

**Table 31 (cont.). Listing of Manufacturers and Contractors of Cured-in-place Lining Installed by Inversion.**

Manufacturer/ Contractor	Telephone Number	Fax Number	Address	Coverage Area	Contact Person
Griner's Pipeline Services, Inc.	(352) 383-1222	(352) 383-6607	21902 State Rd. 46 Mount Dora, FL 32757	FL, GA	N/A <sup>2</sup>
The Groce Company, Inc.	(713) 941-2525	(713) 645-5900	P.O. Box 34605 Houston, TX 77234	TX	David Groce
Hall Albert	(817) 624-9391	(817) 625-2941	201 N.E. 29th St. Fort Worth, TX 76106	TX	Phillip Stephenson
Hytek Pipe Restoration	(800) 886-8434	N/A	3755 Avocado Blvd., Suite 202 La Mesa, CA 91941	CA	N/A
Insight Pipe Contracting	(724) 452-6060	(724) 452-3226	344 Little Creek Rd. Harmony, PA 16037	Western PA	Mike Marburger
Insituform Technologies, Inc. <sup>1</sup>	(800) 234-2992	(636) 519-8010	702 Spirit 40 Park Dr. Chesterfield, MO 63005	National	N/A
Jim Dandy Sewer Services, Inc	(206) 633-1141	(206) 784-2095	1327 N. Northlake Way Seattle, WA 98103	WA	Doug Harris
Kottke Underground Technologies, Inc.	(888) 664-4233	(541) 664-5417	P.O. Box 937 Medford, OR 97501	OR	N/A
McCann's Sewer and Drain Cleaning Service, Inc.	(608) 835-7797	(608) 835-2497	611 North Burr Oak Ave. Oregon, WI 53575	WI	Kelly McCann
Merlo, Inc.	(314) 581-7575	(314) 842-2216	33 Fox Meadows St. Louis, MO 63127	MO, IL	Steve Merlo
Mr. Rooter	(208) 772-3091	(208) 772-5187	P.O. Box 3364 Haden, ID 83835	WA, ID	Brian Wells
Naperville Plumbing, Inc.	(630) 355-1020	(630) 717-0171	455 Davey Rd. Lemont, IL 60439	IL	Mickey Mounts
National Envirotech Group, Inc. <sup>1</sup>	(800) 547-1235	(281) 874-0333	12707 N. Freeway, Suite 592 Houston, TX 77060	National	N/A
NO-DIG Pipeliners, LLC	(610) 384-9612	(610) 384-9615	P.O. Box 608 Downingtown, PA 19335	PA	Charlie Johnson
Northwest Plumbing Drain Station	(248) 615-1700	(248) 879-2942	1459 East 9 Mile Ferndale, MI 48220	MI	Joe Piscopo
Olthoff, Inc.	(708) 758-6540	(708) 758-1087	1800 East Joe Orr Chicago Heights, IL 60411	IL, IN	Dale Olthoff
Performance Liner National Sales	(407) 898-1091	(407) 898-1092	P.O. Box 547797 Orlando, FL 32854	National	Walter Huber
Performance Pipelining, Inc. <sup>1</sup>	(815) 433-1275	(815) 433-0107	1779 Chessie Lane Ottawa, IL 61350	National	N/A
Perma-Liner Industries, Inc. <sup>1</sup>	(727) 507-9749	(727) 507-9849	6196 126th Ave. North Largo, FL 33773	National	Jerry D'Hulster
Perma-Liner Mid Atlantic	(301) 353-1100	(301) 528-2809	26946 Ridge Rd. Damascus, MD 20872	MD	Jerry Shields
Pipelining Products, Inc. <i>New York Office</i>	(718) 747-9000	(718) 747-1186	151-45 6th Rd. Whitestone, NY 11357	NY	N/A
Pipelining Products, Inc. <i>North Carolina Office</i>	(919) 319-9696	(919) 319-0046	251 West Chatham St. Cary, NC 27511	NC	N/A
Pipeline Rehabilitation Services	(888) 588-8943	N/A	34145 Pacific Coast Hwy, Suite #351 Dana Point, CA 92629	CA	Steve Poirier
Plumber-Rooter	(800) 525-6295	(203) 857-4881	P.O. Box 546 Norwalk, CT 06852	CT, NY	Greg Cooper
Plummer's Environmental Services, Inc.	(616) 452-1313	(616) 452-1293	1518 Steele Ave., Southwest Grand Rapids, MI 49507	MI	Tom Gilder

