the test specimen or until a maximum strain (see 12.7) of 5.0 % is reached, whichever occurs first.

4.3 Procedure A employs a strain rate of 0.01 mm/mm/min (0.01 in./in./min) and is the preferred procedure for this test method, while Procedure B employs a strain rate of 0.10 mm/mm/min (0.10 in./in./min).

5. Significance and Use

5.1 Flexural properties as determined by these test methods are especially useful for quality control and specification purposes.

5.2 Materials that do not fail by the maximum strain allowed under these test methods (3-point bend) may be more suited to a 4-point bend test. The basic difference between the two test methods is in the location of the maximum bending moment and maximum axial fiber stresses. The maximum axial fiber stresses occur on a line under the loading nose in 3-point bending and over the area between the loading noses in 4-point bending.

5.3 Flexural properties may vary with specimen depth, temperature, atmospheric conditions, and the difference in rate of straining as specified in Procedures A and B (see also Note 7).

5.4 Before proceeding with these test methods, reference should be made to the ASTM specification of the material being tested. Any test specimen preparation, conditioning, dimensions, or testing parameters, or combination thereof, covered in the ASTM material specification shall take precedence over those mentioned in these test methods. Table 1 in Classification System D4000 lists the ASTM material specifications that currently exist for plastics.

6. Apparatus

6.1 *Testing Machine*— A properly calibrated testing machine that can be operated at constant rates of crosshead motion over the range indicated, and in which the error in the load measuring system shall not exceed ±1 % of the maximum load expected to be measured. It shall be equipped with a deflection measuring device. The stiffness of the testing machine shall be such that the total elastic deformation of the system does not exceed 1 % of the total deflection of the test specimen during testing, or appropriate corrections shall be made. The load indicating mechanism shall be essentially free from inertial lag at the crosshead rate used. The accuracy of the testing machine shall be verified in accordance with Practices E4.

TABLE 1 Flexural Strength

Material	Mean, 10^3 psi	Values Expressed in Units of % of 10^3 psi			
		V_r[A]	V_R[B]	r[C]	R[D]
ABS	9.99	1.59	6.05	4.44	17.2
DAP thermoset	14.3	6.58	6.58	18.6	18.6
Cast acrylic	16.3	1.67	11.3	4.73	32.0
GR polyester	19.5	1.43	2.14	4.05	6.08
GR polycarbonate	21.0	5.16	6.05	14.6	17.1
SMC	26.0	4.76	7.19	13.5	20.4

[A] V_r = within-laboratory coefficient of variation for the indicated material. It is obtained by first pooling the within-laboratory standard deviations of the test results from all of the participating laboratories: $Sr = [[(s_1)^2 + (s_2)^2 \ldots + (s_n)^2]/n]^{1/2}$ then V_r = (S_r divided by the overall average for the material) × 100.

[B] V_r = between-laboratory reproducibility, expressed as the coefficient of variation: $S_R = \{S_r^2 + S_L^2\}^{1/2}$ where S_L is the standard deviation of laboratory means. Then: V_R = (S_R divided by the overall average for the material) × 100.

[C] r = within-laboratory critical interval between two test results = 2.8 × V_r.

[D] R = between-laboratory critical interval between two test results = 2.8 × V_R.

6.2 *Loading Noses and Supports*—The loading nose and supports shall have cylindrical surfaces. The default radii of the loading nose and supports shall be 5.0 ± 0.1 mm (0.197 ± 0.004 in.) unless otherwise specified in an ASTM material specification or as agreed upon between the interested parties. When the use of an ASTM material specification, or an agreed upon modification, results in a change to the radii of the loading nose and supports, the results shall be clearly identified as being obtained from a modified version of this test method and shall include the specification (when available) from which the modification was specified, for example, Test Method D790 in accordance with Specification D4101.

6.2.1 *Other Radii for Loading Noses and Supports*—When other than default loading noses and supports are used, in order to avoid excessive indentation, or failure due to stress concentration directly under the loading nose, they must comply with the following requirements: they shall have a minimum radius of 3.2 mm (⅛ in.) for all specimens. For specimens 3.2 mm or greater in depth, the radius of the supports may be up to 1.6 times the specimen depth. They shall be this large if significant indentation or compressive failure occurs. The arc of the loading nose in contact with the specimen shall be sufficiently large to prevent contact of the specimen with the sides of the nose. The maximum radius of the loading nose shall be no more than four times the specimen depth.

6.3 *Micrometers*— Suitable micrometers for measuring the width and thickness of the test specimen to an incremental discrimination of at least 0.025 mm (0.001 in.) should be used. All width and thickness measurements of rigid and semirigid plastics may be measured with a hand micrometer with ratchet. A suitable instrument for measuring the thickness of nonrigid test specimens shall have: a contact measuring pressure of 25 ± 2.5 kPa (3.6 ± 0.36 psi), a movable circular contact foot 6.35 ± 0.025 mm (0.250 ± 0.001 in.) in diameter and a lower fixed anvil large enough to extend beyond the contact foot in all directions and being parallel to the contact foot within 0.005 mm (0.002 in.) over the entire foot area. Flatness of foot and anvil shall conform to the portion of the Calibration section of Test Methods D5947.

7. Test Specimens

7.1 The specimens may be cut from sheets, plates, or molded shapes, or may be molded to the desired finished dimensions. The actual dimensions used in Section 4.2, Calculation, shall be measured in accordance with Test Methods D5947.

NOTE 2—Any necessary polishing of specimens shall be done only in the lengthwise direction of the specimen.

7.2 *Sheet Materials (Except Laminated Thermosetting Materials and Certain Materials Used for Electrical Insulation, Including Vulcanized Fiber and Glass Bonded Mica):*

7.2.1 *Materials 1.6 mm (1⁄16 in.) or Greater in Thickness*—For flatwise tests, the depth of the specimen shall be the thickness of the material. For edgewise tests, the width of the specimen shall be the thickness of the sheet, and the depth shall not exceed the width (see Notes 3 and 4). For all tests, the support span shall be 16 (tolerance ±1) times the depth of the beam. Specimen width shall not exceed one fourth of the support span for specimens greater than 3.2 mm (1⁄8 in.) in depth. Specimens 3.2 mm or less in depth shall be 12.7 mm (1⁄2 in.) in width. The specimen shall be long enough to allow for overhanging on each end of at least 10 % of the support span, but in no case less than 6.4 mm (1⁄4 in.) on each end. Overhang shall be sufficient to prevent the specimen from slipping through the supports.

NOTE 3—Whenever possible, the original surface of the sheet shall be unaltered. However, where testing machine limitations make it impossible to follow the above criterion on the unaltered sheet, one or both surfaces shall be machined to provide the desired dimensions, and the location of the specimens with reference to the total depth shall be noted. The value obtained on specimens with machined surfaces may differ from those obtained on specimens with original surfaces. Consequently, any specifications for flexural properties on thicker sheets must state whether the original surfaces are to be retained or not. When only one surface was machined, it must be stated whether the machined surface was on the tension or compression side of the beam.

NOTE 4—Edgewise tests are not applicable for sheets that are so thin that specimens meeting these requirements cannot be cut. If specimen depth exceeds the width, buckling may occur.

7.2.2 *Materials Less than 1.6 mm (1⁄16 in.) in Thickness*—The specimen shall be 50.8 mm (2 in.) long by 12.7 mm (1⁄2 in.) wide, tested flatwise on a 25.4-mm (1-in.) support span.

NOTE 5—Use of the formulas for simple beams cited in these test methods for calculating results presumes that beam width is small in comparison with the support span. Therefore, the formulas do not apply rigorously to these dimensions.

NOTE 6—Where machine sensitivity is such that specimens of these dimensions cannot be measured, wider specimens or shorter support spans, or both, may be used, provided the support span-to-depth ratio is at least 14 to 1. All dimensions must be stated in the report (see also Note 5).

