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An American National Standard

Standard Practice for Rehabilitation of Existing Sewers and Conduits with Deformed Polyethylene (PE) Liner[1]

This standard is issued under the fixed designation F1606; 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 covers the requirements for the installation of deformed polyethylene (PE) liner for pipeline rehabilitation.

1.2 This practice describes a method by which the PE liner may be installed with little or no excavation.

1.3 This practice applies to the rehabilitation of 3 to 18- in. (76 to 457-mm) diameter pipe in terms of installation. The specifier determines what DR is used based on conditions of the specific application.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D638 Test Method for Tensile Properties of Plastics

D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

D1600 Terminology for Abbreviated Terms Relating to Plastics

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials

F412 Terminology Relating to Plastic Piping Systems

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

F1533 Specification for Deformed Polyethylene (PE) Liner

2.2 *NASSCO Standard:*

Recommended Specifications for Sewer Collection System Rehabilitation[3]

3. Terminology

3.1 *General*—Abbreviations used in this practice are in accordance with Terminology D1600, and definitions are in accordance with Terminology F412, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *deformed pipe*—HDPE or MDPE pipe manufactured in deformed shape with a reduced cross-sectional area that includes the most common u-geometric form for use in existing sewer and conduit rehabilitation. (See Fig. 1.)

3.2.2 *dimpling*—a localized deformation resulting from expansion, during rounding of a thermoplastic deformed PE pipe, into space where a side connector meets an existing conduit and where there is no support for the deformed PE pipe.

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

3.2.4 *liner*—PE reformed pipe fully functional as pipe within a rehabilitated pipe.

3.2.5 *manifolds*—set of the equipment required for heat and pressure processing of the deformed pipe.

3.2.6 *pipeline*— existing sewer to be rehabilitated.

3.2.7 *reformed pipe*—PE deformed pipe processed by heat and pressure after insertion into the pipeline and reformed to a fit conforming to the existing pipe (See Fig. 1.)

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

4. Significance and Use

4.1 This practice is to provide guidance for designers and specifiers, regulatory agencies, owners, and inspection organizations who are involved in the rehabilitation of conduits.

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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.

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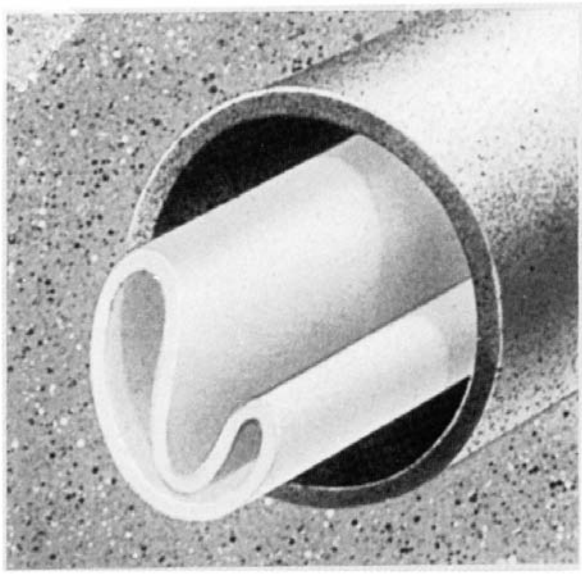
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] NASSCO, Inc. 2470 Longstone Lane, Suite M, Marriottsville, MD 21104. http://nassco.org/



(*a*) Deformed Pipe

(*b*) *Reformed Pipe*

NOTE 1—This figure is intended only for clarification of terms specific to this practice and shows representative deformed and reformed pipe shapes. Other deformed pipe shapes may meet the general requirements of this practice.

FIG. 1 Deformed Pipe and Reformed Pipe—Clarification of Terms

Modifications may be required depending on specific job conditions to establish a project specification. The manufacturer of the product should be consulted for design and installation information.

5. Materials

5.1 The deformed PE liner should be in accordance with Specification F1533.

5.2 The following are minimum cell classification numbers for HDPE polyethylene pipe based on Specification D3350. Specification D3350 should be consulted for property value limits based on these cells.

