Designation: F 1947 – 04

An American National Standard

Standard Practice for Installation of Folded Poly (Vinyl Chloride) (PVC) Pipe into Existing Sewers and Conduits[1]

This standard is issued under the fixed designation F 1947; 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 (4 to 15 in. diameter) by the insertion of a folded PVC pipe, which is heated, pressurized, and expanded against the interior surface of an existing pipe with either a mechanical rounding device or steam pressure. The finished PVC pipe will be continuous and conform to the existing conduit. This rehabilitation process can be used in a variety of gravity applications, such as sanitary sewers, storm sewers, and process piping.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

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.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

D 1600 Terminology for Abbreviated Terms Relating to Plastics

D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D 2122 Test Method of Determining Dimensions of Thermoplastic Pipe and Fittings

F 412 Terminology Relating to Plastic Piping Systems

F 1417 Test Method for Installation Acceptance of Plastic Gravity Sewer Lines Using Low-Pressure Air

F 1504 Specification for Folded Poly(Vinyl Chloride) (PVC) Pipe for Existing Sewer and Conduit Rehabilitation

2.2 *NASSCO Standard:*

Recommended Specifications for Sewer Collection System Rehabilitation[3]

3. Terminology

3.1 *Definitions*— Terminology used in this practice is in conformance with Terminology F 412 and abbreviations used in this practice are in accordance with Terminology D 1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *containment tube*, *n*—an optional elastomeric material placed between the folded pipe and the existing pipe to protect the folded pipe during insertion, for containment of steam during the installation process, and to provide a waterproof barrier against infiltration, inflow, and standing water. This tube remains within the pipe but provides no structural support.

3.2.2 *dimples (dimpling)*, *n*—Where a side connection meets the existing pipe, there is not existing pipe support for the PVC pipe during expansion causing a point of thermoplastic pipe expansion slightly beyond the existing pipe wall. This formation of an external departure from the formed pipe wall is termed dimpling.

3.2.3 *folded pipe*, *n*—PVC pipe that has been manufactured in a folded shape for use in existing pipeline rehabilitation (see Fig. 1).

3.2.4 *formed pipe*, *n*—folded pipe that has been inserted into an existing sewer or conduit and expanded with heat, pressure, and, if applicable, a rounding device to conform to and take the shape of the existing pipe (see Fig. 1).

3.2.5 *insertion point*, *n*—an existing manhole, existing access shaft, or an excavated pit that serves as the point of entrance for the folded pipe into the existing pipe.

3.2.6 *rounded field sample*, *n*—a rounded field sample is formed when the folded pipe has been inserted into a mold pipe and expanded with heat and pressure to conform to the mold pipe.

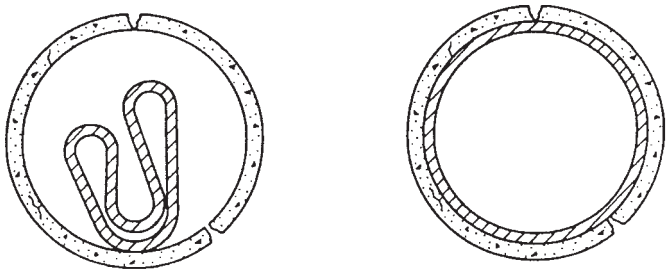
3.2.7 *rounding device*, *n*—a flexible, bullet-shaped device, which may be used to unfold and expand the folded pipe tightly against the wall of the existing pipe.

[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 April 1, 2004. Published April 2004. Originally approved in 1998. Last previous edition approved in 1998 as F 1947 – 98.

[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 NASSCO, 140 Circle Drive, Suite 103, Maitland, FL 32751.



NOTE—This figure is intended only for clarification of terms specific to this practice and shows a representative folded pipe shape. Other folded pipe shapes may meet the requirements of this practice.

FIG. 1 Folded Pipe and Formed Pipe, Clarification of Terms

3.2.8 *termination point, n*—an existing manhole, existing access shaft, or an excavated pit that serves as the point of exit of the folded 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.

5. Materials

5.1 The folded poly (vinyl chloride) (PVC) pipe shall be in accordance with Specification F 1504.

5.2 The folded pipe shall be spooled in a continuous length for storage and shipping to the job site. Handling and storing shall be in accordance with the manufacturer's published recommendations.