7.3 *Laminated Thermosetting Materials and Sheet and Plate Materials Used for Electrical Insulation, Including Vulcanized Fiber and Glass-Bonded Mica*—For paper-base and fabric-base grades over 25.4 mm (1 in.) in nominal thickness, the specimens shall be machined on both surfaces to a depth of 25.4 mm. For glass-base and nylon-base grades, specimens over 12.7 mm (1⁄2 in.) in nominal depth shall be machined on both surfaces to a depth of 12.7 mm. The support span-to-depth ratio shall be chosen such that failures occur in the outer fibers of the specimens, due only to the bending moment (see Note 7). Therefore, a ratio larger than 16:1 may be necessary (32:1 or 40:1 are recommended). When laminated materials exhibit low compressive strength perpendicular to the laminations, they shall be loaded with a large radius loading nose (up to four times the specimen depth to prevent premature damage to the outer fibers.

7.4 *Molding Materials (Thermoplastics and Thermosets)*—The recommended specimen for molding materials is 127 by 12.7 by 3.2 mm (5 by 1⁄2 by 1⁄8 in.) tested flatwise on a support span, resulting in a support span-to-depth ratio of 16 (tolerance ±1). Thicker specimens should be avoided if they exhibit significant shrink marks or bubbles when molded.

7.5 *High-Strength Reinforced Composites, Including Highly Orthotropic Laminates*—The span-to-depth ratio shall be chosen such that failure occurs in the outer fibers of the specimens and is due only to the bending moment (see Note 7). A span-to-depth ratio larger than 16:1 may be necessary (32:1 or 40:1 are recommended). For some highly anisotropic composites, shear deformation can significantly influence modulus measurements, even at span-to-depth ratios as high as 40:1. Hence, for these materials, an increase in the span-to-depth ratio to 60:1 is recommended to eliminate shear effects when modulus data are required, it should also be noted that the flexural modulus of highly anisotropic laminates is a strong function of ply-stacking sequence and will not necessarily correlate with tensile modulus, which is not stacking-sequence dependent.

NOTE 7—As a general rule, support span-to-depth ratios of 16:1 are satisfactory when the ratio of the tensile strength to shear strength is less than 8 to 1, but the support span-to-depth ratio must be increased for composite laminates having relatively low shear strength in the plane of the laminate and relatively high tensile strength parallel to the support span.

8. Number of Test Specimens

8.1 Test at least five specimens for each sample in the case of isotropic materials or molded specimens.

8.2 For each sample of anisotropic material in sheet form, test at least five specimens for each of the following conditions. Recommended conditions are flatwise and edgewise tests on specimens cut in lengthwise and crosswise directions of the sheet. For the purposes of this test, "lengthwise" designates the principal axis of anisotropy and shall be interpreted to mean the direction of the sheet known to be stronger in flexure. "Crosswise" indicates the sheet direction known to be the weaker in flexure and shall be at 90° to the lengthwise direction.

9. Conditioning

9.1 *Conditioning*—Condition the test specimens in accordance with Procedure A of Practice D618 unless otherwise specified by contract or the relevant ASTM material specification. Conditioning time is specified as a minimum. Temperature and humidity tolerances shall be in accordance with Section 7 of Practice D618 unless specified differently by contract or material specification.

9.2 *Test Conditions*—Conduct the tests at the same temperature and humidity used for conditioning with tolerances in accordance with Section 7 of Practice D618 unless otherwise specified by contract or the relevant ASTM material specification.

10. Procedure

10.1 *Procedure A:*

10.1.1 Use an untested specimen for each measurement. Measure the width and depth of the specimen to the nearest 0.03 mm (0.001 in.) at the center of the support span. For specimens less than 2.54 mm (0.100 in.) in depth, measure the depth to the nearest 0.003 mm (0.0005 in.). These measurements shall be made in accordance with Test Methods D5947.

10.1.2 Determine the support span to be used as described in Section 7 and set the support span to within 1 % of the determined value.

10.1.3 For flexural fixtures that have continuously adjustable spans, measure the span accurately to the nearest 0.1 mm (0.004 in.) for spans less than 63 mm (2.5 in.) and to the nearest 0.3 mm (0.012 in.) for spans greater than or equal to 63 mm (2.5 in.). Use the actual measured span for all calculations. For flexural fixtures that have fixed machined span positions, verify the span distance the same as for adjustable spans at each machined position. This distance becomes the span for that position and is used for calculations applicable to all subsequent tests conducted at that position. See Annex A2 for information on the determination of and setting of the span.

10.1.4 Calculate the rate of crosshead motion as follows and set the machine for the rate of crosshead motion as calculated by Eq 1:

$$R = ZL^2/6d \tag{1}$$

where:

R = rate of crosshead motion, mm (in.)/min,
L = support span, mm (in.),
d = depth of beam, mm (in.), and
Z = rate of straining of the outer fiber, mm/mm/min (in./in./min). Z shall be equal to 0.01.

In no case shall the actual crosshead rate differ from that calculated using Eq 1, by more than ±10 %.

10.1.5 Align the loading nose and supports so that the axes of the cylindrical surfaces are parallel and the loading nose is midway between the supports. The parallelism of the apparatus may be checked by means of a plate with parallel grooves into which the loading nose and supports will fit when properly aligned (see A2.3). Center the specimen on the supports, with the long axis of the specimen perpendicular to the loading nose and supports.

10.1.6 Apply the load to the specimen at the specified crosshead rate, and take simultaneous load-deflection data. Measure deflection either by a gage under the specimen in contact with it at the center of the support span, the gage being mounted stationary relative to the specimen supports, or by measurement of the motion of the loading nose relative to the supports. Load-deflection curves may be plotted to determine the flexural strength, chord or secant modulus or the tangent modulus of elasticity, and the total work as measured by the area under the load-deflection curve. Perform the necessary toe compensation (see Annex A1) to correct for seating and indentation of the specimen and deflections in the machine.

10.1.7 Terminate the test when the maximum strain in the outer surface of the test specimen has reached 0.05 mm/mm (in./in.) or at break if break occurs prior to reaching the maximum strain (Notes 8 and 9). The deflection at which this strain will occur may be calculated by letting r equal 0.05 mm/mm (in./in.) in Eq 2:

$$D = rL^2/6d \tag{2}$$

where:

D = midspan deflection, mm (in.),
r = strain, mm/mm (in./in.),
L = support span, mm (in.), and
d = depth of beam, mm (in.).

NOTE 8—For some materials that do not yield or break within the 5 % strain limit when tested by Procedure A, the increased strain rate allowed by Procedure B (see 10.2) may induce the specimen to yield or break, or both, within the required 5 % strain limit.

NOTE 9—Beyond 5 % strain, this test method is not applicable. Some other mechanical property might be more relevant to characterize materials that neither yield nor break by either Procedure A or Procedure B within the 5 % strain limit (for example, Test Method D638 may be considered).

10.2 *Procedure B:*

10.2.1 Use an untested specimen for each measurement.

10.2.2 Test conditions shall be identical to those described in 10.1, except that the rate of straining of the outer surface of the test specimen shall be 0.10 mm/mm (in./in.)/min.

10.2.3 If no break has occurred in the specimen by the time the maximum strain in the outer surface of the test specimen has reached 0.05 mm/mm (in./in.), discontinue the test (see Note 9).

11. Retests

11.1 Values for properties at rupture shall not be calculated for any specimen that breaks at some obvious, fortuitous flaw, unless such flaws constitute a variable being studied. Retests shall be made for any specimen on which values are not calculated.

12. Calculation

12.1 Toe compensation shall be made in accordance with Annex A1 unless it can be shown that the toe region of the curve is not due to the take-up of slack, seating of the specimen, or other artifact, but rather is an authentic material response.