Type	PE 2406	PE 3408
Density	2	3
Melt	3	4
Flexural Modulus	4	5
Tensile Strength	3	4
ESCR	3	3
HDB	3	4
Color and UV Stabilizer	C, D, or E	C, D, or E

5.3 The deformed pipe should be spooled 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.

5.4 There should be no evidence of splits, cracks, crazing or breaks in the deformed pipe on the spool. If any of these conditions are evident, the damaged material should be replaced.

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 shall 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 for Sewer Collection System Rehabilitation.

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. The interior of the pipeline should be carefully inspected to determine the location of any conditions that may prevent proper insertion of the deformed pipe, such as protruding service taps, collapsed or crushed pipe, out-of-roundness, significant line sags, and deflected joints. All such conditions should be noted in the plans so that they can be corrected prior to liner installation. If a user desires to ignore any of the obstacles with PE liner pipe, the contractor should inform the user about expected results.

6.1.4 *Line Obstructions*—The inside of the existing pipeline should be clear of obstructions that will prevent the proper insertion and full expansion of the deformed pipe. Obstructions could include dropped or 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 diameter or 1-in. (25 mm), whichever is less; and other obstructions in cross-sectional area of more than 14 % based on the inside diameter of the existing pipe. If inspection reveals an obstruction that cannot be removed by cleaning or rodding, then a point repair excavation should 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. Such conditions require access at these points for termination and start of a new insertion.

6.2 *Bypassing*—If flow cannot be interrupted for the necessary duration, bypassing of flow is required around the sections of the existing pipeline designated for rehabilitation. The bypass should be made by plugging the line at the point upstream of the pipe to be reconstructed and bypassing the flow to a downstream point or adjacent system. The bypass lines, pump, and pump-sump pit dimensions, if required, should be of adequate capacity and size to handle the flow during the installation period. Services within this work area will be temporarily out of service.

NOTE 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 main line is back in service.

6.3 *Insertion:*

6.3.1 The spool of deformed pipe should be positioned near the insertion point. A cable should be strung through the existing conduit and attached to the deformed pipe. The deformed pipe should be pulled (with a power winch and the cable) directly through the insertion point to the termination point. Pulling forces should be limited so as not to exceed the axial strain limits of the deformed pipe. The measured pulling operation limits pulling force to allowable tensile stress (1500 psi or 50 % of the yield) times the pipe wall cross sectional area.

6.3.2 After the insertion is complete, the tension from the winch should be relieved and the deformed pipe should be cutoff at the insertion point and restrained at the termination point. Allowances for pipe length normalization should be made to attain correct length.

6.4 *Reforming:*

6.4.1 Temperatures and pressures should be monitored and recorded throughout the installation process to ensure that each phase of the process is achieved at the required levels. Temperature gages should be placed near the upstream and downstream manholes to measure the liner's outside temperature.

6.4.2 Steam and air pressure are applied through the inlet manifold and the deformed pipe should be reformed to conform to the existing pipe wall. The deformed pipe shall be pressurized up to 14.5 psig (100 kPa) max, at a steam temperature in excess of 235°F (112.8°C), and less than 260°F (126.7°C), while the termination point valves, located at the outlet manifold, are kept open to provide heat flow. The minimum temperature needed at the outside of the HDPE pipe should be 185 ± 9°F (85 ± 5°C). The pressure should then be increased in increments up to a maximum of 26 psig (179.4 kPa). Maximum pressure may be lower, depending on DR and condition of the pipeline.

6.4.3 The reforming pressure should be maintained to ensure complete expansion of the pipe and to allow for dimpling at side connections.

6.5 *Cool Down*—The reformed pipe should be cooled to a temperature of 100°F (38°C). The pressure should then be slowly increased to approximately 33 psig (227.7 kPa), while applying air or water for continued cooling. The equipment should be disconnected after ambient temperature is attained.

6.6 After the reformed pipe has cooled down, the terminating ends should be trimmed to a minimum of 3 in. (76.2 mm) beyond the existing pipe to account for possible shrinkage during cooling to ground temperatures.

6.7 *Service Connections*—After the liner has been reformed and stabilized, the existing active service connections should 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 2—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.

