



Standard Practice for Installation of Machine Spiral Wound Poly (Vinyl Chloride) (PVC) Liner Pipe for Rehabilitation of Existing Sewers and Conduits¹

This standard is issued under the fixed designation F1741; 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 rehabilitation of sewer lines and conduits for existing pipelines 6 to 180 in. in diameter by the insertion of a machine-made field-fabricated spiral wound liner pipe into the existing pipeline using a winding machine which remains stationary in the insertion pit or, alternatively, which travels along the interior of the existing pipeline. These rehabilitation processes can be used in a variety of gravity applications such as sanitary sewers, storm sewers, culverts, and process piping.

1.1.1 When using stationary installation equipment for existing pipelines 6 to 48 in., after insertion, the spiral wound liner pipe is expanded until it presses against the interior surface of the existing pipeline. Alternatively, for existing pipelines 6 to 108 in. in diameter, the spiral wound liner pipe is inserted as a fixed diameter into the existing pipeline and is not expanded, and the annular space between the spiral wound liner pipe and the existing pipe is grouted.

1.1.2 When using the traveling installation equipment for existing pipelines 6 to 180 in. the spiral wound liner pipe is installed in contact with the interior surface of the existing pipeline to form a close fit liner, except in the corners of rectangular pipes or where obstructions or offsets occur. Alternatively, for existing pipelines 6 to 180 in. in diameter and for similar sized existing non circular pipelines such as arched or oval or rectangular shapes, the spiral wound liner is installed as a fixed diameter into the exiting pipeline to form a non-close fit liner and the annular space between the spiral wound liner pipe and the existing pipe is grouted.

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.

1.3.1 Particular attention is drawn to those safety regulations and requirements involving entering into and working in confined spaces.

2. Referenced Documents

2.1 ASTM Standards:²

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C495 Test Method for Compressive Strength of Lightweight Insulating Concrete

D883 Terminology Relating to Plastics

D1600 Terminology for Abbreviated Terms Relating to Plastics

F412 Terminology Relating to Plastic Piping Systems

F1417 Practice for Installation Acceptance of Plastic Non-pressure Sewer Lines Using Low-Pressure Air

F1697 Specification for Poly(Vinyl Chloride) (PVC) Profile Strip for Machine Spiral-Wound Liner Pipe Rehabilitation of Existing Sewers and Conduit

2.2 Uni-Bell Standard:

UNI-B-5-89 Recommended Practice for the Installation of PVC Sewer Pipe³

3. Terminology

3.1 *General*—Definitions are in accordance with Terminologies **D883** and **F412**. Abbreviations are in accordance with Terminology **D1600**, unless otherwise indicated.

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 Nov. 1, 2008. Published December 2008. Originally approved in 1996. Last previous edition approved in 2007 as F1741–07. DOI: 10.1520/F1741-08.

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 Uni-Bell, 2655 Villa Creek Drive, Suite 155, Dallas TX 75234.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *extruded PVC profile strip*—a product available in various widths, consisting of a smooth inside surface and a ribbed outer surface with mechanically locked male and female edges which are self interlocking, or separate locking strips which serve the same purpose Type A and Type B are different profiles and are installed by different installation methods. See Fig. 1 and Table 1 for Type A and Fig. 2 and Table 2 for Type B. See Fig. 1 and Fig. 3 for installation method for Type A and Fig. 2 and Fig. 4 for installation method for Type B.

3.2.2 *insertion point*—an existing manhole, existing access shaft, or excavated pit that serves as the point where a winding machine field fabricates the spiral wound liner pipe and simultaneously inserts the spiral wound liner pipe into the existing pipeline.

3.2.3 *non-circular pipe*—arched, oval or rectangular or a combination thereof.

3.2.4 *production run*—a continuous extrusion of a given profile type.

3.2.5 *spiral wound liner pipe*—a product field fabricated from extruded PVC profile strip to a round shape, or noncircular shape, such as arched or oval or rectangular. (See Fig. 5.)

3.2.6 *steel reinforcement*— a shaped steel strip or clip inserted into the inside of the PVC profile to provide additional reinforcement and stiffening. (See Fig. 3 and Fig. 4.)

3.2.7 *termination point*—an existing manhole, existing access shaft, or an excavated pit that serves as the point of exit of the spiral wound liner pipe from the existing pipe.

4. Significance and Use

4.1 This practice is for use by designers and specifiers, regulatory agencies, owners, and inspection organizations who are involved in the rehabilitation of non-pressure sewers and conduits. Modifications may be required for specific job conditions.

5. Materials

5.1 The extruded profile strip used for the field fabrication of spiral wound liner pipe shall be in accordance with Specification F1697.

5.2 The profile strip should be coiled onto a reel in a continuous length for storage and shipping to the job site. Handling and storage should be in accordance with the manufacturer's published recommendations.

5.3 The adhesive or sealants, or both, used with the male and female mechanical locking elements should be compatible with the PVC compound and the spiral wound liner pipe process so as not to affect the properties of the spiral wound finished liner pipe.

5.4 The steel reinforcing strips shall be used to reinforce the extruded PVC profile strip, where the design conditions requires additional stiffness, such as for non-circular shaped pipes.