12.2 *Flexural Stress (σ_f)*—When a homogeneous elastic material is tested in flexure as a simple beam supported at two points and loaded at the midpoint, the maximum stress in the outer surface of the test specimen occurs at the midpoint. This stress may be calculated for any point on the load-deflection curve by means of the following equation (see Notes 10-12):

$$\sigma_f = 3PL/2bd^2 \tag{3}$$

where:

σ = stress in the outer fibers at midpoint, MPa (psi),
P = load at a given point on the load-deflection curve, N (lbf),
L = support span, mm (in.),
b = width of beam tested, mm (in.), and
d = depth of beam tested, mm (in.).

NOTE 10—Eq 3 applies strictly to materials for which stress is linearly proportional to strain up to the point of rupture and for which the strains are small. Since this is not always the case, a slight error will be introduced if Eq 3 is used to calculate stress for materials that are not true Hookean materials. The equation is valid for obtaining comparison data and for specification purposes, but only up to a maximum fiber strain of 5 % in the outer surface of the test specimen for specimens tested by the procedures described herein.

NOTE 11—When testing highly orthotropic laminates, the maximum stress may not always occur in the outer surface of the test specimen.[4] Laminated beam theory must be applied to determine the maximum tensile stress at failure. If Eq 3 is used to calculate stress, it will yield an apparent strength based on homogeneous beam theory. This apparent strength is highly dependent on the ply-stacking sequence of highly orthotropic laminates.

NOTE 12—The preceding calculation is not valid if the specimen slips excessively between the supports.

12.3 *Flexural Stress for Beams Tested at Large Support Spans* (σ_f)—If support span-to-depth ratios greater than 16 to 1 are used such that deflections in excess of 10 % of the support span occur, the stress in the outer surface of the specimen for a simple beam can be reasonably approximated with the following equation (see Note 13):

$$\sigma_f = (3PL/2bd^2)[1+6(D/L)^2 - 4(d/L)(D/L)] \quad (4)$$

where:

σ_f, *P, L, b,* and *d* are the same as for Eq 3, and
D = deflection of the centerline of the specimen at the middle of the support span, mm (in.).

NOTE 13—When large support span-to-depth ratios are used, significant end forces are developed at the support noses which will affect the moment in a simple supported beam. Eq 4 includes additional terms that are an approximate correction factor for the influence of these end forces in large support span-to-depth ratio beams where relatively large deflections exist.

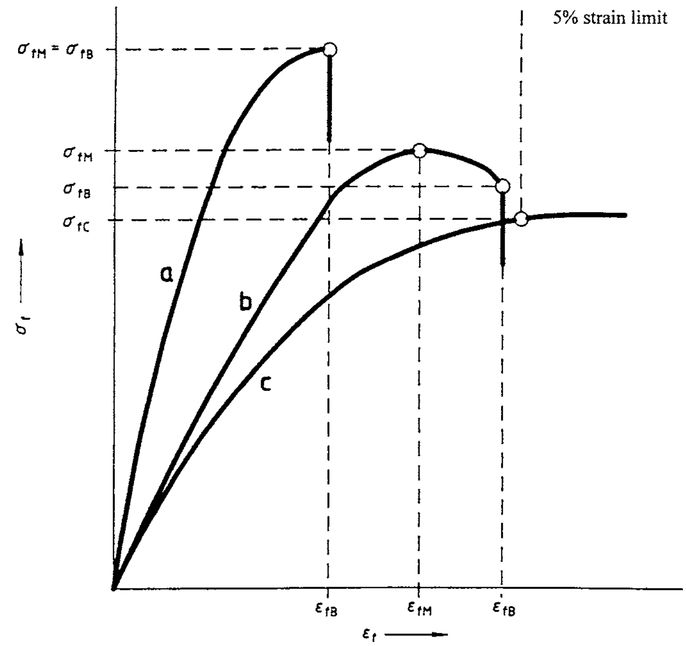
12.4 *Flexural Strength* (σ_{fM})—Maximum flexural stress sustained by the test specimen (see Note 11) during a bending test. It is calculated according to Eq 3 or Eq 4. Some materials that do not break at strains of up to 5 % may give a load deflection curve that shows a point at which the load does not increase with an increase in strain, that is, a yield point (Fig. 1, Curve B), *Y*. The flexural strength may be calculated for these materials by letting *P* (in Eq 3 or Eq 4) equal this point, *Y*.

12.5 *Flexural Offset Yield Strength*—Offset yield strength is the stress at which the stress-strain curve deviates by a given strain (offset) from the tangent to the initial straight line portion of the stress-strain curve. The value of the offset must be given whenever this property is calculated.

NOTE 14—This value may differ from flexural strength defined in 12.4. Both methods of calculation are described in the annex to Test Method D638.

12.6 *Flexural Stress at Break* (σ_{fB})—Flexural stress at break of the test specimen during a bending test. It is calculated according to Eq 3 or Eq 4. Some materials may give a load deflection curve that shows a break point, *B,* without a yield point (Fig. 1, Curve a) in which case $\sigma_{fB} = \sigma_{fM}$. Other materials may give a yield deflection curve with both a yield and a break point, *B* (Fig. 1, Curve b). The flexural stress at break may be calculated for these materials by letting *P* (in Eq 3 or Eq 4) equal this point, *B*.

12.7 *Stress at a Given Strain*—The stress in the outer surface of a test specimen at a given strain may be calculated in accordance with Eq 3 or Eq 4 by letting *P* equal the load read from the load-deflection curve at the deflection corresponding to the desired strain (for highly orthotropic laminates, see Note 11).



NOTE 1—Curve a: Specimen that breaks before yielding.
Curve b: Specimen that yields and then breaks before the 5 % strain limit.
Curve c: Specimen that neither yields nor breaks before the 5 % strain limit.

FIG. 1 Typical Curves of Flexural Stress (σ_f) Versus Flexural Strain (ε_f)

12.8 *Flexural Strain,* ε_f—Nominal fractional change in the length of an element of the outer surface of the test specimen at midspan, where the maximum strain occurs. It may be calculated for any deflection using Eq 5:

$$\varepsilon_f = 6Dd/L^2 \quad (5)$$

where:

ε_f = strain in the outer surface, mm/mm (in./in.),
D = maximum deflection of the center of the beam, mm (in.),
L = support span, mm (in.), and
d = depth, mm (in.).

12.9 *Modulus of Elasticity:*

12.9.1 *Tangent Modulus of Elasticity*—The tangent modulus of elasticity, often called the "modulus of elasticity," is the ratio, within the elastic limit, of stress to corresponding strain. It is calculated by drawing a tangent to the steepest initial straight-line portion of the load-deflection curve and using Eq 6 (for highly anisotropic composites, see Note 15).

$$E_B = L^3 m/4bd^3 \quad (6)$$

where:

E_B = modulus of elasticity in bending, MPa (psi),

[4] For a discussion of these effects, see Zweben, C., Smith, W. S., and Wardle, M. W., "Test Methods for Fiber Tensile Strength, Composite Flexural Modulus and Properties of Fabric-Reinforced Laminates, " *Composite Materials: Testing and Design (Fifth Conference), ASTM STP 674*, 1979, pp. 228–262.

L = support span, mm (in.),
b = width of beam tested, mm (in.),
d = depth of beam tested, mm (in.), and
m = slope of the tangent to the initial straight-line portion of the load-deflection curve, N/mm (lbf/in.) of deflection.

NOTE 15—Shear deflections can seriously reduce the apparent modulus of highly anisotropic composites when they are tested at low span-to-depth ratios.[4] For this reason, a span-to-depth ratio of 60 to 1 is recommended for flexural modulus determinations on these composites. Flexural strength should be determined on a separate set of replicate specimens at a lower span-to-depth ratio that induces tensile failure in the outer fibers of the beam along its lower face. Since the flexural modulus of highly anisotropic laminates is a critical function of ply-stacking sequence, it will not necessarily correlate with tensile modulus, which is not stacking-sequence dependent.