5.3 The optional containment tube should be an elastomeric material capable of containing the steam required to process the folded pipe and serve as a protective waterproofing barrier. The containment tube shall be compatible with the PVC compound, the folded pipe installation process, and the existing pipe so as not to effect the properties of the finished pipe.

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 shall be removed from the existing pipeline. The pipeline should be cleaned with hydraulically-powered equipment, high-velocity jet cleaners, or mechanically-powered equipment in accordance with NASSCO Recommended Specifications for Sewer Collection System Rehabilitation.

6.1.3 *Inspection of Pipelines*—Inspection of pipelines shall be performed by experienced personnel trained in locating breaks, obstacles, and service connections by closed circuit television. The interior of the pipeline shall be inspected carefully to determine the location of any conditions that may prevent proper installation of the folded 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 prior to installation.

6.1.4 *Line Obstructions*—The existing pipeline shall be clear of obstructions that will prevent the proper insertion and full expansion of the folded pipe such as offset joints of more than 12.5 % of inside pipe diameter, service connections that protrude into the pipe more than 12.5 % of the inside pipe diameter or 1 in. (25 mm), whichever is less; and, other reductions 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 shall be made to uncover and remove or repair the obstruction. Typically, bends along the pipe length in excess of 30° and changes in pipe size cannot be accommodated along an insertion length of the folded pipe. Such conditions require access at these points for termination and start of a new insertion.

NOTE 1—Some processes may accommodate larger obstructions. Consult the product manufacturer for applications which exceed these typical limitations.

6.2 *Bypassing*—If flow can not be interrupted for the necessary duration, bypassing of the flow is required around the sections of the existing pipe designated for rehabilitation. 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 shall be of adequate capacity and size to handle any extreme flows expected during the installation period. Services within the rehabilitation area will be out of service temporarily.

NOTE 2—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.

6.3 *Insertion*:

6.3.1 The spool of folded shall be positioned near the insertion point and contained in a heating chamber. A temperature, as recommended by the manufacturer, shall be maintained in the heating chamber for a minimum of 1 h to fully heat the length of folded pipe to be inserted. Shorter insertion lengths may be fully heated over a shorter time period as recommended by the manufacturer.

6.3.2 A containment tube then may be pulled through the existing conduit, secured at both ends, and inflated with air at low pressure.

NOTE 3—The containment tube allows for thorough and even heating of the folded pipe by providing a barrier between the folded pipe and infiltration or standing water in the existing pipeline.

6.3.3 A cable shall be strung through the existing conduit (and containment tube, if applicable) and attached to the folded pipe. The folded pipe shall be heated along the entire length and pulled, with a power winch unit and the cable, directly from the spool, through the insertion point, through the containment tube (if utilized), and within the existing pipe into the terminating manhole. A dynamometer shall be provided on the winch or cable to monitor the pulling force. Pulling forces

shall be monitored so as not to exceed the axial strain limits of the folded pipe material as recommended by the manufacturer.

6.3.4 After insertion is complete, the winch cable shall be secured at the termination end, and the folded pipe shall be cut off at the insertion point and secured.

6.4 *Expansion*:

6.4.1 To check that adequate temperatures are being achieved prior to expansion, suitable monitors to gage temperature shall be placed at the insertion and termination ends.

6.4.2 Through the use of heat and pressure or heat, pressure, and a rounding device, the folded pipe shall be expanded fully. Expansion pressures shall be sufficient to unfold the PVC pipe, press it against the wall of the existing conduit, and form dimples at service connections.

NOTE 4—Folded pipe expansion pressures typically are in the range of 8 to 10 psi (55 to 69 kPa) but may vary based on field conditions.

6.4.3 If a rounding device is used, it should be propelled at a controlled rate within the folded pipe expanding the folded pipe in a sequential manner. The rounding device shall be flexible and inflated with continual pressure so that is pressurizes the formed pipe against the existing pipe wall while pushing water ahead of the expansion process. The expansion rate (or rounding device speed) shall not exceed 5 ft/s (1.52 m/s).