6. Installation Recommendations

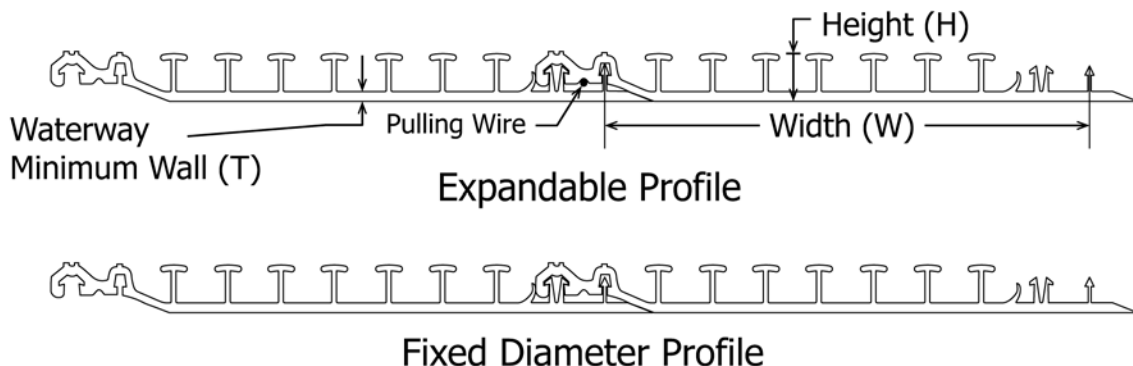
6.1 Cleaning and Inspection:

6.1.1 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 .

6.1.2 *Cleaning of Pipeline*—Internal debris should be removed from the existing pipeline. Gravity pipes should be cleaned with hydraulically powered equipment, high-velocity jet cleaners, or mechanically powered equipment in accordance with NASSCO recommended specifications.

6.1.3 *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 by direct visual inspection. The interior of the pipeline should be carefully inspected to determine the location of any conditions that may prevent proper installation of the spiral wound liner pipe, such as protruding service taps, collapsed or crushed pipe, out-of-roundness, significant line sags, and deflected joints. These conditions should be noted and corrected, if necessary, prior to installation.

6.1.4 *Line Obstructions*—The existing pipeline should be clear of obstructions that will prevent the proper insertion, and expansion if required, of the spiral wound liner pipe. Obstructions could include dropped or offset joints of more than 12.5 % of inside pipe diameter, service connections that



NOTE 1—For values of width, height, and waterway minimum wall, see Table 1.

FIG. 1 Type A-Typical PVC Profile Strip

TABLE 1 Type A Typical Profile Strip Moments of Inertia and Stiffness Factors

Profile Type ^{AB}	Moment of Inertia, I		Depth to Neutral Axis, $\bar{y}$		Minimum Height, H		Profile Area		Minimum Stiffness Factor, EI^C	
	in. ⁴ /in.	(mm ⁴ /m)	in.	(mm)	in.	(mm)	in. ² /in.	(mm ² /mm)	in. ³ ·lbf/in. ²	(MPa·mm ³)
1	0.00047	(7.70)	0.077	(1.98)	0.216	(5.5)	0.118	(3.00)	188.0	(21.2 × 10 ³)
2	0.00140	(23.00)	0.130	(3.30)	0.314	(8.0)	0.146	(3.70)	561	(63.4 × 10 ³)
3	0.00537	(88.00)	0.206	(5.24)	0.511	(13.0)	0.205	(5.20)	2148	(242.7 × 10 ³)
4	0.00386	(63.30)	0.200	(5.08)	0.480	(12.2)	0.125	(3.18)	1600.0	(180.8 × 10 ³)
5	0.00400	(65.50)	0.180	(4.57)	0.488	(12.4)	0.125	(3.18)	1600.0	(180.8 × 10 ³)
6	0.00400	(65.50)	0.180	(4.57)	0.488	(12.4)	0.125	(3.18)	1600.0	(180.8 × 10 ³)

^AOther profiles, possibly using supplementary stiffener elements, may be available. Consult the manufacturer.

^BThe spacing of the ribs may vary for each profile type.

^CStiffness factors listed are the minimum values that will be provided by the manufacturer for the given profile type.