12.9.2 *Secant Modulus*— The secant modulus is the ratio of stress to corresponding strain at any selected point on the stress-strain curve, that is, the slope of the straight line that joins the origin and a selected point on the actual stress-strain curve. It shall be expressed in megapascals (pounds per square inch). The selected point is chosen at a prespecified stress or strain in accordance with the appropriate material specification or by customer contract. It is calculated in accordance with Eq 6 by letting m equal the slope of the secant to the load-deflection curve. The chosen stress or strain point used for the determination of the secant shall be reported.

12.9.3 *Chord Modulus* (E_f)—The chord modulus may be calculated from two discrete points on the load deflection curve. The selected points are to be chosen at two prespecified stress or strain points in accordance with the appropriate material specification or by customer contract. The chosen stress or strain points used for the determination of the chord modulus shall be reported. Calculate the chord modulus, E_f using the following equation:

$$E_f = (\sigma_{f2} - \sigma_{f1})/(\varepsilon_{f2} - \varepsilon_{f1}) \quad (7)$$

where:

σ_{f2} and σ_{f1} are the flexural stresses, calculated from Eq 3 or Eq 4 and measured at the predefined points on the load deflection curve, and ε_{f2} and ε_{f1} are the flexural strain values, calculated from Eq 5 and measured at the predetermined points on the load deflection curve.

TABLE 2 Flexural Modulus

Material	Mean, 10^3 psi	Values Expressed in units of % of 10^3 psi			
		V_r[A]	V_R[B]	r[C]	R[D]
ABS	338	4.79	7.69	13.6	21.8
DAP thermoset	485	2.89	7.18	8.15	20.4
Cast acrylic	810	13.7	16.1	38.8	45.4
GR polyester	816	3.49	4.20	9.91	11.9
GR polycarbonate	1790	5.52	5.52	15.6	15.6
SMC	1950	10.9	13.8	30.8	39.1

[A] V_r = within-laboratory coefficient of variation for the indicated material. It is obtained by first pooling the within-laboratory standard deviations of the test results from all of the participating laboratories: $Sr = [[(s_1)^2 + (s_2)^2 \ldots + (s_n)^2]/n]^{1/2}$ then $V_r = (S_r$ divided by the overall average for the material) × 100.
[B] V_r = between-laboratory reproducibility, expressed as the coefficient of variation: $S_R = \{S_r^2 + S_L^2\}^{1/2}$ where S_L is the standard deviation of laboratory means. Then: $V_R = (S_R$ divided by the overall average for the material) × 100.
[C] r = within-laboratory critical interval between two test results = 2.8 × V_r.
[D] R = between-laboratory critical interval between two test results = 2.8 × V_R.

12.10 *Arithmetic Mean*— For each series of tests, the arithmetic mean of all values obtained shall be calculated to three significant figures and reported as the "average value" for the particular property in question.

12.11 *Standard Deviation*—The standard deviation (estimated) shall be calculated as follows and be reported to two significant figures:

$$s = \sqrt{\left(\sum X^2 - n\bar{X}^2\right)/(n-1)} \quad (8)$$

where:

s = estimated standard deviation,
X = value of single observation,
n = number of observations, and
$\bar{X}$ = arithmetic mean of the set of observations.

13. Report

13.1 Report the following information:

13.1.1 Complete identification of the material tested, including type, source, manufacturer's code number, form, principal dimensions, and previous history (for laminated materials, ply-stacking sequence shall be reported),

13.1.2 Direction of cutting and loading specimens, when appropriate,

13.1.3 Conditioning procedure,

13.1.4 Depth and width of specimen,

13.1.5 Procedure used (A or B),

13.1.6 Support span length,

13.1.7 Support span-to-depth ratio if different than 16:1,

13.1.8 Radius of supports and loading noses, if different than 5 mm. When support and/or loading nose radii other than 5 mm are used, the results shall be identified as being generated by a modified version of this test method and the referring specification referenced as to the geometry used.

13.1.9 Rate of crosshead motion,

13.1.10 Flexural strain at any given stress, average value and standard deviation,

13.1.11 If a specimen is rejected, reason(s) for rejection,

13.1.12 Tangent, secant, or chord modulus in bending, average value, standard deviation, and the strain level(s) used if secant or chord modulus,

13.1.13 Flexural strength (if desired), average value, and standard deviation,

13.1.14 Stress at any given strain up to and including 5 % (if desired), with strain used, average value, and standard deviation,

13.1.15 Flexural stress at break (if desired), average value, and standard deviation,

13.1.16 Type of behavior, whether yielding or rupture, or both, or other observations, occurring within the 5 % strain limit, and

13.1.17 Date of specific version of test used.

14. Precision and Bias

14.1 Tables 1 and 2 are based on a round-robin test conducted in 1984, in accordance with Practice E691, involving six materials tested by six laboratories using Procedure A. For each material, all the specimens were prepared at one source. Each "test result" was the average of five individual determinations. Each laboratory obtained two test results for each material.

NOTE 16—**Caution:** The following explanations of *r* and *R* (14.2-14.2.3) are intended only to present a meaningful way of considering the approximate precision of these test methods. The data given in Tables 2 and 3 should not be applied rigorously to the acceptance or rejection of materials, as those data are specific to the round robin and may not be representative of other lots, conditions, materials, or laboratories. Users of these test methods should apply the principles outlined in Practice E691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 14.2-14.2.3 would then be valid for such data.

14.2 *Concept of "r" and "R" in* Tables 1 and 2—If S_r and S_R have been calculated from a large enough body of data, and for test results that were averages from testing five specimens for each test result, then:

14.2.1 *Repeatability*— Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the *r* value for that material. *r* is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

14.2.2 *Reproducibility*— Two test results obtained by different laboratories shall be judged not equivalent if they differ by more than the *R* value for that material. *R* is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

14.2.3 The judgments in 14.2.1 and 14.2.2 will have an approximately 95 % (0.95) probability of being correct.

14.3 *Bias*—No statement may be made about the bias of these test methods, as there is no standard reference material or reference test method that is applicable.

15. Keywords

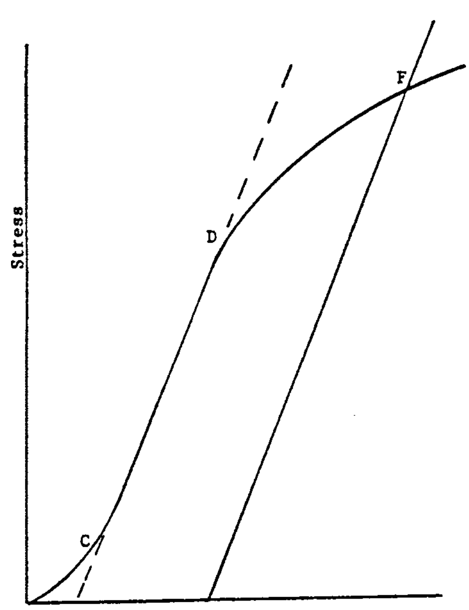
15.1 flexural properties; plastics; stiffness; strength

ANNEXES

(Mandatory Information)

A1. TOE COMPENSATION

A1.1 In a typical stress-strain curve (see Fig. A1.1) there is a toe region, *AC,* that does not represent a property of the material. It is an artifact caused by a takeup of slack and alignment or seating of the specimen. In order to obtain correct values of such parameters as modulus, strain, and offset yield point, this artifact must be compensated for to give the corrected zero point on the strain or extension axis.