<sup>1</sup>Designates company headquarters, <sup>2</sup>N/A – not available

**Table 31 (cont.). Listing of Manufacturers and Contractors of Cured-in-place Lining Installed by Inversion.**

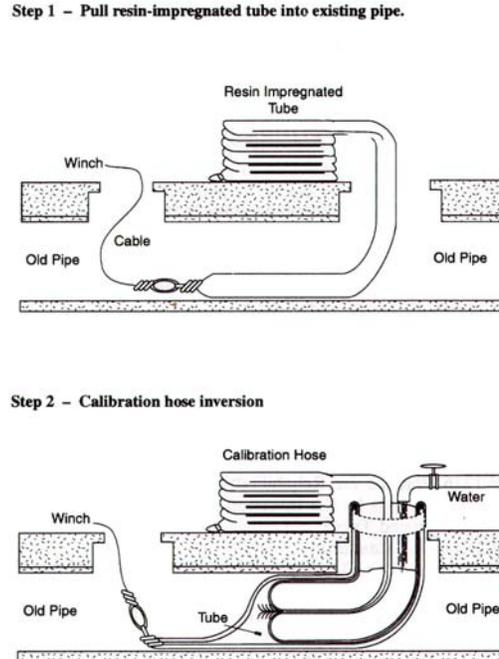
Manufacturer/ Contractor	Telephone Number	Fax Number	Address	Coverage Area	Contact Person
Retro-Line Technologies	(321) 228-2246	(321) 228-2246	4850 South U.S. Hwy. 1 Grant, FL 32949	FL	Craig McEwen
Richards & Sons Plumbing	(916) 933-4199	N/A <sup>2</sup>	P.O. Box 5045 El Dorado Hills, CA 95762	CA	Ed Richards
Rinker Materials Pipeline Renewal	(800) 939-1277	(614) 529-6441	4143 Weaver Court Hilliard, OH 43026	Southern IL, IN, KY, MI, OH	N/A
Roche Plumbing & Heat- ing, Inc.	(970) 870-7922	(970) 870-6001	16 East Logan St. Steamboat Springs, CO 80477	CO	Ken Roche
Roy's Plumbing, Inc.	(716) 873-5000	(716) 877-7752	140 Cooper Ave. Tonawanda, NY 14150	NY	Mike Doendorf
Sancon Engineering	(800) 726-2664	(714) 891-2524	5841 Engineering Dr. Huntington Beach, CA 92649	CA	Chuck Parsons
SewerTV	(714) 871-1414	(714) 871-1418	2316 East Amerige Fullerton, CA 92831	CA	Dave Flynn
Site Lines, Inc.	(517) 552-1367	(517) 552-1368	2681 Golf Club Dr. Howell, MI 48843	MI	Todd Summers
South Baldwin Plumbing	(334) 947-6246	(850) 478-4507	23790 US Hwy. 90 Robertsdale, AL 36567	AL, MS, FL	N/A
Southeast Pipe Survey	(912) 647-2847	(912) 647-2869	3523 Williams St. Patterson, GA 31557	AL, FL, GA, NC, SC, TN	N/A
Southern Utilities, Inc.	(941) 574-2743	(941) 772-3045	2525 Southeast 19th Place Cape Coral, FL 33904	FL	Mike Angel
Southwest Pipeline	(888) 570-3534	N/A	225 W. Third St., Suite E. Long Beach, CA 90802	HI	N/A
Southwestern Packing & Seals	(800) 843-4950	(318) 687-4337	P.O. Box 19369 Shreveport, LA 71129	LA, TX	David Neathery
Spray Com, Inc.	(660) 826-0274	N/A	1620 West 14th St. Sedalia, MO 65301	MO	Gary Bartley
Stewart's De Rooting	(805) 965-8813	(805) 963-3095	208 Palm Ave. Santa Barbara, CA 93101	CA	Skip Stewart
Suncoast Infrastructure, Inc.	(901) 385-3863	(901) 266-0655	6376 Daybreak Dr. Bartlet, TN 38135	MS, LA, AR, FL, Southern AL	David Peaks
T-C, Inc.	(317) 542-9291	(317) 542-0352	973 N. Shadeland Av. #166 Indianapolis, IN 46219	IN, KY	Dennis Denney
Technical Inspections, Inc.	(954) 563-4233	(954) 563-5598	1098 Northeast 35th St. Oakland Park, FL 33334	FL	Pat Dean
Trenchless Rehabilitation Services	(610) 431-5973	(610) 431-5974	P.O. Box 836 West Chester, PA 19380	PA	Lou Anzalone
Tri-State Grouting	(302) 286-0701	(302) 286-0704	567 Walther Rd. Newark, DE 197024	DE, MD	Mark Schneider
Visu-Sewer	(800) 876-8478	(262) 695-2359	W230 N4855 Betker Rd. Pewaukee, WI 53072	Northern IL, IA, SD, ND, WI, MN	N/A
Walden Associated Tech- nologies, Inc.	(800) 495-6036	(618) 397-0098	7895 Saint Clair Ave. East St. Louis, IL 62203	IL, MO	Ken Walden
Wastewater Services, Inc.	(318) 335-4904	(318) 335-0157	P.O. Drawer 957 Oakdale, LA 71463	LA	N/A
W.L. Hailey & Co. Inc.	(615) 255-3161 Ext. 144	(615) 256-1316	P.O. Box 40646, 2971 Kraft Dr. Nashville, TN 37204	TN, KY, Northern AL, GA, MS	Randy Hous- ton
Young & Sons Enterprises	(801) 282-1806	(801) 280-7369	5276 West Legacy Hill Dr. West Jordan, UT 84084	UT	Jon Young
ZZ Liner, Inc.	(310) 329-8717	N/A	539 W. 140th St. Gardena, CA 90248	CA	N/A

<sup>1</sup>Designates company headquarters, <sup>2</sup>N/A – not available

## Pulled-in-place Installation Method for Cured-in-place Lining

### *Description*

Pulled-in-place installation method for cured-in-place lining uses a winch to pull a resin-impregnated tube through a deteriorated culvert. A calibration hose is then inserted into the center of the installed tube. Both the calibration hose and the resin-impregnated tube are attached to the vertical standpipe, or other apparatus, to create a leak-proof seal. Hydrostatic water pressure, or pressurized air/steam, is applied into the vertical standpipe, or apparatus, which forces the calibration hose to invert the resin-impregnated tube. As the liner is inverted, the resin allows it to attach and conform to the existing culvert walls. Once installed, the thermosetting resin is cured through heat provided by circulating hot water or steam. Figure 20 presents the pulled-in-place installation method.