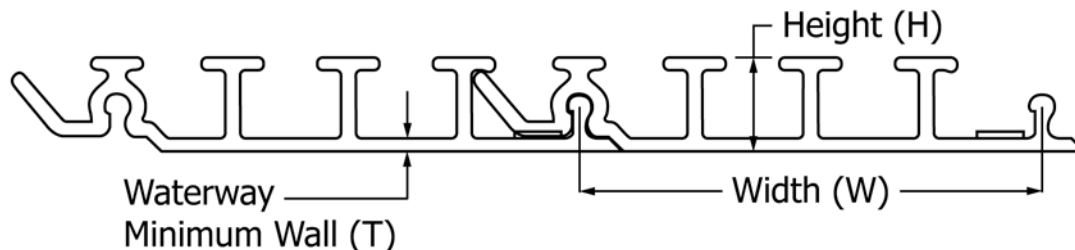


FIG. 2 Type B-Typical PVC Profile Strip

TABLE 2 Type B Typical Profile Strip Moments of Inertia and Stiffness Factors

Profile Type	Moment of Inertia, I		Depth to Neutral Axis, $\bar{y}$		Minimum Height, H		Profile Area		Minimum Stiffness Factor, EI	
	in. ⁴ /in.	(mm ⁴ /m)	in.	(mm)	in.	(mm)	in. ² /in.	(mm ² /mm)	in. ³ ·lbf/in. ²	(MPa·mm ³)
1	0.00106	(17.43)	...	...	0.319	(8.10)	0.132	(3.36)	362.5	40955
2	0.00218	(35.80)	0.26	(6.56)	0.422	(10.71)	0.150	(3.80)	745.0	84127
3	0.00571	(93.58)	0.58	(14.67)	0.578	(14.67)	0.227	(5.76)	1946.3	219900
4	0.01165	(190.92)	0.76	(19.35)	0.762	(19.35)	0.290	(7.36)	3971.0	448656
5	0.04142	(678.68)	1.12	(28.53)	1.123	(28.53)	0.463	(11.75)	14116.0	1594900
6	0.00444	(72.78)	0.56	(14.22)	0.560	(14.22)	0.187	(4.76)	1513.8	171042



FIG. 3 Shaped Steel Reinforcing Strip Type A

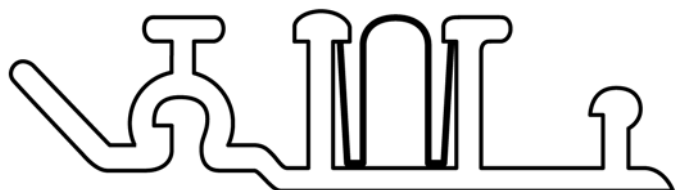


FIG. 4 Shaped Steel Reinforcing Strip Type B

protrude into the pipe more than 12.5 % of the inside pipe diameter or 1-in. (25-mm), whichever is less; and other obstructions in cross-sectional area of more than 16 % based on the inside diameter of the existing pipe. If inspection reveals an obstruction that cannot be removed by conventional equipment, then a point repair excavation should be made to uncover and remove or repair the obstruction. The angle of any bend along the pipeline that can be negotiated by the spiral wound liner pipe depends on a combination of factors such as

the condition of the existing pipe, the location of the bend within the pipeline, and whether there are multiple bends. For a determination of whether a given bend can be accommodated, or whether access will be required for termination and start of a new insertion, consult the supplier of the liner material. Depending on the method of installation used, insertion and expansion, or fixed diameter, some changes in pipe size along the insertion length of the spiral wound liner pipe can be accommodated, and it is recommended that the spiral wound liner pipe material supplier be contacted.

6.2 *Bypassing*—The spiral wound liner pipe process does not require a dry pipeline and can be installed with some flow in the existing pipe or lateral connections, or both. If necessary, 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 any extreme flows expected during the installation period.

6.2.1 Under certain conditions, part or all of the installation may be carried out with some flow in the existing pipeline or service connections, or both.

6.3 *Pipe Liner Fabrication and Insertion Using Stationary Installation Equipment:*

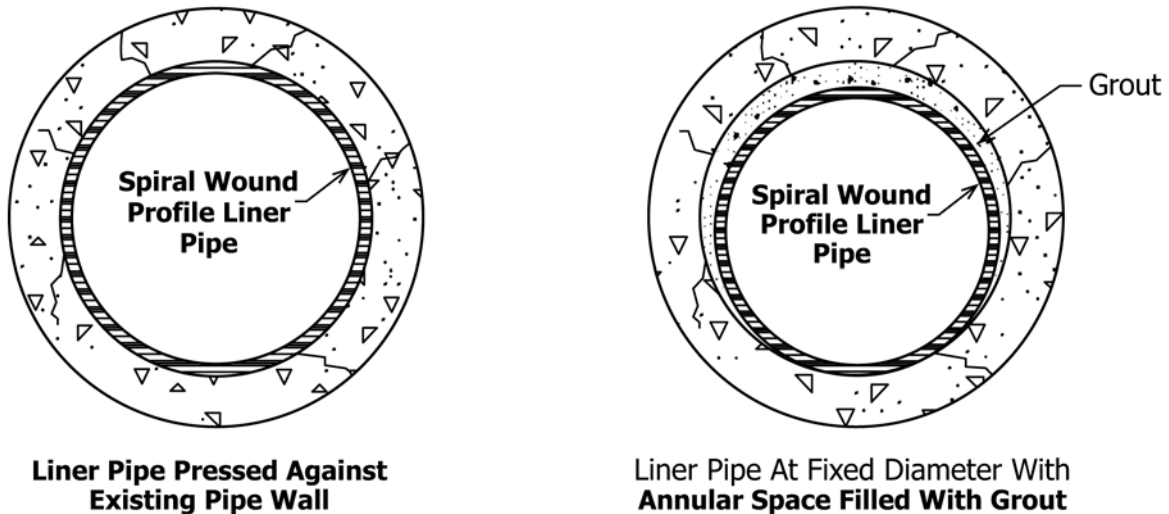


FIG. 5 Typical Spiral Wound Liner Pipe

6.3.1 A winding machine should be placed in the insertion pit and oriented so that the liner pipe can be spirally wound and inserted (rotated and pushed) directly into the existing pipeline. A reel of extruded PVC profile strip should be positioned near the insertion point. The initial winding process begins with the profile strip being fed into the winding machine, forming the profile strip into the required spiral wound liner pipe diameter, which is simultaneously rotated and pushed along the existing pipeline for its full length to the termination point. As the profile strip is formed into a spiral, wound liner pipe in the winding machine, the required sealant or adhesive, or both unless already in place, shall be placed within the primary and secondary locks of the locking configuration at the edge of the profile strip, and wire is placed between the primary and secondary locks of the locking configuration when the spiral wound liner pipe is to be expanded (see Fig. 6 and Fig. 7).