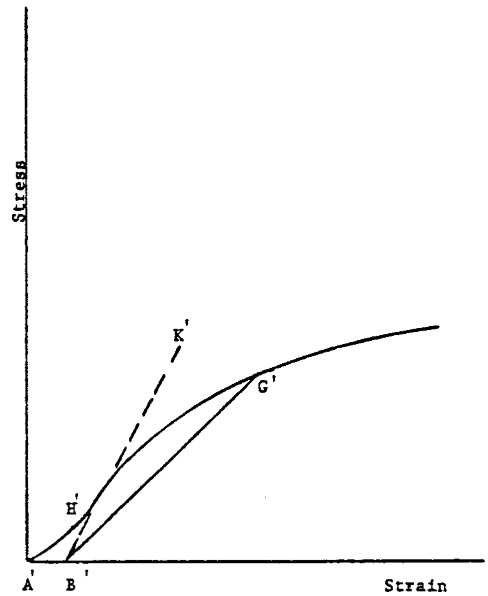


NOTE 1—Some chart recorders plot the mirror image of this graph.

FIG. A1.1 Material with Hookean Region

A1.2 In the case of a material exhibiting a region of Hookean (linear) behavior (see Fig. A1.1), a continuation of the linear *(CD)* region of the curve is constructed through the zero-stress axis. This intersection *(B)* is the corrected zero-strain point from which all extensions or strains must be measured, including the yield offset *(BE),* if applicable. The elastic modulus can be determined by dividing the stress at any point along the Line *CD* (or its extension) by the strain at the same point (measured from Point *B,* defined as zero-strain).

A1.3 In the case of a material that does not exhibit any linear region (see Fig. A1.2), the same kind of toe correction of the zero-strain point can be made by constructing a tangent to the maximum slope at the inflection Point *H'.* This is extended to intersect the strain axis at Point *B',* the corrected zero-strain point. Using Point *B'* as zero strain, the stress at any point *(G')* on the curve can be divided by the strain at that point to obtain a secant modulus (slope of Line *B' G').* For those materials with no linear region, any attempt to use the tangent through the inflection point as a basis for determination of an offset yield point may result in unacceptable error.



NOTE 1—Some chart recorders plot the mirror image of this graph.

FIG. A1.2 Material with No Hookean Region

A2. MEASURING AND SETTING SPAN

A2.1 For flexural fixtures that have adjustable spans, it is important that the span between the supports is maintained constant or the actual measured span is used in the calculation of stress, modulus, and strain, and the loading nose or noses are positioned and aligned properly with respect to the supports. Some simple steps as follows can improve the repeatability of your results when using these adjustable span fixtures.

A2.2 Measurement of Span:

A2.2.1 This technique is needed to ensure that the correct span, not an estimated span, is used in the calculation of results.

A2.2.2 Scribe a permanent line or mark at the exact center of the support where the specimen makes complete contact. The type of mark depends on whether the supports are fixed or rotatable (see Figs. A2.1 and A2.2).

A2.2.3 Using a vernier caliper with pointed tips that is readable to at least 0.1 mm (0.004 in.), measure the distance between the supports, and use this measurement of span in the calculations.

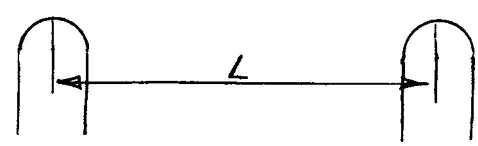


FIG. A2.1 Markings on Fixed Specimen Supports

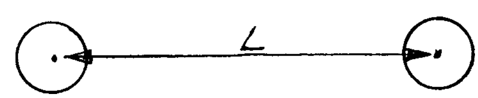


FIG. A2.2 Markings on Rotatable Specimen Supports

A2.3 *Setting the Span and Alignment of Loading Nose(s)*—To ensure a consistent day-to-day setup of the span and ensure the alignment and proper positioning of the loading nose, simple jigs should be manufactured for each of the standard setups used. An example of a jig found to be useful is shown in Fig. A2.3.

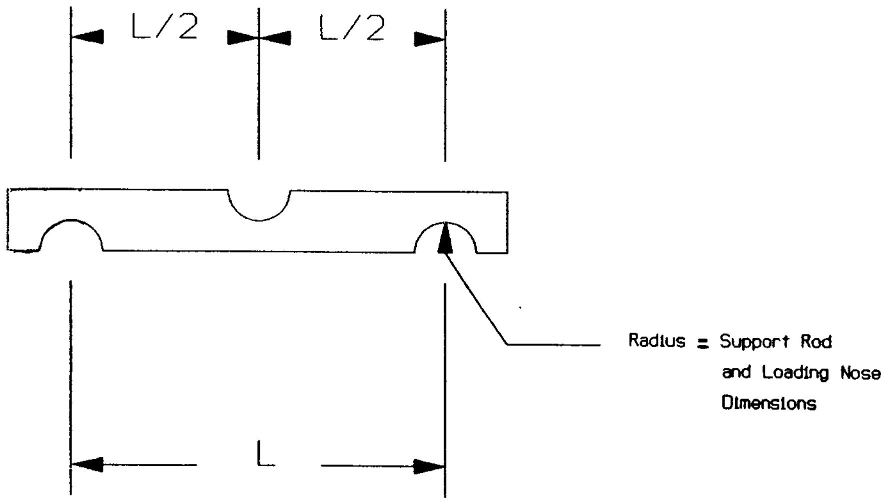


FIG. A2.3 Fixture Used to Set Loading Nose and Support Spacing and Alignment

APPENDIX

(Nonmandatory Information)

X1. DEVELOPMENT OF A FLEXURAL MACHINE COMPLIANCE CORRECTION

X1.1 Introduction

X1.1.1 Universal Testing instrument drive systems always exhibit a certain level of compliance that is characterized by a variance between the reported crosshead displacement and the displacement actually imparted to the specimen. This variance is a function of load frame stiffness, drive system wind-up, load cell compliance and fixture compliance. To accurately measure the flexural modulus of a material, this compliance should be measured and empirically subtracted from test data. Flexural modulus results without the corrections are lower than if the correction is applied. The greater the stiffness of the material the more influence the system compliance has on results.

X1.1.2 It is not necessary to make the machine compliance correction when a deflectometer/extensometer is used to measure the actual deflection occurring in the specimen as it is deflected.

X1.2 Terminology

X1.2.1 *Compliance*—The displacement difference between test machine drive system displacement values and actual specimen displacement

X1.2.2 *Compliance Correction*—An analytical method of modifying test instrument displacement values to eliminate the amount of that measurement attributed to test instrument compliance.

X1.3 Apparatus

X1.3.1 Universal Testing machine

X1.3.2 Load cell

X1.3.3 Flexure fixture including loading nose and specimen supports

X1.3.4 Computer Software to make corrections to the displacements

X1.3.5 Steel bar, with smoothed surfaces and a calculated flexural stiffness of more than 100 times greater than the test material. The length should be at least 13 mm greater than the support span. The width shall match the width of the test specimen and the thickness shall be that required to achieve or exceed the target stiffness.

X1.4 Safety Precautions

X1.4.1 The universal testing machine should stop the machine crosshead movement when the load reaches 90 % of load cell capacity, to prevent damage to the load cell.

X1.4.2 The compliance curve determination should be made at a speed no higher than 2 mm/min. Because the load builds up rapidly since the steel bar does not deflect, it is quite easy to exceed the load cell capacity.

X1.5 Procedure

NOTE X1.1—A new compliance correction curve should be established each time there is a change made to the setup of the test machine, such as, load cell changed or reinstallation of the flexure fixture on the machine. If the test machine is dedicated to flexural testing, and there are no changes to the setup, it is not necessary to re-calculate the compliance curve.

NOTE X1.2—On those machines with computer software that automatically make this compliance correction; refer to the software manual to determine how this correction should be made.

X1.5.1 The procedure to determine compliance follows:

X1.5.1.1 Configure the test system to match the actual test configuration.

X1.5.1.2 Place the steel bar in the test fixture, duplicating the position of a specimen during actual testing.