**Figure 20. Drawing. Pulled-in-place Installation Method for Cured-in-place Lining.**<sup>(82)</sup>

### *Effective Uses, Advantages, and Limitations*

General characteristics and effective uses of the pulled-in-place installation method for cured-in-place lining are presented in Table 32. Advantages and limitations associated with the pulled-in-place installation method for cured-in-place lining are presented in Table 33.

**Table 32. General Characteristics and Effective Uses of the Pulled-in-place Installation Method for Cured-in-place Lining.<sup>(5,6)</sup>**

Applications	Diameter Range	Liner Material	Maximum Installation
Gravity & Pressure Pipelines	100 - 1,400 millimeters (4 - 55 inches)	Thermoset Resin/ Fabric Composite	150 meters (492 feet)

**Table 33. Advantages and Limitations of the Pulled-in-place Installation Method for Cured-in-place Lining.<sup>(5,6,7)</sup>**

Advantages	Limitations
No joints	Flow bypass is required
Grouting is not normally required	Requires trained personnel to operate special equipment
Minimal or no reduction in flow capacity	Tubing must be specially constructed for each project
Minor or no excavation required	Lateral connections, service connections, and termination ends may require watertight sealing
Non-circular shapes can be accommodated	Resin requires a long time period to cure
	Liner lengths are limited by pull-in forces
	Styrene monomer-based resins used in making the liner are potentially toxic prior to completion of the curing process

**Costs**

According to the USFS Draft Report on trenchless technology for Forest Service culverts,<sup>(9)</sup> the range of costs for pulled-in-place installation method for cured-in-place lining is approximated to be \$100 per linear foot for 45.7-centimeter (18-inch) diameter pipes and approximately \$800 per linear foot or more for the largest diameters.

**General Installation Guidelines**

Installation guidelines for the pulled-in-place installation method for cured-in-place lining are presented below:<sup>(14,82)</sup>

1. Prior to entering access areas and performing inspection or cleaning operations, test the atmosphere in the insertion pits to determine the presence of toxic or flammable vapors, or the lack of oxygen in accordance with local, State, or Federal safety regulations.
2. Thoroughly clean the existing culvert. Gravity culverts should be cleaned with hydraulically powered equipment (high-velocity jet cleaners).

3. Inspect the existing culvert to determine the location of any conditions that may hinder proper insertion of the Cured-in-place lining, such as protrusions, collapsed sections, deflected joints, etc.
4. Clear line obstructions discovered during the inspection before inserting the liner. Generally, most bend angles and changes in existing culvert diameter can be accommodated. If obstructions cannot be cleared, point repair excavation should be used to remove and repair the obstruction.
5. Completely impregnate the fabric tube with resin and run through a set of rollers separated by a space to properly distribute the resin. Apply a resin volume sufficient to fill all voids in the tube material and fully saturate all resin absorbing materials. Add 3% to 15% excess resin to the estimated volume to account for changes in resin volume due to polymerization and migration of resin into cracks and joints in the deteriorated culvert. Lubricate the calibration hose prior to installation. This can be achieved by applying lubricant to the fluid in the standpipe or by applying lubricant directly to the calibration hose.
6. Bypassing of flow is required, unless flow can be shut off during installation.
7. If the resin-impregnated tube is to be inverted utilizing air/steam pressure, perforate the impermeable plastic coating of the resin-impregnated fabric. Perforating will allow resin to be forced against the inner wall of the calibration hose, permanently becoming part of the fabric tube.
8. Utilizing a power winch, pull the resin-impregnated tube through the deteriorated culvert.
9. If inverting the resin-impregnated tube with hydrostatic head, insert the calibration hose with the impermeable plastic membrane side out into the center of the resin-impregnated tube. At the lower end of the standpipe, turn the calibration hose inside out and attach both the calibration hose and the resin-impregnated tube to the standpipe, or other apparatus so that a watertight seal is created. Fill the standpipe with water, creating a sufficient head to cause the calibration hose to invert throughout the pipe, forcing the resin-impregnated tube to bond to the existing culvert.
10. If inverting the resin-impregnated tube with air/steam pressure, insert the calibration hose through the guide chute with the impermeable plastic membranes side out into the center of the resin-impregnated tube. Attach the calibration hose and resin-impregnated tube to the upper end of the chute so that a leak-proof seal is created. Obtain the minimum air/steam pressure needed to hold the tube tight against the existing culvert and the maximum allowable pressure from the manufacturer. Apply the appropriate air/steam pressure to cause the calibration hose to invert throughout the pipe, forcing the resin-impregnated tube to bond to the existing culvert.
11. After inversion is completed, circulate hot water or steam throughout the liner with approved equipment. Equipment should be suited with temperature gages and be capable of circulating the hot water or steam uniformly throughout the liner. The initial cure will occur during the heat-up process is completed when exposed portions of the liner appear to be hard and sound.

After initial cure, raise the temperature to the resin manufacturer’s recommended post-cure temperature. Hold this temperature for the recommended period of time by recirculating the water or steam throughout the liner and heating apparatus. Maintain the recommended pressures throughout the curing process.