6.4.4 Once the rounding device has reached the termination point, the expansion pressure shall be maintained for a minimum period of 2 min to ensure the complete expansion of the pipe at local deformities and to allow for complete dimpling at side connections.

6.5 *Cool Down*—The formed pipe shall be cooled to a temperature below 100°F (38°C) before relieving the pressure required to hold the PVC pipe against the existing pipe wall.

NOTE 5—Shrinkage of the formed pipe during cool-down typically is minimal due to the friction provided where the formed pipe conforms to existing pipeline irregularities, such as offset joints.

6.6 After the formed pipe has cooled down, the terminating ends shall be trimmed to a minimum of 3 in. (76.2 mm) beyond the existing pipe as allowance for possible shrinkage during cooling to ground temperature.

6.7 *Service Connections*—After the formed pipe has been installed, and leakage tested, if applicable, the existing active service connections shall be reconnected. This should be done without excavation from the interior of the pipeline by means of a television camera and a remote control cutting device unless otherwise specified by the owner.

NOTE 6—In many cases, a good seal is provided where the formed pipe dimples at service connections; however, this practice should not be construed to provide a 100 % watertight seal at all service connections. If total elimination of infiltration and inflow 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.

7. Inspection and Acceptance

7.1 The installation may be inspected by closed-circuit television. The formed pipe shall be continuous over the entire length of the insertion and conform to the walls of the existing pipe evidenced by visible joint definition and mirroring of existing pipe irregularities. Variations from true line and grade may be inherent because of the conditions of the existing pipeline. No infiltration of groundwater through the formed pipe wall 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 a combination thereof, gravity pipes shall be tested for leakage. This test shall take place after the formed pipe has cooled down to ambient temperature. 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 methods shall be used.

7.2.1 An exfiltration test method involves plugging the formed 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 U.S. gal/in. of internal pipe diameter/mile/day, providing that all air has been bled from the line. The leakage quantity shall 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 shall not exceed 10 ft (3.0 m) of water of 4.3 psi (29.7 kPa) and the water level inside of the standpipe shall be 2 ft (0.6 m) higher than the top of the pipe or 2 ft (0.6 m) higher than the groundwater level, whichever is greater. The test shall be conducted for a minimum of 1 h.

7.2.2 An air test shall be conducted in accordance with Test Method F 1417.

7.3 *Field Sampling*—For each insertion length designated by the owner in the contract documents or purchase order, a rounded field sample shall be prepared at the insertion or termination point, or both, by installing the folded PVC pipe into a mold pipe. The mold pipe shall be of like diameter to the existing pipe and should be a minimum of one diameter in length. The following test procedures shall be followed after the sample is expanded and cooled-down as an integral part of the folded PVC installation process and removed from the mold pipe.

TABLE 1 Rounded Field Sample Dimensions

Nominal Outside Diameter (in)	Minimum Wall Thickness (in.)		
	DR 50	DR 41	DR 35
4.000	- - -	- - -	0.114
6.000	- - -	0.146	0.171
8.000	0.160	0.195	0.229
9.000	0.180	0.219	0.257
10.000	0.200	0.243	0.286
12.000	0.240	0.292	0.343
15.000	0.300	0.365	0.429

TABLE 2 Rounded Field Sample Physical Properties

Specification D 1784 PVC Compound Classification	Minimum Flexural Modules of Elasticity, psi (mPa)[A]
13223	280 000 (1931)
12334	320 000 (2206)
12344	360 000 (2482)

[A] Measured in accordance with 7.3.2.

7.3.1 *Dimensions*:

7.3.1.1 *Rounded Field Sample Diameter*—The average outside diameter of the rounded field sample shall meet the requirements given in Table 1 with a tolerance of –7.0 ± 5.0 % when tested in accordance with the applicable section of Test Method D 2122.

7.3.1.2 *Rounded Field Sample Wall Thickness*—The minimum wall thickness of the sample, when measured in accordance with the applicable sections of Test Method D 2122, shall not be less than the values specified in Table 1.

7.3.2 *Flexural Properties*—The flexural modulus of elasticity shall be measured in accordance with Test Method D 790, Test Method 3, Procedure A, and shall meet the requirements of Specification F 1504. Specimens shall be oriented on the testing machine with the interior surface of the rounded field samples against the loading supports.