X1.5.1.3 Set the crosshead speed to 2 mm/min. or less and start the crosshead moving in the test direction recording crosshead displacement and the corresponding load values.

X1.5.1.4 Increase load to a point exceeding the highest load expected during specimen testing. Stop the crosshead and return to the pre-test location.

X1.5.1.5 The recorded load-deflection curve, starting when the loading nose contacts the steel bar to the time that the highest load expected is defined as test system compliance.

X1.5.2 Procedure to apply compliance correction is as follows:

X1.5.2.1 Run the flexural test method on the material at the crosshead required for the measurement.

X1.5.2.2 It is preferable that computer software be used to make the displacement corrections, but if it is not available compliance corrections can be made manually in the following manner. Determine the range of displacement (D) on the load versus displacement curve for the material, over which the modulus is to be calculated. For Young's Modulus that would steepest region of the curve below the proportional limit. For Secant and Chord Modulii that would be at specified level of strain or specified levels of strain, respectively. Draw two vertical lines up from the displacement axis for the two chosen displacements (D1, D2) to the load versus displacement curve for the material. In some cases one of these points maybe at zero displacement after the toe compensation correction is made. Draw two horizontal lines from these points on the load displacement curve to the Load (P) axis. Determine the loads (L1, L2).

X1.5.2.3 Using the Compliance Correction load displacement curve for the steel bar, mark off L1 and L2 on the Load (P) axis. From these two points draw horizontal lines across till they contact the load versus displacement curve for the steel bar. From these two points on the load deflection curve draw two vertical lines downwards to the displacement axis. These two points on the displacement axis determine the corrections (c1, c2) that need to be made to the displacements measurements for the test material.

X1.5.2.4 Subtract the corrections (c1, c2) from the measured displacements (D1, D2), so that a true measures of test specimen deflection (D1-c1, D2-c2) are obtained.

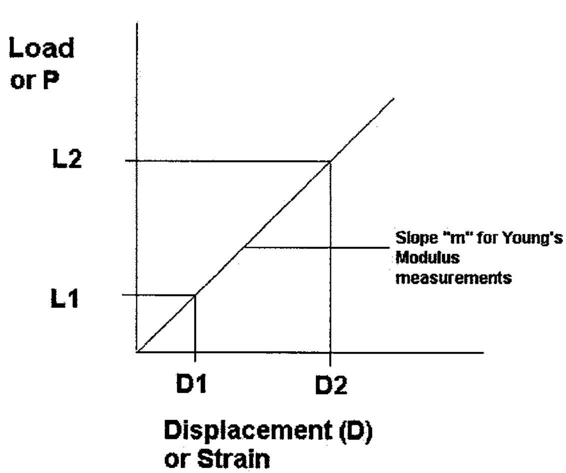


FIG. X1.1 Example of Modulus Curve for a Material

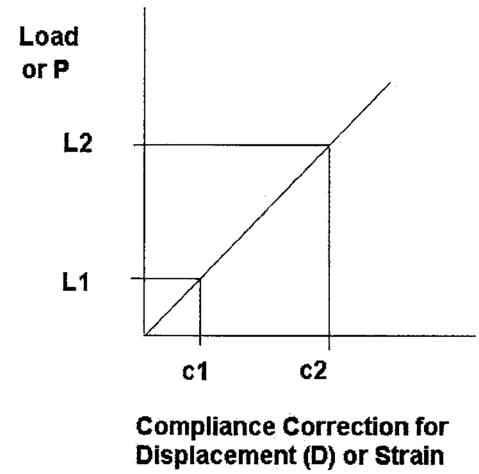


FIG. X1.2 Compliance Curve for Steel Bar

X1.6 Calculations

X1.6.1 Calculation of Chord Modulus

X1.6.1.1 Calculate the stresses ($\sigma f1$, $\sigma f2$) for load points L1 and L2 from Fig. X1.1 using the equation in 12.2, Eq 3.

X1.6.1.2 Calculate the strains ($\varepsilon f1$, $\varepsilon f2$) for displacements D1-c1 and D2-c2 from Fig. X1.3 using the equation in 12.8, Eq 5.

X1.6.1.3 Calculate the flexural chord modulus in accordance with 12.9.3, Eq 7.

X1.6.2 Calculation of Secant Modulus

X1.6.2.1 Calculation of the Secant Modulus at any strain along the curve would be the same as conducting a chord modulus measurement, except that $\sigma f1 = 0$, L1= 0, and D1-c1 = 0.

X1.6.3 Calculation of Young's Modulus

X1.6.3.1 Determine the steepest slope "m" along the curve, below the proportional limit, using the selected loads L1 and L2 from Fig. X1.1 and the displacements D1-c1 and D2-c2 from Fig. X1.3.

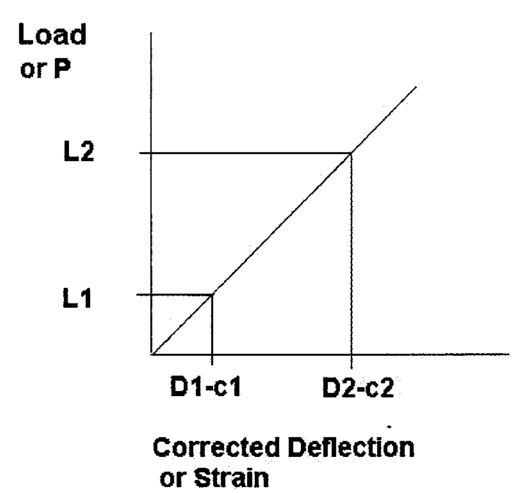


FIG. X1.3 Example of the Material Curve Corrected for the Compliance Corrected Displacement or Strain

X1.6.3.2 Calculate the Young's modulus in accordance with 12.9.1, Eq 6.

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D790 - 07$^{\varepsilon 1}$) that may impact the use of this standard. (April 1, 2010)

(1) Revised Section 9.

TECHNICAL SPECIFICATIONS
CURED-IN-PLACE PIPE (CIPP) FOR MAINLINE RENEWAL

PART 1 - PRODUCTS

1.1 GENERAL

It is the intent of this specification to provide for the reconstruction of pipelines and conduits by the installation of a resin-impregnated flexible tube that is either inverted or pulled into the original pipeline/conduit and expanded to fit tightly against said pipeline/conduit by the use of water or air pressure. The resin system shall then be cured by elevating the temperature of the water or air used for the inflation to a sufficient enough level for the initiators in the resin to effect a reaction. The finished cured-in-place pipe (CIPP) shall be such that when the thermosetting resin cures, the total wall thickness shall be a homogeneous and monolithic felt and resin composite matrix, chemically resistant to withstand internal exposure to domestic sewage or stormwater.

1.2 QUALIFICATIONS

Since sewer products are intended to have a 50-year design life, and in order to minimize the Owner's risk, only proven products with substantial successful long-term track records will be approved.

In order for the CIPP and Installation Contractors to be deemed commercially acceptable and approved for this project they must meet the following criteria:

A. CIPP

1. The CIPP product must have been installed in a minimum of 5,000,000 linear feet or 4,000 manhole to manhole line sections of successful wastewater collection system installations in the U.S. and must be documented to the satisfaction of the Owner.

2. The CIPP shall comply with the latest versions of ASTM D5813, F1216 or ASTM F1743, including appendices.

3. For the CIPP to be considered Commercially Proven, it shall have been successfully in service in an application similar to this project for a minimum of 10 years and documented to the satisfaction of the Owner.

4. The lining tube manufacturer shall operate under a quality management system that is third party certified to ISO 9001 or other internationally recognized organization standards. Proof of certification shall be submitted with the Bidder's bid and required for approval.

5. Third-party test results supporting the structural properties and long-term performance of the CIPP shall be submitted for approval, and such data shall be satisfactory to the Owner. No CIPP will be approved without independent third party testing verification.