12. If heated water was used to cure the resin, drain the heated water from a small hole made in the downstream end and replace with the introduction of cool water into the inversion standpipe. Cool the liner to a temperature below 37.7°C (100°F) before relieving the static head in the inversion standpipe.
13. If air/steam was used to cure the resin, drain the air/steam through a small hole made in the downstream end and replace with the introduction of cool water in the guide chute. Cool the liner to a temperature below 43.3°C (110°F) before relieving the pressure within the section.
14. Cut and seal the termination ends with a resin mixture compatible with the installed liner if the liner does not fit tightly against the original pipe.
15. Inspect the completed installation by closed-circuit TV or manually if the diameter permits man-entry. The liner should be continuous over the entire length.
16. If leakage or other testing is required, perform testing to specifications and prior to the re-opening of lateral and service connections.
17. Reconnect lateral and service connections with a television camera and a remote-control cutting device or manually where the diameter permits man-entry.
18. Finally, restore flow and initiate site cleanup.

**Standards/Specifications**

Table 34 presents the current standards and specifications associated with the pulled-in-place installation method for cured-in-place lining.

**Table 34. Standards Associated with the Pulled-in-place Installation Method for Cured-in-place Lining.** <sup>(14,23)</sup>

Standard/Specification	Description
ASTM D 5813 – Standard Specification for Cured-In-Place Thermosetting Resin Sewer Pipe (1995) <sup>(73)</sup>	Covers specification, evaluation, and testing of materials used in the rehabilitation of existing pipes by the installation and cure of a resin-impregnated fabric liner.
ASTM F 1743 – Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Pulled-In-Place Installation of Cured-in-Place Thermosetting Resin Pipe (1996) <sup>(82)</sup>	Describes the procedures for the reconnection of pipelines and conduits by the pulled-in-place installation of a resin-impregnated, flexible fabric tube into an existing conduit and secondarily inflated through the inversion of a calibration hose by the use of hydrostatic head or air pressure.
NASSCO Specification for Cured-in-place Pipe (CIPP) (as provided by Lanzo Lining Services for the Inliner® Pull-In-Place process) (1999) <sup>(14)</sup>	Describes the specifications, design considerations, materials, equipment, and installation of CIPP installed by the pull-in-place process.

In addition to the two (2) specific ASTM standards presented in Table 34, the following list of related standards were also associated with the pulled-in-place installation method for cured-in-place lining:

- ASTM D 543 – Test Method for Resistance of Plastics to Chemical Reagents<sup>(25)</sup>
- ASTM D 638 – Test Method for Tensile Properties of Plastics<sup>(49)</sup>
- ASTM D 695 – Test Method for Compressive Properties of Rigid Plastics(2001)<sup>(74)</sup>
- ASTM D 790 – Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials<sup>(26)</sup>
- ASTM D 883 – Terminology Relating to Plastics<sup>(70)</sup>
- ASTM D 903 – Test Method for Peel or Stripping Strength of Adhesive Bonds<sup>(75)</sup>
- ASTM D 1600 – Terminology for Abbreviated Terms Relating to Plastics<sup>(27)</sup>
- ASTM D 1682 – Test Methods for Breaking Load and Elongation of Textile Fabric<sup>(76)</sup>
- ASTM D 3039 – Test Method for Tensile Properties of Fiber-Resin Composites<sup>(77)</sup>
- ASTM D 3567 – Practice for Determining Dimensions of “Fiberglass” (Class-Fiber-Thermosetting Resin) Pipe and Fittings<sup>(78)</sup>
- ASTM D 3681 – Test Method for Chemical Resistance of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting Resin) Pipe in a Deflected Condition<sup>(79)</sup>
- ASTM D 4814 – Specification for Automotive Spark—Ignition Engine Fuel<sup>(81)</sup>
- ASTM F 412 – Terminology Relating to Plastic Piping Systems<sup>(31)</sup>
- ASTM F 1216 – Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube<sup>(72)</sup>

### ***Contractors and Manufacturers***

A listing of manufacturers and contractors of cured-in-place lining installed by the pulled-in-place method is presented in Table 35.