6.8 The numeric information given for the processing of the liner are the standard practical information. Where the specific cases require, such as long pipelines, unusually difficult conditions, extremely fragile pipelines and unique jobs, the processing parameters may vary. The final outcome of the processing should comply with this practice. The design engineer should determine the applicable processing parameters in accordance with the manufacturer's specific specifications and instructions.

7. Inspection and Acceptance

7.1 The installation may be inspected by closed-circuit television. The reformed pipe should be continuous over the entire length of the insertion and conform to the walls of the existing pipe evidenced by visible joint deformation and mirroring of existing pipe irregularities. Variations from true line and grade may be inherent because of the conditions of the original piping. No infiltration of groundwater through the reformed wall should be observed. All service entrances should be accounted for and 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 should take place after the reformed pipe has cooled down to ambient temperature. This test is limited to pipe lengths with no service laterals. One of the following two methods should be used:

7.2.1 *Exfiltration Test Method*—This test involves plugging the reformed 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/in. of internal pipe diameter per mile per day, providing that all air has been bled from the line. The leakage quantity should be gauged 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). 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 groundwater level, whichever is greater. The test should be conducted for a minimum of 1 h.

7.2.2 *Air Test*—This test should be conducted in accordance with Test Method F1417.

NOTE 3—The leakage test is intended to evaluate the watertightness of the mainline only.

7.3 For each insertion length designated by the owner in the contract documents or purchase order, a reformed field sample should be prepared at the insertion or termination point, or both. The mold pipe shall be of like diameter to the existing pipe. The sample may be taken from one reformed pipe diameter length removable sleeve. The following test procedures should be followed after the sample is expanded, cooled-down and removed from the mold pipe.

7.3.1 *Dimensions:*

7.3.1.1 *Reformed Pipe Diameter*—The average outside diameter of the reformed pipe shall meet the requirements given in Table 1 with a tolerance of ±1.0 % when tested in accordance with applicable section of Test Method D2122.

7.3.1.2 *Installed Pipe Wall Thickness*— The minimum wall thickness of the reformed pipe, when measured in accordance with Test Method D2122, shall not be less than the value specified in Table 1.

7.3.2 *Flexural Properties*—The tangent flexural modulus of elasticity should be measured in accordance with Test Method D790, (that is, compression molded samples) and should meet the pipe manufacturer's plant flexural test property.

7.3.3 *Tensile Properties*—The tensile strength should be measured in accordance with Test Method D638, (that is, compression molded or pipe wall samples) and should meet the pipe manufacturer's plant tensile test property.

7.3.4 *Special Sizes*—Where existing system conditions or special local requirements make other diameters or dimensions necessary, other sizes, or dimension ratios, or both, shall be acceptable for engineered applications, when mutually agreed upon by the customer and the manufacturer, if the deformed liner is manufactured from plastic compounds meeting the material requirements of this specification, and the strength and design requirements are calculated on the same basis as those used in the specification. For diameters not shown in Table 1, the tolerance shall be the same percentage as used for diameters shown in Table 1. Minimum wall thickness shall be calculated by dividing the minimum diameter by the dimension ratio.

TABLE 1 Dimensions and Tolerances[A,B]

Outside Diameter, in.	Outside Diameter Tolerances, in.	Minimum Wall Thickness, in.			
		DR17	DR24	DR26	DR32.5
3.00	+.00–.015	0.176	0.124	0.115	—
4.00	+.00–.015	0.234	0.166	0.153	—
6.00	+.00–.015	0.352	0.249	0.230	0.184
8.00	+.00–.020	0.469	0.332	0.306	0.245
10.00	+.00–.020	0.587	0.416	0.384	0.307
12.00	+.00–.025	0.704	0.499	0.461	0.368
15.00	+.00–.050	0.879	0.623	0.575	0.460
18.00	+.00–.060	1.055	0.748	0.690	0.552
SI Units, mm					
76	+.00–.381	4.47	3.15	2.92	—
102	+.00–.381	5.94	4.22	3.89	—
152	+.00–.381	8.94	6.32	5.84	4.67
203	+.00–.508	11.91	8.43	7.77	6.22
254	+.00–.508	14.91	10.57	9.75	7.80
305	+.00–.635	17.88	12.67	11.71	9.35
381	+.00–1.270	22.33	15.82	14.60	11.68
457	+.00–1.524	26.80	19.00	17.53	14.02

[A] The listed outside diameter tolerances are provided for manufactured liner pipe.
[B] The reformed pipe permits variance of nominal outside diameter during installation of −0.4 to +3.4 % to match existing pipe inside diameter. The larger variance may increase the DR value. Existing inside pipe diameters outside this range will necessitate special sizes.