B. Installation Contractor

1. The Installation Contractor shall satisfy all insurance, financial and bonding requirements of the Owner, and shall have installed within the United States a minimum of 1,000,000 lineal feet of the same CIPP being represented by the bidder. In addition, the Installation Contractor shall have had at least 5 years active experience in the installation of the proposed CIPP.

2. The Installation Contractor superintendent(s) designated for the project shall have installed a minimum of 100,000 lineal feet and shall have 5 years of installation experience of the same CIPP being represented by the bidder. This shall be documented to the Owner's satisfaction in the form of a resume of work experience detailing scope of work (linear footage and pipe diameters), location of work, and reference contact information for each project listed.

3. The Installation Contractor shall operate under a quality management system that is third party certified to ISO 9001 or other internationally recognized organization standards. Proof of certification shall be submitted with the Bidder's bid and required for approval.

1.3 STRUCTURAL REQUIREMENTS

A. Each CIPP shall be designed to withstand internal and/or external loads as dictated by the site and pipe conditions. Unless specified differently by the Owner/Engineer in the contract documents, the design thickness of the CIPP shall be derived using the standard engineering methodology as found in ASTM F1216, Appendix X1. The long-term flexural modulus shall not exceed 50 percent of the short-term value for the CIPP and shall be substantiated through third-party testing. The thickness calculations, signed and sealed by a registered professional engineer, shall be submitted to the Owner prior to CIPP installation.

B. The layers of the finished CIPP shall be uniformly bonded. It shall not be possible to separate any two layers with a probe or point of a knife blade so that the layers separate cleanly or such that the knife blade moves freely between the layers. If separation of the layers occurs during testing of the field samples, new samples will be cut from the work. Any reoccurrence may be cause for rejection of the work.

C. The Enhancement Factor 'K' to be used in the CIPP design shall be assigned a value of 7.

D. Long-term testing in general accordance with ASTM D2990 must have been performed for flexural creep of the CIPP pipe material to be installed. Such testing results are to be used to determine the long-term, time dependent flexural modulus to be utilized in the product design. This is a performance test of the materials (CIPP Tube and Resin) and general workmanship of the installation and curing as defined within the relevant ASTM standard. A percentage of the instantaneous flexural modulus value (as measured by ASTM D790 testing) will be used in design calculations for external buckling. The percentage, or the long-term creep retention value utilized, will be verified by this testing. Retention values exceeding 50% of the short-term test results shall not be applied unless substantiated by qualified third party test data to the Owner's satisfaction. The materials utilized for the contracted project shall be of a quality equal to or better than the materials used in the long-term test with respect to the initial flexural modulus used in the CIPP design.

E. The CIPP shall meet the following minimum strength requirements:

MINIMUM PHYSICAL PROPERTIES

Property	ASTM Test Method	Polyester System	Filled Polyester System	Vinyl Ester System
Flexural Strength	D790	4,500 psi	4,500 psi	4,500 psi
Flexural Modulus (initial)	D790	250,000 psi	400,000 psi	250,000 psi
Flexural Modulus (50-year)	D790	125,000 psi	205,000 psi	125,000 psi

F. The required CIPP wall thickness shall be based as a minimum on the physical properties in Section 1.3.E. above (or greater values if substantiated by third-party testing) and in accordance with the design equations in the Appendix X1 of ASTM F1216, and the following design parameters:

Design Safety Factor (typically used value)	=	2.0
Retention Factor for Long-Term Flexural Modulus to be used in Design	=	50% max
(As determined by long-term tests described in Section 3.1.B and approved by the Owner)		
Ovality* (calculated from (X1.1 of ASTM F1216)	=	% (1)
Enhancement Factor, K	=	7.0
Groundwater Depth (above invert of pipe)	=	feet (1)
Soil Depth (above crown of pipe)	=	feet
Soil Modulus (only required for fully deteriorated design conditions)	=	psi (1)
Soil Density (only required for fully deteriorated design conditions)	=	lb/ft^3(1)
Live Load (only required for fully deteriorated design conditions)	=	e.g. H20 Highway
Design Condition (partially or fully deteriorated)*	=	*

* Based on review of video logs, design conditions of pipeline can be fully or partially deteriorated. (See ASTM F1216 Appendix) The Owner will be sole judge as to pipe conditions and parameters utilized in design.

(1) In the absence of other information and to ensure uniformity in bidding, the following assumptions shall be used: ovality = 2%; groundwater depth at half depth to invert; soil modulus = 1000 psi; soil density = 120 lb/ft^3.

1.4 MATERIALS

A. CIPP Tube

1. The CIPP tube shall consist of one or more layers of a flexible needled felt or an equivalent nonwoven or woven material, or a combination of nonwoven and woven materials, capable of carrying resin, withstanding installation pressures and curing temperatures. The CIPP tube should be compatible with the resin system to be used on this project. The material should be able to stretch to fit irregular pipe sections and negotiate bends.

2. The CIPP tube should be fabricated under controlled conditions to a size that, when installed, will tightly fit the internal circumference and the length of the original conduit. Allowances should be made for the longitudinal and circumferential stretching that

occurs during placement of the CIPP tube. Maximum stretching allowances shall be as defined in ASTM F1216 or ASTM F1743. The Installation Contractor shall verify the lengths in the field before cutting the CIPP tube to length. Continuous individual liners can be made over one or more manhole to manhole sections.

3. The CIPP tube shall be uniform in thickness and when subjected to the installation pressures shall meet or exceed the designed wall thickness.

4. Any plastic film applied to the CIPP tube on what will become the interior wall of the finished CIPP shall be compatible with the resin system used, translucent enough that the resin is clearly visible, and shall be firmly bonded to the felt material.

5. At time of manufacture, each lot of CIPP tube shall be inspected and certified to be free of defects. The CIPP tube shall be marked for distance at regular intervals along its entire length, not to exceed five feet. Such markings shall also include the CIPP tube Manufacturer's name or identifying symbol.

6. The CIPP tube may be made of single or multiple layer construction where any layer must not be less than 1.5 mm thick. A suitable mechanical strengthener membrane or strip may be placed in between layers where required to control longitudinal stretching.

B. Resin Components

1. The resin system shall be a corrosion resistant polyester or vinyl ester, along with a compatible catalyst system.

2. The resin used shall not contain non-strength enhancing fillers.

3. When combined with the CIPP tube, the resin system shall provide a CIPP that meets the structural requirements of ASTM F1216 or ASTM F1743, the minimum physical properties specified in Section 1.3.E., and those properties which are to be utilized in the design of the lining system for this project.

4. When combined with the CIPP tube, the resin system shall provide a CIPP that complies with the chemical resistance requirements specified in ASTM F1216 or ASTM F1743.

PART 2 - EXECUTION

2.1 GENERAL

A. The Installation Contractor shall deliver the resin impregnated CIPP tube to the site and provide all equipment required to insert and cure the CIPP within the host pipe. The Installation Contractor shall designate a location where the CIPP tube will be vacuum impregnated with the resin prior to installation. If requested by the Owner, the Installation Contractor shall notify the Engineer at least 48 hours prior to wet out to allow the Engineer to observe the materials and wet out procedure. All procedures to prepare the CIPP for installation shall be in strict accordance with the Manufacturer's recommendations.

B. The CIPP shall be vacuum impregnated with resin not more than 120 hours before the time of installation and stored out of direct sunlight at a temperature of less than 70° F.

2.2 NOTIFICATION AND PREPARATION

A. The Installation Contractor shall notify all residents affected by this construction at least 24 hours prior to any service disruption affecting their service connection. The Installation Contractor shall make every effort to maintain service usage throughout the duration of the project.

B. The Installation Contractor shall perform cleaning, video, and inspection prior to installation of the CIPP. The Installation Contractor, when required, shall remove all debris from within the pipe that will interfere with the installation of the CIPP. The Owner shall provide a dumpsite for such debris removed during the cleaning operations.