**Table 35. Listing of Manufacturers and Contractors of Cured-in-place Lining Installed by the Pulled-in-place Method.**

Manufacturer/ Contractor	Telephone Number	Fax Number	Address	Coverage Area	Contact Person
CAT Contracting, Inc. <sup>1</sup>	(281) 449-5218	(281) 449-5234	5000 Askins Lane Houston, TX 77093	National	Art Kidder
Eckard Brandes, Inc.	(808) 486-0016	(808) 486-0042	98-030 Hekaha St., Suite 22 Aiea, HI 96701	N/A <sup>2</sup>	Jeff Higbee
E.E. Cruz, Inc.	(732) 946-9700	(732) 946-7592	Cruz Plaza Holmdel, NJ 07733	NJ, CT	N/A
Gelco Services, Inc. <i>Oregon Office</i>	(888) 223-8017	(503) 391-8317	1705 Salem Industrial Dr. NE Salem, OR 97303	N/A	N/A
Gelco Services, Inc. <i>California Office</i>	(530) 406-1199	(530) 406-7991	1244 Wilson Way Woodland, CA 95695	N/A	N/A
Gelco Services, Inc. <i>Washington Office</i>	(888) 322-1199	(253) 876-9932	3411 C St. NE, Suite 16 Auburn, WA 98002	N/A	N/A
Ground & Pipe Technologies	(334) 388-5640	(344) 264-8980	1120 Parker St. P.O. Box 9204 Montgomery, AL 36108	N/A	N/A
InfraCorps Technologies, Inc.	(804) 272-6600	(804) 272-1110	7400 Beaufont Springs, Suite 415 Richmond, VA 23225	N/A	Richard Herrick
Inland Waters <i>Michigan Office</i>	(800) 992-9118	(313) 841-5270	2021 S. Schaefer Hwy. Detroit, MI 48217	N/A	N/A
Inland Waters <i>Ohio Office</i>	(800) 869-3949	(216) 861-3156	2195 Drydock Ave. Cleveland, OH 44113	N/A	N/A
Inliner Technologies <sup>1</sup>	(812) 723-0704	(812) 723-5998	1468 West Hospital Rd. Paoli, IN 47454	National	N/A
Kenny Construction Co.	(847) 541-8200	(847) 541-8838	250 Northgate Parkway Wheeling, IL 60090	IL	N/A
Lametti & Sons	(651) 426-1380	(651) 426-0044	16028 Forest Blvd. North Hugo, MN 55038	MN, NE, ND, SD, WI, IA	N/A
Lanzo Lining Services <i>Roseville, MI Office</i>	(810) 775-7566	(810) 775-2328	28135 Groesbeck Hwy. Roseville, MI 48066	N/A	N/A
Lanzo Lining Services <i>Detroit, MI Office</i>	(313) 965-8840	(313) 961-6769	65 Cadillac Tower, Suite 2200 Detroit, MI 48226	N/A	N/A
Lanzo Lining Services <i>Pompano Beach, FL Office</i>	(954) 979-0802	(954) 979-9897	1900 N.W. 44th St. Pompano Beach, FL 33064	N/A	N/A
Lanzo Lining Services <i>Miami, FL Office</i>	(305) 663-5559	(305) 663-9515	4659 Ponce De Leon Blvd., Ste. 301 Coral Gables, FL 33146	N/A	N/A
Masterliner Incorporated <sup>1</sup>	(888) 344-3733	(985) 386-0250	42305 South Airport Rd. Hammond, LA 70403	National	N/A
Pacific Rehab Construction	(907) 272-3000	(907) 272-3004	P.O. Box 230628 Anchorage, AK 99523	N/A	Ken Ihde
Reynolds Inliner, LLC	(812) 865-3232	(812) 865-3075	4520 N. State Rd. 37 Orleans, IN 47452	IN, FL, GA, KY, LA, TN, MS, NC SC, OH, TX, WV	N/A
S.O.S. Construction	(305) 477-6847	(305) 477-6745	2909 N.W. 82nd Ave. Miami, FL 33122	N/A	Ray Sanchez
Southeast Pipe Survey <sup>1</sup>	(912) 647-2847	(912) 647-2869	3523 Williams St. Patterson, GA 31557	AL, FL, GA, NC, SC, TN	N/A
Western Slope Utilities	(970) 453-6176	(970) 453-4044	P.O. Box 2098 68 Continental Ct. Suite B-8 Breckenridge, CO 80424	AZ, CO, NM, UT, WY	N/A

<sup>1</sup>Designates company headquarters, <sup>2</sup>N/A – not available

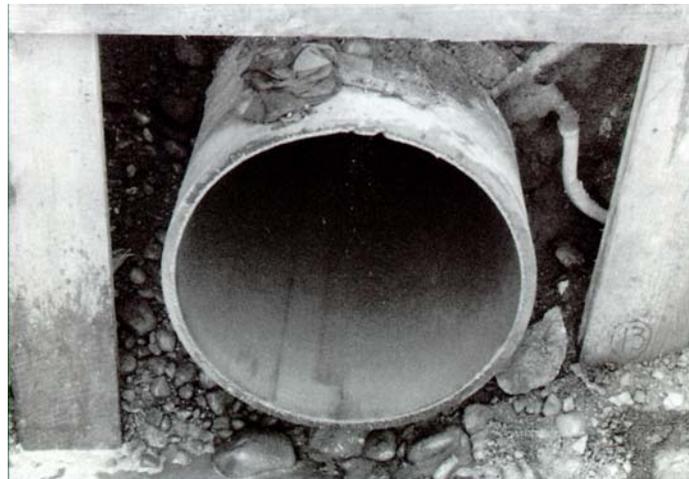
## SPRAY-ON LINING

Spray-on lining techniques are used to protect existing culverts from corrosion and repair small point leaks. For man-entry culverts, reinforced sprayed mortars can effectively be used. Non-man entry culverts require the lining to be applied with a centrifugal lining machine. Lining material is pumped to the high-speed, rotating application head of the centrifugal lining machine. As the machine moves through the culvert, a uniform thickness liner is applied. Cement-mortar lining and epoxy lining are the two (2) most common spray-on lining techniques.

### Cement-mortar Spray-on Lining

#### *Description*

Cement-mortar spray-on liners are usually applied to existing steel and iron culverts to provide protection against corrosion. Lining is applied by the rotating head of an electric or air-powered machine. Mortar is supplied to the machine through a system of high-pressure hoses or by other mechanical means. A uniform thickness liner is applied as the machine moves through the existing culvert at a constant speed. Thus, the thickness of the liner applied is directly related to the speed at which the machine moves. After the liner has been applied, rotating or conical drag trowels provided a smooth troweled finish. Figure 21 presents a finished installation of cement-mortar spray-on lining. Unless reinforced, cement-mortar spray-on lining adds little or no structural integrity to the existing culvert. Reinforced cement-mortar spray-on lining is limited to man-entry culverts. Installations are limited by pipe diameter, valve locations, bends, and length of supply hose.