6.3.2 When the spiral wound liner pipe is to be expanded as shown in Fig. 6, the end of the spiral wound liner pipe at the termination point should be torsionally restrained. A specific length of the inserted spiral wound liner pipe is released at the termination point by pulling the wire out of the expandable interlocked joint, thereby severing the secondary lock (see Fig.

6), thus releasing the profile strip to slide freely along the primary rock when a torque is applied to the inserted spiral wound liner pipe. The winding operation should be recommenced, thereby creating a torque which is applied to the released end, thus causing a radial growth or expansion over the released length of the spiral wound liner pipe. The initial radial growth should be permitted to continue until the released end of the spiral wound liner pipe is pressed against the existing pipeline (see Fig. 6), thus halting radially growth and torsionally restraining the spiral wound liner pipe. Subsequent secondary lock release and winding should continue until the spiral wound liner pipe is pressed against the full length of the existing pipe. The annular space between the expanded spiral wound liner pipe and the existing pipeline should be sealed at the ends with a sealing material that is compatible with the spiral wound liner pipe material.

6.4 Pipe Liner Fabrication Using Traveling Installation Equipment:

6.4.1 A traveling winding machine should be placed in the insertion point and oriented so that the winding machine can travel directly into the existing pipeline. A reel of extruded

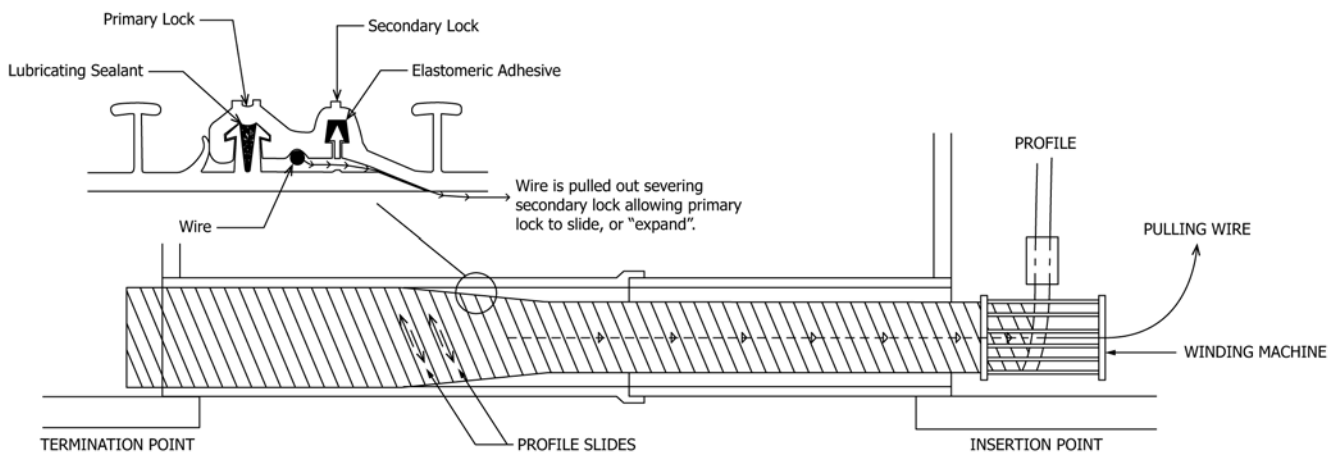


FIG. 6 Insertion of Expandable Spiral Wound Liner

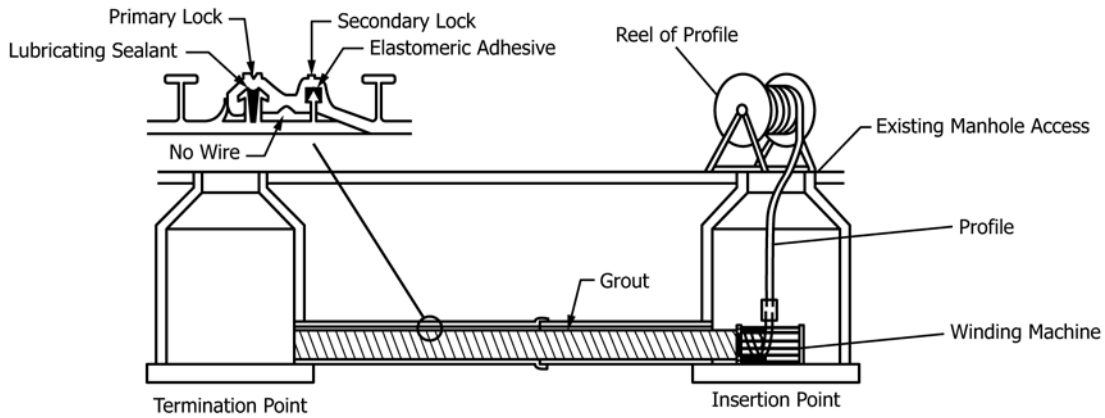


FIG. 7 Insertion of Fixed-Diameter Spiral Wound Liner

PVC profile strip should be positioned near the insertion point. The winding process begins with the profile strip being fed into the winding machine. The traveling winding machine then simultaneously rotates and moves along the existing pipeline for its full length to the termination point, forming the profile strip into the required spiral wound liner pipe diameter or rectangular or non-circular pipeline shape, such as arched or oval. As the profile strip is formed into a spiral wound liner pipe in the winding machine, the sealant or adhesive, or both unless already in place, shall be placed within the primary lock of the locking configuration at the edge of the profile strip. (See Fig. 8 and Fig. 9)