C. It shall be the responsibility of the Installation Contractor to notify the Owner of line obstructions, offset joints or collapsed pipe that will prevent the insertion of the tube or significantly reduce the capacity of the sewer. The Owner, with input from the Installation Contractor, shall determine the method of pipe repair required and shall address these concerns on a case-by-case basis.

D. Protruding laterals or services shall be trimmed flush with the inside of the main sewer wall prior to installation of the CIPP. Trimming shall not cause damage to the lateral or service beyond the inside face of the main sewer.

2.3 BYPASS PUMPING

A. The Installation Contractor, when required, shall provide for the flow of sewage around the section or sections of pipe designated for repair. When possible, the bypass shall be made by plugging the line at an existing upstream manhole and pumping the flow into a downstream manhole or adjacent system. The pump and bypass lines shall be of adequate capacity and size to handle the flow. The Installation Contractor shall furnish all necessary pumping equipment, conduit, etc. to adequately, safely, and environmentally divert sewage flow around the work.

B. When requested by the Engineer, the Installation Contractor shall submit a general bypass plan.

2.4 TELEVISION INSPECTION

A. The Installation Contractor shall provide video equipment capable of properly documenting the conditions as found within the pipe. Lighting for the video camera shall illuminate the entire periphery of the sewer. The camera shall be radial view type capable of viewing 360° within the pipe and shall provide an unobstructed view of the full pipe.

B. The video shall begin with a clear identification of the pipeline location, upstream and downstream manhole designation, and pipe diameter. The video shall provide an accurate length measurement of the entire segment and of the distance to each lateral connection. The Installation Contractor shall pan all lateral connections on both the pre and post videos.

C. Reverse video set-ups shall be utilized when line obstructions prevent full segment televising from the initial set-up direction.

D. Both a pre-lining and post-lining video shall be submitted to the Owner for approval. The discs shall be clearly and properly labeled.

2.5 INSTALLATION

A. The CIPP shall be installed in accordance with the practices given in ASTM F1216 (for direct inversion installations) or ASTM F1743 (for pulled-in-place installations). The quantity of resin used for the CIPP tube's impregnation shall be sufficient to fill the volume of air voids in the CIPP tube with additional allowances being made for polymerization shrinkage and the loss of any resin through cracks and irregularities in the original pipe wall. A vacuum impregnation process shall be used in conjunction with a roller system to achieve a uniform distribution of the resin throughout the CIPP tube.

B. The resin-impregnated CIPP tube shall be installed into the host pipe by methods specified in ASTM F1216 or ASTM F1743 and proven through previous successful installations. The insertion method shall not cause abrasion or scuffing of the CIPP tube. Hydrostatic or air pressure shall be used to inflate the CIPP tube and mold it against the walls of the host pipe. There will be no use of sewage in place of clean water for insertion of the CIPP tube, or for the curing of the CIPP.

C. Temperature gauges shall be placed between the CIPP tube and the host pipe's invert position to monitor the temperatures during the cure cycle.

2.6 CURING

A. After the CIPP tube installation is completed the Installation Contractor shall supply a suitable heat source and recirculation equipment (if required). The equipment shall be capable of delivering hot water or steam throughout the section to uniformly raise the temperature above the temperature required to affect a cure of the resin.

B. The heat source shall be fitted with suitable monitors to gauge the temperature of the incoming and outgoing heat supply (for water cure) and outgoing heat supply (for steam cure). Water or air temperature in the pipe during the cure period shall be as recommended by the resin Manufacturer.

C. Initial cure shall be deemed to be completed when inspection of the exposed portions of CIPP appears to be hard and sound and the remote temperature sensor(s) indicates that the temperature is of a magnitude to realize an exotherm. The cure period shall be of a duration recommended by the resin Manufacturer, as modified for the installation process, during which time the recirculation of the heat and/or cycling of the heat exchanger to maintain the temperature continues.

2.7 COOL DOWN

Cool down may be accomplished by the introduction of cool water or air to replace water or pressurized air being relieved. Care shall be taken in the release of the hydrostatic head so that a vacuum will not be developed.

2.8 FINISH

A. The finished CIPP shall be continuous over the entire length of an insertion run and be as free as commercially practical from visual defects such as foreign inclusions, dry spots, pinholes, and delamination. The CIPP shall be homogeneous and free of any leakage from the surrounding ground to the inside of the CIPP.

B. Where the CIPP is installed through an intermediate manhole uninterrupted, the invert shall be maintained smooth through the manhole, with approximately the bottom half of the CIPP continuous through the manhole. The invert of the manhole shall be shaped and grouted as necessary to support the liner. The cost of this work shall be included in the CIPP unit price.

C. During the warranty period, any defects which will affect the integrity or strength of the CIPP, collect solids, or reduce hydraulic flow capabilities of the product shall be repaired at the Installation Contractor's expense in a manner mutually agreed upon by the Owner and the Installation Contractor.

2.9 REINSTATE LATERALS AND SERVICES

A. Accurate location of the lateral and service connections shall be made by inspection of the pre-installation video or sewer walk.

B. After the CIPP has been installed, all existing active lateral sewers and services shall be reinstated unless otherwise indicated by the Owner or on the plans. The reinstatement of laterals and services shall be done without excavation unless otherwise specified by the Engineer. Reinstatement of laterals and services will be accomplished from the interior of the CIPP by means of a video camera directed cutting device or by direct man entry when feasible.

C. All cut lateral and service connections shall be free of burrs, frayed edges, or any restriction preventing free flow of wastewater. Laterals shall be reinstated to a minimum of 90% of their original diameter and no more than 100% of their minimum diameter. The CIPP shall be tightly sealed at the cut openings with no gaps.

2.10 QUALITY ASSURANCE PROCEDURES

A. For every two thousand five hundred (2,500) lineal feet of liner installed, two (2) flat plate samples shall be processed and tested. For pipe diameters less than 18 inches, restrained end samples may also be utilized. The CIPP physical properties shall be tested in accordance with ASTM F1216, Section 8, using either allowed sampling method. The flexural properties must meet or exceed the values listed in Section 1.3.E. of this specification and the values submitted to the Owner by the Installation Contractor for this project's CIPP wall design, whichever is greater.

B. Testing shall be completed by an accredited, independent laboratory. Testing results shall be provided to the Owner within 7 days of receipt of such results.

C. Wall thickness of samples shall be determined in a manner consistent with 8.1.2 of ASTM D5813. The minimum wall thickness at any point shall not be less than 87.5% of the specified design thickness calculated in 1.3.F of this document.

D. Flexural testing of the collected samples shall be conducted in accordance with ASTM D790, latest version, with only the structural portion of the CIPP being tested.

E. CIPP installation shall be inspected by post-lining video inspection. Variations from true line and grade may be inherent because of the conditions of the original piping. No infiltration of groundwater should be observed. All service entrances should be unobstructed and accounted for.

PART 3 - PAYMENT

Payment for the work included in this section will be in accordance with the unit prices set forth in the proposal for the quantity of work performed. Progress payments will be made on the work performed during each monthly period.

When not defined, payment shall be broken down as follows:

A. Mobilization and demobilization shall be paid for as one lump sum amount.

B. Cleaning shall be paid for per lineal foot of line cleaned. Items for both light and heavy cleaning shall be designated as appropriate.

C. Protruding lateral shall be paid for per each removed.

D. CIPP shall be paid per lineal foot of each diameter rehabilitated as measured from center of manhole to center of manhole.

E. Lateral reinstatement shall be paid per each lateral reinstated.

F. Bypass pumping shall be paid for as one lump sum and shall include all incidentals required for the bypass efforts.

G. Traffic control shall be paid as one lump sum and shall include all incidentals required for traffic control.

All other incidental costs such as sample testing shall be included in the cost of these items.