**Figure 21. Photo. Completed Installation of Cement-mortar Spray-on Lining.<sup>(8)</sup>**

*Effective Uses, Advantages, and Limitations*

General characteristics and effective uses of cement-mortar spray-on lining are presented in Table 36. Advantages and limitations associated with cement-mortar spray-on lining are presented in Table 37.

**Table 36. General Characteristics and Effective Uses of Cement-mortar Spray-on Lining.**<sup>(5,8,83)</sup>

Applications	Diameter Range	Liner Material	Maximum Installation
Gravity & Pressure Pipelines	76 - 4,500 millimeters (3 - 177 inches)	Cement-mortar	450 meters (1,476 feet)

**Table 37. Advantages and Limitations of Cement-mortar Spray-on Lining.**<sup>(5,8,83)</sup>

Advantages	Limitations
Does not block lateral and service connections	Flow bypass is required
	Existing culvert must be dry prior to applying the cement-mortar
Protects against corrosion	Long curing time (up to seven days)
	Possible reduction in flow capacity
Reinforcement can be used	Generally does not enhance the structural integrity of the existing pipe
	It has been observed in steep terrain that it is difficult to maintain a constant rate of speed through the culvert while applying the lining, which results in the liner being sprayed on too thin (would crack off later during curing) or too thick (slump or tear off due to gravity)

**Costs**

Currently, the only cost information available from the gathered literature sources was extracted from case studies. Specific case study costs are presented as follows.

*Water Main Cleaning and Lining – A Utility Perspective* by Mac Ewen and Naef (1988)<sup>(84)</sup> presented a case study on the rehabilitation of water mains with cement-mortar spray-on lining. The cast iron water mains had lost significant hydraulic capacity due to corrosion and the build up of mineral deposits (tuberculation). Rehabilitation procedures took place over a thirteen (13) year period (1974 through 1987) with cleaning and lining costs ranging from approximately \$7.50 to \$25.00 per linear foot. Note that these costs were reported for 1974 through 1987 and have not been adjusted to include inflation.

***General Installation Guidelines***

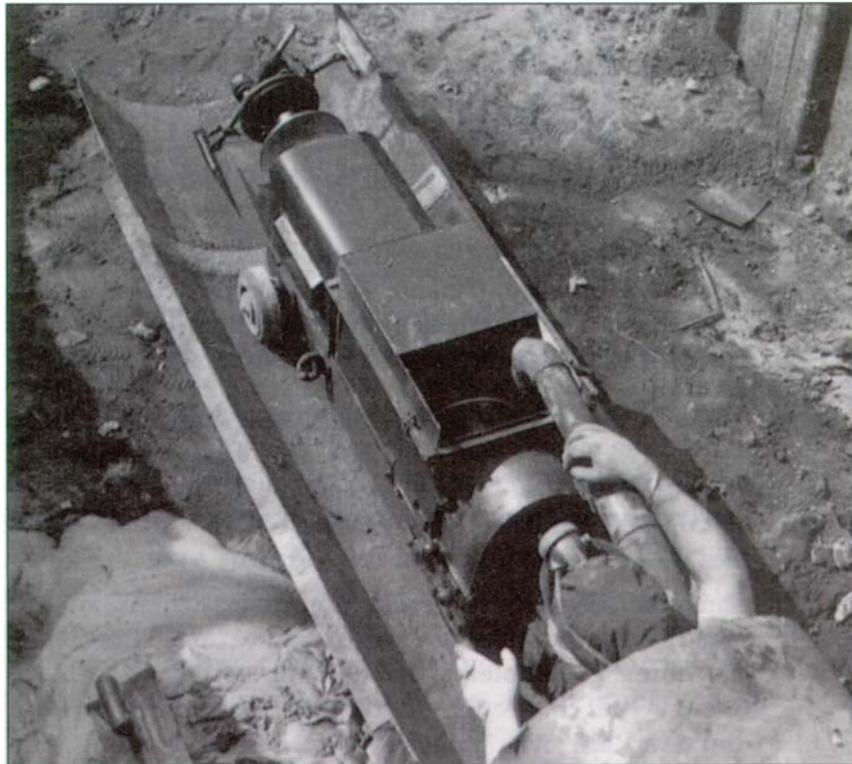
A general list of installation guidelines for cement-mortar spray-on lining is provided below:<sup>(8,83)</sup>

1. Inspect the existing culvert to determine the location of bends, in-line valves, changes in diameter and other discontinuities. Remove all 22.5°, 45°, and 90° bends for 30.5-centimeter (2-inch) diameter pipe and smaller and 45° and 90° bends for 40.6-centimeter (16-inch) diameter pipe.
2. Shut off or bypass the flow to dewater the culvert. Clean and inspect the culvert for leaking valves. Allow the culvert to completely dry prior to lining.
3. Place the lining machine into the culvert to be lined. Obtain the pre-mixed cement-mortar from a mixing van or nearby concrete plant.
4. Immediately prior to lining, remove all foreign material, including sand and loose debris that might have accumulated after the initial cleaning.
5. If the deteriorated culvert is not sufficient to allow man-entry, use a remote- or winch-powered lining machine similar to that illustrated in Figure 22. Supply cement-mortar to the machine through high-pressure hoses. Uniformly apply the cement mortar by ensuring the machine travels through the system at a constant rate.