6.4.2 When the spiral wound liner pipe is to be pressed against the existing pipe wall the traveling winding machine should be adjusted to apply the spiral wound liner pipe directly against the existing pipe wall. As the profile strip is formed into a spiral wound liner pipe in the winding machine, the sealant or adhesive, or both unless already in place, shall be placed within the primary lock of the locking configuration at the edge of the profile strip. The space between the spiral wound liner pipe and the existing pipeline should be sealed at the ends with a sealing material that is compatible with the spiral wound liner pipe material.

6.5 Grouting:

6.5.1 When the spiral wound liner pipe is inserted into the existing pipeline and grouted, the following procedure should be followed. The annular space between the expanded spiral

wound liner pipe and the existing pipeline should be sealed at the ends with a sealing material that is compatible with the spiral wound liner pipe material. Grout is then injected throughout the annular space in a variety of ways such as through openings in the end seals, at reconnected service connections, or through grout holes drilled in the spiral wound liner pipe at appropriate points, or combination thereof. Prior to commencing the grouting operation, all service openings must be opened and measures taken to prevent the grout from entering the service connections or the spiral wound liner pipe. In addition, any holes drilled in the spiral wound liner pipe for the grouting operation should be sealed.

6.5.2 When the spiral wound liner pipe is inserted into the existing pipeline as a fixed diameter and grouted, the following procedure should be followed. The annular space between the fixed-diameter spiral wound liner pipe and the existing pipeline should be sealed at the ends with a sealing material that is compatible with the spiral wound liner pipe material. A series of tubes which act as grout injection tubes or breather tubes, or both, at appropriate points are placed through the end seals and around the spiral wound liner pipe and grout pumped into them until satisfactory fill is obtained when grout overflows breather tubes located at the crown of the pipe. Prior to commencing the grouting operation, all service openings must be opened and measures taken to prevent the grout from entering the service connections or the spiral wound liner pipe. In addition, any

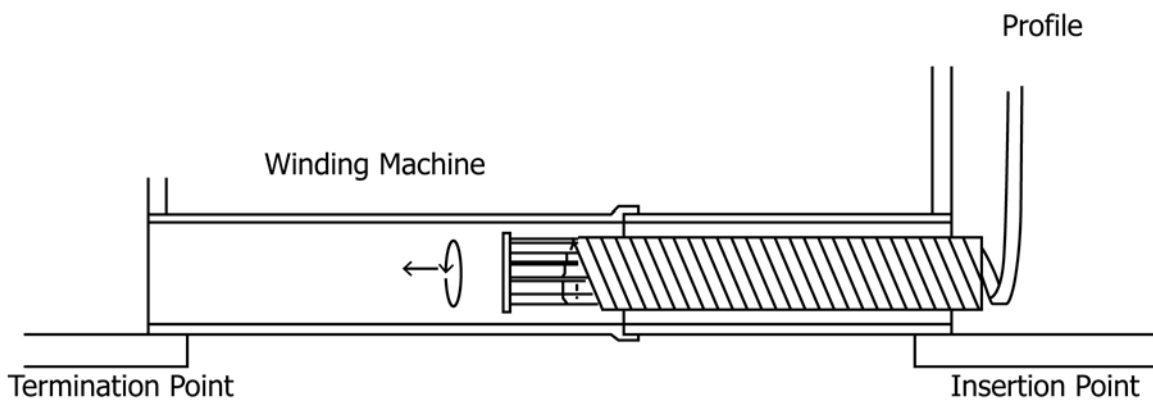


FIG. 8 Insertion of Fixed-Diameter Spiral Wound Liner Using Traveling Installation Equipment