NOTE 7—The evaluation of rounded field sample flexural properties is intended as an installation quality control test to verify that these properties were not negatively affected through installation processing of the PVC material. The minimum physical properties required in Table 2 are the same as required for the manufactured pipe in Specification F 1504.

8. Keywords

8.1 installation–underground; plastic pipe–thermoplastic; poly (vinyl chloride) PVC plastic pipe; rehabilitation

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 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 distortion not greater than 12.5 % of the nominal inside diameter.

X1.1.2 *fully deteriorated pipe*—the existing 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 rounded PVC 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.

X1.2 *Design:*

X1.2.1 *Partially Deteriorated Design Condition*—The formed PVC pipe is designed to support only the external hydraulic loads to groundwater (and internal vacuum) since the soil and surcharge loads can be supported by the existing pipe. The groundwater level shall be determined and the thickness of the formed PVC pipe should be sufficient to withstand this hydrostatic pressure without collapsing. The following equations may be used to determine the thickness required:

$$P = \frac{2KE_1}{(1\ v^2)} \bullet \frac{1}{(DR\ 1)^3} \bullet \frac{C}{N} \tag{X1.1}$$

where:

P = external pressure, psi (mPa),
DR = dimension ratio of PVC pipe (outside diameter/thickness),
C = ovality reduction factor =

$$\left[\left(1 \frac{q}{100}\right) / \left(1 + \frac{q}{100}\right)^2 \right]^3 \tag{X1.2}$$

where:

q = percentage ovality of original pipe =

$$100 \times (D - D_{min})/D \tag{X1.3}$$

or

$$100 \times (D_{max} - D)/D \tag{X1.4}$$

where:

D = 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 formed PVC pipe, psi (mPa), reduced to account for long-term effects (see Note X1.1),
K = enhancement factor of the should and existing pipe adjacent to the new pipe (a value of 7.0 is recommended where there is full support of the existing pipe),
v = 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 for E_L will be given for 50 years of continuous loading at the maximum ground or fluid temperature expected to be reached over the life of the structure.

Rearrange Eq X1.1 and solve for formed PVC pipe thickness, t:

$$t = \frac{D}{\left[\frac{2\ KE_LC}{PN\ (1\ v^2)}\right]^{1/3} + 1} \tag{X1.5}$$

X1.2.2 *Fully-Deteriorated Design Condition*—The formed PVC pipe is designed to support hydraulic, soil and live without collapsing using the following equation:

$$q_t = \frac{C}{N}\,[32R_wB'E'_s\,(E_LI/D^3)]^{1/2} \quad \text{(X1.6)}$$

where:

q_t = total external pressure on pipe, psi (mPa),
= 0.433 H_w = wHR_w/144 + Ws, English Units,
= 0.00981 H_w + wH_sR_w/1000 + Ws, metric units,
R_w = water buoyancy factor (0.67 min) = 1-0.33 (H_w/H)
H_w = height of water above top of pipe, ft (m),
H = height of soil above top of pipe, ft (m),
w = soil density, lb/ft^3 (kN/m^3),
Ws = live load, psi (mPa),
B' = coefficient of elastic support = $1/(1 + 4e^{-0.065H})$ English units, $(1/(1 + 4e^{-0.213H})$ metric units,
l = moment of inertia of PVC pipe, 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 (2.0 is recommended),
E'_s = modulus of soil reaction, psi (mPa) (see Note X1.2),
E_L = modulus of elasticity of formed PVC pipe, psi (mPa), reduced to account for long-term effects (see Note X1.1), and
D = mean inside diameter existing pipe, in. (mm).

NOTE X1.2—For definition of modulus of soil reaction, see Uni-Bell Standard UNI-B-5-89. Rearrange Eq X1.4 and solve for thickness, t:

$$t = 0.721D\,[\frac{(Nq_1/C)^2}{E_L R_w B'E_s}]^{1/3} \quad \text{(X1.7)}$$

X1.2.2.1 The minimum design thickness for a fully deteriorated condition also should meet the requirements of Eq X1.2.