**Figure 22. Photo. Lining Machine for Non-man Entry Culverts.<sup>(8)</sup>**

6. If deteriorated culvert is large enough to permit man entry, use a remote- or man-operated machine. A man-operated lining machine is pictured in Figure 23. For pipe twenty-four (24) inches in diameter and larger, temporarily cover or plug all openings in the existing culvert, such as manholes, lateral connections, and service connections, before lining. Supply cement-mortar through high-pressure hoses or by other mechanical means if the machine is man operated. Uniformly apply the cement mortar by ensuring the machine travels through the system at a constant rate.



**Figure 23. Photo. Lining Machine for Man Entry Culverts.<sup>(8)</sup>**

7. Troweling of the newly applied cement-mortar should be done mechanically with either rotating trowels or a conical drag trowel attached to the lining machine. Hand place cement-mortar and trowel in places where machine lining is impractical (such as sharp bends and areas closely adjacent to valves).
8. Cap and cure the newly lined culvert with non-pressurized water immediately after lining operations have been completed. Allow cure to continue until accepted by the user, but no longer than seven (7) days.

9. If the newly cement-mortar lined pipe was less than 61 centimeters (24 inches) in diameter, clear lateral and service connections measuring 5 centimeters (2 inches) in diameter or less by back flushing with air or water before the final set of the cement occurs.
10. Inspect the completed lining by closed-circuit TV or manually if the diameter permits man-entry. The liner should be continuous over the entire length.
11. If testing or chlorination are required, perform operations to specifications.
12. Finally, restore flow and initiate site cleanup.

***Standards/Specifications***

Table 38 presents the current standards and specifications associated with cement-mortar spray-on lining.

**Table 38. Standards Associated with Cement-mortar Spray-on Lining.**<sup>(8,83)</sup>

Standard/Specification	Description
AWWA C602 – Standard for Cement-Mortar Lining of water Pipelines in Place-4 in (100 mm) and Larger (2000) <sup>(85)</sup>	Describes the specifications, design considerations, materials, equipment, and installation method for cement-mortar spray-on lining of existing pipelines
AWWA M28 – Rehabilitation of Water Mains (2001) <sup>(8)</sup>	Provides common operating procedures used when lining a pipe with nonstructural cement-mortar

In addition to the two (2) standards presented in Table 38, the following American Water Works Association (AWWA) standard was also associated with cement-mortar spray-on lining:

- AWWA C205 – Cement-Mortar Protective Lining and Coating for Steel Water Pipe – 4 in. (100 mm) and Larger – Shop Applied<sup>(7)</sup>

***Contractors and Manufacturers***

A listing of manufacturers and contractors of cement-mortar spray-on lining is presented in Table 39.

**Table 39. Listing of Manufacturers and Contractors of Cement-mortar Spray-on Lining.**

Manufacturer/ Contractor	Telephone Number	Fax Number	Address	Coverage Area	Contact Person
A.P. Construction, Inc. <i>New Jersey Office</i>	(856) 227-2030	(856) 227-2273	915 S. Black Horse Pike Blackwood, NJ 08012	N/A <sup>2</sup>	N/A
A.P. Construction, Inc. <i>Pennsylvania Office</i>	(215) 922-2323	(215) 922-2700	1080 N. Delaware Ave. Suite 1500 Philadelphia, PA 19125	N/A	N/A
ARB Inc. <sup>1</sup>	(800) 622-2699	(949) 454-7190	26000 Commercentre Dr. Lake Forest, CA 92630	National	N/A
ARB Inc. <i>Pittsburg, CA Office</i>	(800) 898-3478	(925) 432-2958	1875 Loveridge Rd. Pittsburg, CA 94565	N/A	N/A
ARB Inc. <i>Thousand Palms, CA Office</i>	(800) 243-4188	(760) 343-2740	72400 Vista Chino Dr. Thousand Palms, CA 92276	N/A	N/A
ARB Inc. <i>Ventura, CA Office</i>	(805) 643-4188	(805) 643-7268	2235-A North Ventura Ave. Ventura, CA 93001	N/A	N/A
ARB Inc. <i>Texas Office</i>	(800) 443-3805	(936) 756-8671	10617 Jefferson Chemical Rd. Conroe, TX 77301	N/A	N/A
Cement Lining Company, Inc.	(713) 840-0415	(713) 840-1319	Five Greenway Plaza Suite 1775 Houston, TX 77046	N/A	N/A
Spiniello Companies <i>Eastern Operations</i>	(973) 539-6363	(973) 539-4802	35 Airport Rd. Morristown, NJ 07962	N/A	N/A
Spiniello Companies <i>Western Division</i>	(562) 903-8888	(562) 903-8869	13241 Lakeland Rd. Santa Fe Springs, CA 90670	N/A	N/A
W. Walsh Company, Inc.	(508) 226-4300	(508) 266-8449	32 Walton St. Attleboro, MA 02703	N/A	N/A

<sup>1</sup>Designates company headquarters, <sup>2</sup>N/A – not available

## Epoxy Spray-on Lining

### *Description*

Epoxy spray-on lining systems are effectively used to line potable water systems. Similar to cement-mortar spray-on lining, epoxy spray-on lining requires the use of a specialized machine for lining. At a constant rate of speed, the applicator head and supply hoses are pulled through the existing culvert, while centrifugally applying a uniform thickness (minimum of one (1) mm) of epoxy. After the lining is applied, curing begins and continues for approximately sixteen (16) hours.