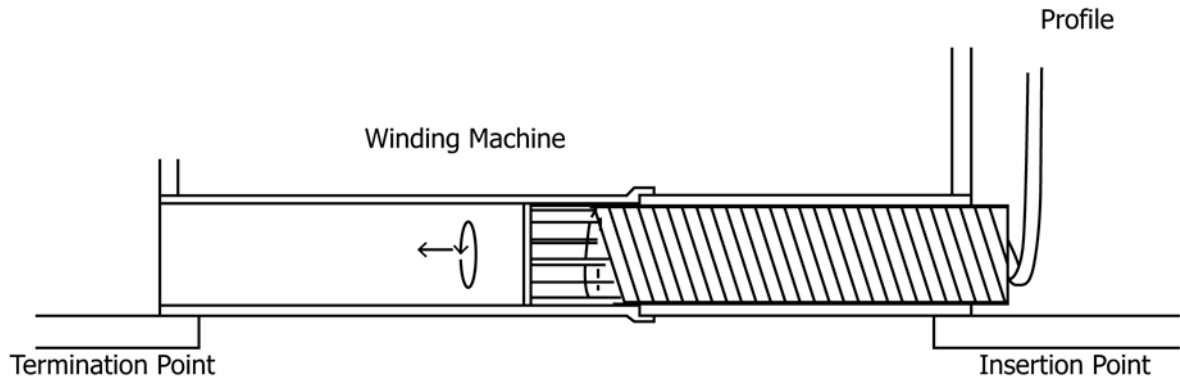


FIG. 9 Insertion of Close Fit Spiral Wound Liner Using Traveling Installation Equipment

holes drilled in the spiral wound liner pipe for the grouting operation should be sealed.

6.5.3 The grouting operation takes place in two ways. Grouting can proceed in lifts or stages to attain satisfactory fill, or it can be done in a continuous stage thereby subjecting the spiral wound liner pipe to a grouting pressure (see X1.2.4). When the grouting operation is done in lifts, generally the rise of the first lift is limited by the tendency of the spiral wound pipe to float off the invert of the existing pipe, which should be controlled. Succeeding lifts are limited in vertical rise by spiral wound liner pipe wall deflection.

6.5.4 The grouting of the annular space is very important to the structural integrity of the rehabilitated pipeline and should be designed and executed with great care. The grouting plan should be recommended by the spiral wound liner pipe material supplier and be reviewed and approved by the owner's representative in advance of the work. Although the goal of grouting is to fill 100 % of the annular space, hydrostatic buckling strength provided for the project site conditions is determined by a combination of profile type used and the amount fill of the annular space (see X1.2.1). The grout should consist of the following: Portland cement, water and some combination recommended by the manufacturer of fly ash, lime, admixtures, bentonite clay, and sand (zero % of any component, other than Portland cement and water is acceptable). The grout shall be tested in accordance with Test Methods C39/C39M or C495 or C109/C109M. Grout mix shall be appropriate to the job and liner manufacturer. The grout mix, including viscosity and minimum compressive strength to be used for the project application, should be as recommended by the spiral wound liner pipe material supplier and approved by the owner's representative prior to commencement of the work. Grout components should be clean, fresh, and stored in a suitable dry condition. Premixed grouts and grout admixtures should be used in accordance with their manufacturer's specifications. Mixing and pump equipment may be, but not limited to, paddle or colloidal mixers and screw, peristaltic, or piston pumps. All equipment should be kept clean and free from buildup.

NOTE 1—Design guidelines for determining an allowable grout pressure against the spiral wound liner pipe, whether grouting in a continuous stage or in lifts, are given in Appendix X1.

6.6 *Service Connections*—After the spiral wound liner pipe has been installed and leakage tested, if applicable, the existing active service connections should be reconnected. This should be done, without excavation if possible, from the interior of the pipeline by means of a television camera and a remote control cutting device, or manually where the size of the spiral wound liner pipe permits man-entry.

NOTE 2—Where annular space grouting is not employed with the profile wall liner pipe, this practice does not provide a seal at service connections due to the continuous spiral channels in the profile liner. The dimensions of the channels in the profile liner for a specific profile type can be determined from Table 1 and Fig. 1. If a seal is desired, other means, which are beyond the scope of this practice, may be necessary to seal service connections and to rehabilitate service lines and manholes. The liner manufacturer should be consulted regarding suitable means.

7. Inspection and Acceptance

7.1 The installation should be inspected either by closed-circuit television or by direct visual inspection. The spiral wound liner pipe should be continuous over the entire length of the insertion. Variations from true line and grade may be inherent because of the conditions of the existing pipeline. No infiltration of ground water through the spiral wound liner pipe should be observed. All service entrances should be accounted for and be unobstructed.

7.2 *Leakage Testing*—If required by the owner or designated in the contract documents or purchase order, or both, gravity pipes should be tested for leakage. This test is limited to pipe lengths with no service laterals, or lines with service laterals which have not yet been reinstated. One of the following two test methods should be used:

7.2.1 An exfiltration test method involves plugging the spiral wound liner pipe at both ends and filling it with water. The allowable water exfiltration for any length of pipe between termination points should not exceed 50 gal per inch of internal spiral wound line pipe diameter per mile per day, providing that all air has been bled from the line. The leakage quantity should be gaged by the water level in a temporary standpipe placed in the upstream plug. 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 standpipe should be 2 ft (0.6 m) higher

than the top of the pipe or 2 ft (0.6 m) higher than the ground water level, whichever is greater. The test should be conducted for a minimum of 1 h.

7.2.2 An air test conducted in accordance with Test Method **F1417**.

NOTE 3—The leakage test is intended to evaluate the water tightness of pipe lengths, with no service laterals or lines with service laterals which have not yet been reinstated.

NOTE 4—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.