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 shall 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 and live loads or is expected to reach this condition over the design life of the rounded PE 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 reformed PE pipe is designed to support only the external hydraulic loads due to groundwater since the soil and surcharge loads can be supported by the existing pipe. The groundwater level should be determined by the owner and the thickness of the reformed PE pipe should be sufficient to withstand the hydrostatic loadings without collapsing. The following equations may be used to determine the critical collapse pressure, with benefit of a safety factor, N.

$$P = \frac{2E_L}{(1-\mu^2)} \cdot \frac{1}{(DR-1)^3} \cdot \frac{1}{N} \tag{X1.1}$$

where:

P = groundwater pressure, psi (MPa),
DR = dimension ratio for PE pipe (outside diameter/thickness),
N = factor of safety (2.0 is recommended),
E_L = apparent modulus of elasticity of reformed PE pipe, psi (MPa), accounting for long-term loading effects (See Note X1.3), and

μ = Poisson's ratio (0.45).

NOTE X1.1—Equation Eq X1.1 is a mathematical modification of the traditional Timoshenko formula. This relationship assumes host pipe not to be fully deteriorated and the remaining pipe provides support for liner placement. It is assumed that the existing voids or holes in the host pipe wall are not critical enough for point repair or replacement but provide no buckling constraint.

$$P = \frac{2K E_L}{(1-\mu^2)} \cdot \frac{1}{(DR-1)^3} \cdot \frac{C}{N} \quad (X1.2)$$

where:

K = support factor of the soil and host pipe adjacent to the liner pipe as provided from long term testing by the manufacturer.

C = ovality reduction factor = $[(1 - q/100) \div (1 + q/100)^2]^3$

q = percentage ovality of original pipe =

$$100 \times \frac{(Mean\ Diameter - Minimum\ Inside\ Diameter)}{Mean\ Inside\ Diameter} \quad (X1.3)$$

or

$$100 \times \frac{(Maximum\ Inside\ Diameter - Mean\ Inside\ Diameter)}{Mean\ Inside\ Diameter} \quad (X1.4)$$

NOTE X1.2—Equation Eq X1.2 developed by applying the traditional Timoshenko buckling equation to external groundwater pressure testing data on reformed PE pipe manufactured in accordance with this practice. Constraints in the equation may vary for differing materials, host pipe condition or installation techniques, or both.

NOTE X1.3— 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 appropriate 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.

X1.2.2 *Fully Deteriorated Design Condition*—The reformed PE pipe is designed to support hydraulic, soil and live loads. The groundwater level, soil type and depth, and surface live loads should be determined by the owner. The following equation may be used to calculate the total allowable external pressure resistance on the pipe. Rearranging the equation and inserting $t^3/12 = I$, the wall thickness required can be determined from assumed external pressure loadings.

$$q_t = \frac{C}{N}\left[32R_w B' E'_s \left(E_L I / D^3\right)\right]^{1/2} \quad (X1.5)$$

where:

q_t = total external pressure on pipe, psi (MPa),

R_w = water buoyancy factor (0.67 minimum) = 1 − 0.33 (Hw/H),

Hw = height of water above top of pipe, 4 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,

B' = $(1/(1 + 4e^{-0.213H})$ SI units (at the soil parameter),

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

t = thickness of PE, 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),[4]

E_L = modulus of elasticity of rounded PE pipe, psi, (MPa), reduced to account for long-term effects, and

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

[4] For a definition of "modulus of soil reaction," see *Handbook of PVC Pipe*, available from Uni-Bell Plastic Pipe Association.