### *Effective Uses, Advantages, and Limitations*

General characteristics and effective uses of epoxy spray-on lining are presented in Table 40. Advantages and limitations associated with epoxy spray-on lining are presented in Table 41.

**Table 40. General Characteristics and Effective Uses of Epoxy Spray-on Lining.**<sup>(5,8)</sup>

Applications	Diameter Range	Liner Material	Maximum Installation
Gravity & Pressure Pipelines	76 - 4,500 millimeters (3 - 177 inches)	Epoxy	450 meters (137 feet)

**Table 41. Advantages and Limitations of Epoxy Spray-on Lining.**<sup>(5,8)</sup>

Advantages	Limitations
Does not block lateral and service connections	Flow bypass is required
	Existing culvert must be dry prior to applying the epoxy
	Possible reduction in flow capacity
Protects against corrosion	Generally does not enhance the structural integrity of the existing pipe

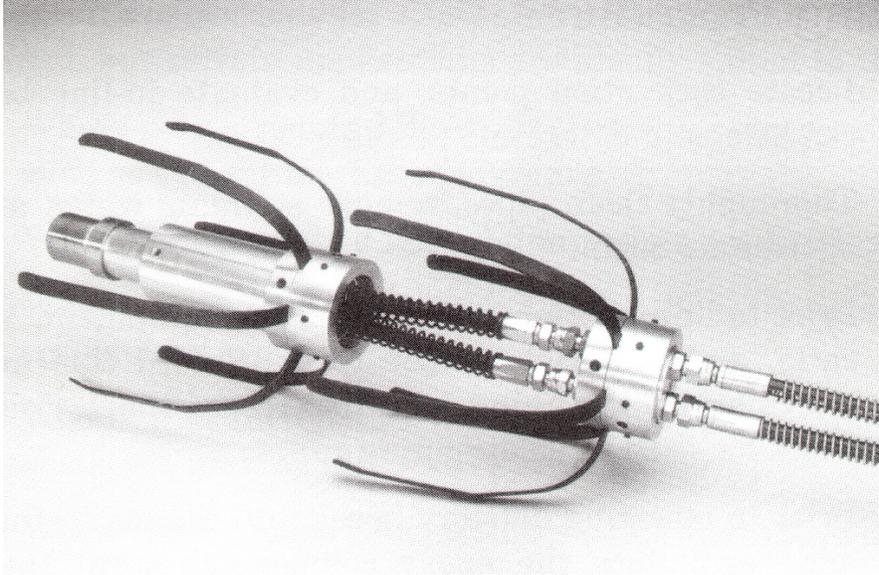
**Costs**

No literature sources were acquired that detailed the general costs associated with epoxy spray-on lining.

**General Installation Guidelines**

The following provides a general list of installation guidelines for epoxy spray-on lining:<sup>(8,83)</sup>

1. Inspect the existing culvert to determine the location of bends, in-line valves, changes in diameter, and other discontinuities.
2. Shut off or bypass the flow to dewater the culvert. Clean and inspect the culvert for leaking valves. Allow the culvert to completely dry prior to lining.
3. Check equipment used to pump and mix the epoxy. Prior to inserting delivery hoses into the culvert, pump and recirculate the epoxy until the temperature specified by the manufacturer is reached.
4. Insert the lining machine into the deteriorated culvert and connect supply hoses. Before the initiation of lining, visually test the epoxy material by test spraying the epoxy onto a test card. A typical epoxy-lining application head is presented in Figure 24.



**Figure 24. Photo. Typical Epoxy Application Head.<sup>(8)</sup>**

5. Begin lining the deteriorated culvert. Closely monitor the winch speed and the rate of supply hose withdrawal. The lining machine should be pulled at a constant and slow enough speed to produce a uniform and minimum epoxy liner thickness of one (1) millimeter. Epoxy lining should only be applied to culverts with temperatures above 3.33°C (38°F).
6. Cap and cure the newly lined culvert immediately after lining operations have been completed. Allow cure to continue for a minimum of sixteen (16) hours or as specified by the manufacturer.
7. Inspect the completed lining by closed-circuit TV or manually if the diameter permits man-entry. The liner should be continuous over the entire length.
8. If testing or chlorination is required, perform operations to specifications.
9. Finally, restore flow and initiate site cleanup.

### ***Standards/Specifications***

Table 42 presents the current standard associated with epoxy spray-on lining.

**Table 42. Standard Associated with Epoxy Lining.<sup>(8)</sup>**

Standard/Specification	Description
AWWA M28 - Rehabilitation of Water Mains (2001) <sup>(8)</sup>	Provides common operating procedures used when lining a pipe with nonstructural epoxy

***Contractors and Manufacturers***

A listing of manufacturers and contractors of epoxy spray-on lining are presented in Table 43.

**Table 43. Listing of Manufacturers and Contractors of Epoxy Spray-on Lining.**

Manufacturer/ Contractor	Telephone Number	Fax Number	Address	Coverage Area	Contact Person
Ground & Pipe Technologies	(334) 388-5640	(344) 264-8980	1120 Parker St. P.O. Box 9204 Montgomery, AL 36108	N/A <sup>2</sup>	N/A
PIM Corporation	(800) 293-6224	(732) 469-8959	201 Circle Dr. No. Suite 106 Piscataway, NJ 08854	N/A	N/A
Raymond International, Inc. <sup>1</sup>	(562) 923-9600	N/A	9603 John St. Santa Fe Springs, CA 90670	National	N/A

<sup>1</sup>Designates company headquarters, <sup>2</sup>N/A – not available