7.3 *Grout Compressive Strength Testing*—If required by the owner or designated in the contract documents or purchase order, or both, samples from the mixed grout being pumped/poured into the annular space should be collected and tested for

compressive strength in accordance with Test Method **C39/C39M**. Samples should be taken and tested for each manhole to manhole pipe section where the annular space is grouted. Measured values of compressive strength should meet the job requirements.

8. Design Considerations

8.1 *General Guidelines*—The design of the spiral wound liner pipe is largely a function of the condition of the existing pipeline. Design equations and details are given in **Appendix X1**.

9. Keywords

9.1 expandable; gravity applications; installation-insertion; PVC profile strip; rehabilitation; spiral wound liner pipe

APPENDIX

(Nonmandatory Information)

X1. STRUCTURAL DESIGN CONSIDERATIONS

X1.1 Terminology

X1.1.1 *Partially Deteriorated Pipe*—The existing pipe can support the soil and surcharge and live loads throughout the design life of the rehabilitated pipe, and the soil adjacent to the existing pipe must provide adequate side support. The conduit may have longitudinal cracks and some distortion of the diameter.

X1.1.2 *Fully Deteriorated Pipe*— The existing pipe is not structurally sound and cannot support soil, surcharge and live loads or is expected to reach this condition over the design life of the spiral wound liner pipe. This condition is evident when sections of the existing pipe are missing, the existing pipe has lost its original shape, or the existing pipe has corroded due to the effects of the fluid, atmosphere, or soil.

X1.1.3 *Non-circular Pipe*— arched, oval or retangular shapes or a combination thereof.

X1.2 Design

X1.2.1 *Partially Deteriorated Design Condition*—The spiral wound PVC liner pipe is designed to support only the external hydraulic loads due to ground water (and internal vacuum) since the soil and surcharge loads can be supported by the existing pipe. The ground water level should be determined and the stiffness factor of the spiral wound liner pipe should be sufficient to withstand this hydrostatic pressure without collapsing. The following equation may be used to determine the stiffness factor required:

X1.2.2 Liner pipe expanded against the existing pipe (with or without grouting):

$$P = \frac{24KE_L I}{(1 - \nu^2)D^3} \cdot \frac{C}{N} \quad (\text{X1.1})$$

where:

- P = external pressure, psi (MPa),
- C = ovality reduction factor,

$$= \left[\left(1 - \frac{q}{100} \right) / \left(1 + \frac{q}{100} \right) \right]^2 \cdot 3,$$
- q = percentage ovality of original pipe

$$= 100 \times (D_E - D_{\min}) / D_E$$

$$= 100 \times (D_{\max} - D_E) / D_E,$$
- D_E = mean inside diameter of existing pipe, in. (mm),
- $D_{\min}$ = minimum inside diameter of existing pipe, in. (mm),
- $D_{\max}$ = maximum inside diameter of existing pipe, in. (mm),
- N = factor of safety (2.0 is recommended),
- E_L = modulus of elasticity of spiral wound liner pipe, psi (MPa), reduced to account for long-term effects (see **Note X1.1**),
- I = moment of inertia of spiral wound liner pipe, in.⁴ /in. (mm⁴/mm) (see **Table 1**),
- $E_L I$ = stiffness factor of spiral wound liner pipe, in.³ · lbf/in.² (MPa · mm³),
- D = mean diameter of spiral wound liner pipe, in. (mm),

$$= D_E - 2(H - \bar{y}),$$
- H = height of profile, in. (mm) (see **Table 1**),
- $\bar{y}$ = depth to neutral axis of spiral wound liner profile pipe, in. (mm) (see **Table 1**),
- K = enhancement factor of the soil and existing pipe adjacent to the new liner pipe (for value contact the liner material supplier), and
- ν = Poisson's ratio (0.38 average).

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 of 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.

X1.2.2.1 Rearrange Eq X1.1 and solve for spiral wound liner pipe stiffness factor, $E_L I$, required:

$$E_L I = \frac{P(1 - \nu^2) D^3}{24K} \cdot \frac{N}{C} \quad (\text{X1.2})$$

NOTE X1.2—The design may involve a trial and error approach since the values of I and D are both dependent on the profile used. However, since the values of the mean inside diameter of the existing pipe D_E , and D , are very close, particularly as diameters increase, the value of D_E may be used in the first trial calculation.

X1.2.2.2 Liner pipe installed as a fixed diameter with the annular space grouted:

$$P = \frac{8 E_L I (K_1^2 - 1)}{D^3} \cdot \frac{C}{N} \quad (\text{X1.3})$$

where:

- P = external pressure, psi (MPa),
- N = factor of safety (2.0 is recommended),
- E_L = modulus of elasticity of spiral wound liner pipe, psi (MPa), reduced to account for long-term effects. See **Note X1.1**,
- C = ovality reduction factor (see Eq X1.1),
- I = moment of inertia of liner profile, in. in.⁴ /in. (mm⁴/mm) (see **Table 1**),
- D = mean diameter of spiral wound liner pipe, in. (mm),
= $D_o - 2(H - \bar{y})$,
- D_o = outside diameter of spiral wound liner pipe, in. (mm),
- H = height of liner profile, in. (mm), (see **Table 1**),
- $\bar{y}$ = depth to neutral axis of liner profile, in. (mm), (see **Table 1**), and
- K_1 = factor determined from ungrouted arc (for value, see the manufacturer) (see **Note X1.3**).

NOTE X1.3—The value of K_1 is determined by the iterative solution of the equation: $\sin K_1 \phi \cos \phi = K_1 \sin \phi \cos K_1 \phi$; where 2ϕ = ungrouted arc.⁴

X1.2.3 *Fully Deteriorated Design Condition*—The spiral wound liner pipe is designed to support hydraulic, soil and live loads without collapsing using the following design procedures for

X1.2.3.1 *Liner Pipe Expanded Against Existing Pipe (With or Without Grouting)*:

$$q_t = \frac{C}{N} [32R_w B' E'_s (E_L I / D^3)]^{1/2} \quad (\text{X1.4})$$

where:

- q_t = total external pressure on pipe, psi (MPa) = $0.433 H_w + wHR_w/144 + W_L$ (inch-pound units) = $0.00981 H_w + wHR_w/1000 + W_L$ (SI units),
- R_w = water buoyancy factor (0.67 min) = $1 - 0.33 (H_w/H)$,
- H_w = height of water above top of liner pipe, ft (m),
- H = height of soil above top of liner pipe, ft (m),
- w = soil density, lb/ft³ (KN/m³),
- W_L = live load, psi (MPa),
- B' = coefficient of elastic support

$$= 1/(1+4e^{-0.065H}), \text{ (inch-pound units)}$$

$$= 1/(1+4e^{-0.213H}), \text{ (SI units),}$$

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

N = factor of safety (2.0 is recommended),

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

E_L = modulus of elasticity of spiral wound liner pipe, psi (MPa), reduced to account for long-term effects (see **Note X1.1**),

I = moment of inertia of spiral wound liner pipe, in.⁴ /in. (mm⁴/mm) (see **Table 1**),

$E_L I$ = stiffness factor of spiral wound liner pipe, in.³ · lbf/in.² (MPa · mm³), and

D = mean diameter of spiral wound liner pipe, in. (mm) (see **X1.2.1**).

NOTE X1.4—For definition of modulus of soil reaction, see UNI-B-5-89.

Rearrange Eq X1.4 and solve for spiral wound liner pipe stiffness factor, $E_L I$, required:

$$E_L I = \frac{(q_t N / C)^2 D^3}{32R_w B' E'_s} \quad (\text{X1.5})$$

(see **Note X1.2**).

X1.2.3.2 *Spiral Wound Liner Pipe Installed as Fixed Diameter With Annular Space Grouted*—The rehabilitation of the existing pipeline by this installation practice results in a rigid composite structure (spiral wound liner pipe/grout/existing pipe). The composite structure should have strength at least equal to that required to sustain the loads, with a factor of safety, specified by the applicable project specifications. The contractor and product supplier should provide details and test data to the owner's representative to prove to his satisfaction that this level of rehabilitation will be accomplished by the design and installation of the composite structure.

X1.2.3.3 The minimum spiral wound liner pipe design stiffness factor, $E_L I$, for a fully deteriorated condition should also meet the requirements of **Eq X1.1** or **Eq X1.2**, as applicable.

X1.2.4 *Grout Pressure*—Where an annular space between the spiral wound liner pipe and the existing pipe is not grouted in stages and the spiral wound liner pipe is not filled with water under pressure or strutted, maximum grouting pressure should be limited to the grout pressure given in **Eq X1.6**

$$P_{cr} = \frac{24EI}{(1 - \nu^2) D^3} \cdot \frac{C}{N} \quad (\text{X1.6})$$

where:

- P_{cr} = critical buckling pressure, psi (MPa),
- N = factor of safety (2.0 is recommended),
- I = moment of inertia of spiral wound liner pipe in.⁴ /in. (mm⁴/mm) (see **Table 1**),
- E = initial modulus of elasticity, of spiral wound liner pipe, psi (MPa),
- EI = stiffness factor of spiral wound liner pipe, in.³ · lbf/in.² (MPa · mm³),
- D = mean diameter of spiral wound liner pipe, in. (mm),
- ν = Poissons ration (0.38 average), and
- C = ovality reduction factor (see **X1.2.1**).

⁴ Reference Timoshenko and Gere, *Theory of Elastic Stability*, p. 300, Eq (h).

X1.3 *Non-Circular Pipe*—arched, oval, or rectangular shaped pipes or a combination thereof.

X1.3.1 The design of the spiral wound liner pipe for non-circular shaped pipes is complex and specific to each situation. The manufacturer shall be consulted for design

recommendations for the rehabilitation of non-circular pipes. In larger sizes of non-circular pipes, a reinforcing framework for the steel reinforced profile strip liner may have to be temporarily installed to support the live grout load.

SUMMARY OF CHANGES

Committee F17 has identified the location of selected changes to this standard since the last issue (F1741–07) that may impact the use of this standard.

(1) Revision of wording in 1.1.2.

(2) **Table 2**: changes to values for Depth to Neutral Axis and Profile Area values to correct conversion errors.

(3) Revision of wording in 6.5.4.

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org). Permission rights to photocopy the standard may also be secured from the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, Tel: (978) 646-2600; <http://www.copyright.com/>