Emerging Trenchless Renewal Technologies for

Pressure Pipe

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AEGION®

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Agenda

- AWWA Structural Classifications
- Emerging Pressure Pipe Renewal Applications
  - InsituMain® Cured-In-Place Pipe (CIPP)
    - Mechanical end fittings
    - Mechanical service connections
  - Thermopipe® Liner
- Selecting appropriate pressure pipe renewal technology

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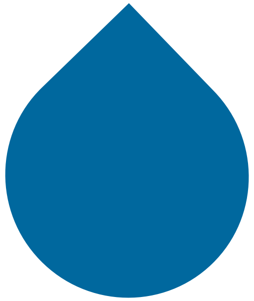
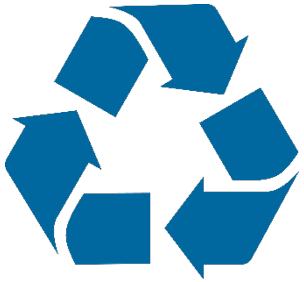
Pressure Pipe Renewal Applications

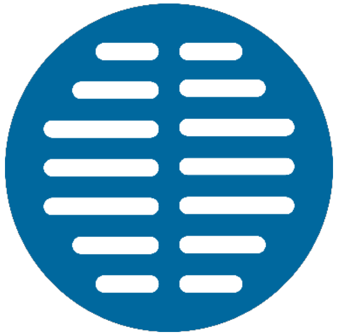
Potable Water



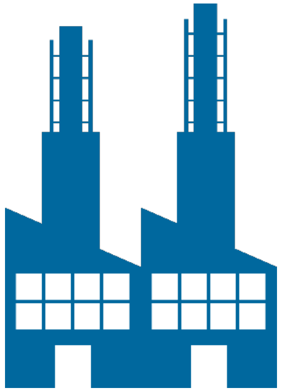
Raw Water



Reclaimed Water



Sanitary Water



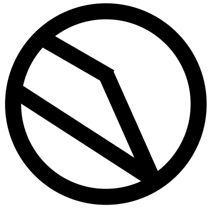
Industrial
(Fire & Process Water)

Common Trenchless Technologies

Slip lining
Installation of a smaller “carrier pipe” into a larger host pipe

Pipe bursting
A method of fracturing the host pipe and pulling in a new pipe that is equal to or greater in size

Coatings
Utilizing spray applied materials to renew the surface of the existing pipe



Directional Drilling
Installation of new pipe through a bored hole under an obstacle

Emerging Trenchless Technologies

Slip lining
Installation of a smaller “carrier pipe” into a larger host pipe

Coatings
Utilizing spray applied materials to renew the surface of the existing pipe

Cured-in-place Pipe (CIPP)
A jointless, seamless resin saturated tube that is installed in the existing host pipe and cured

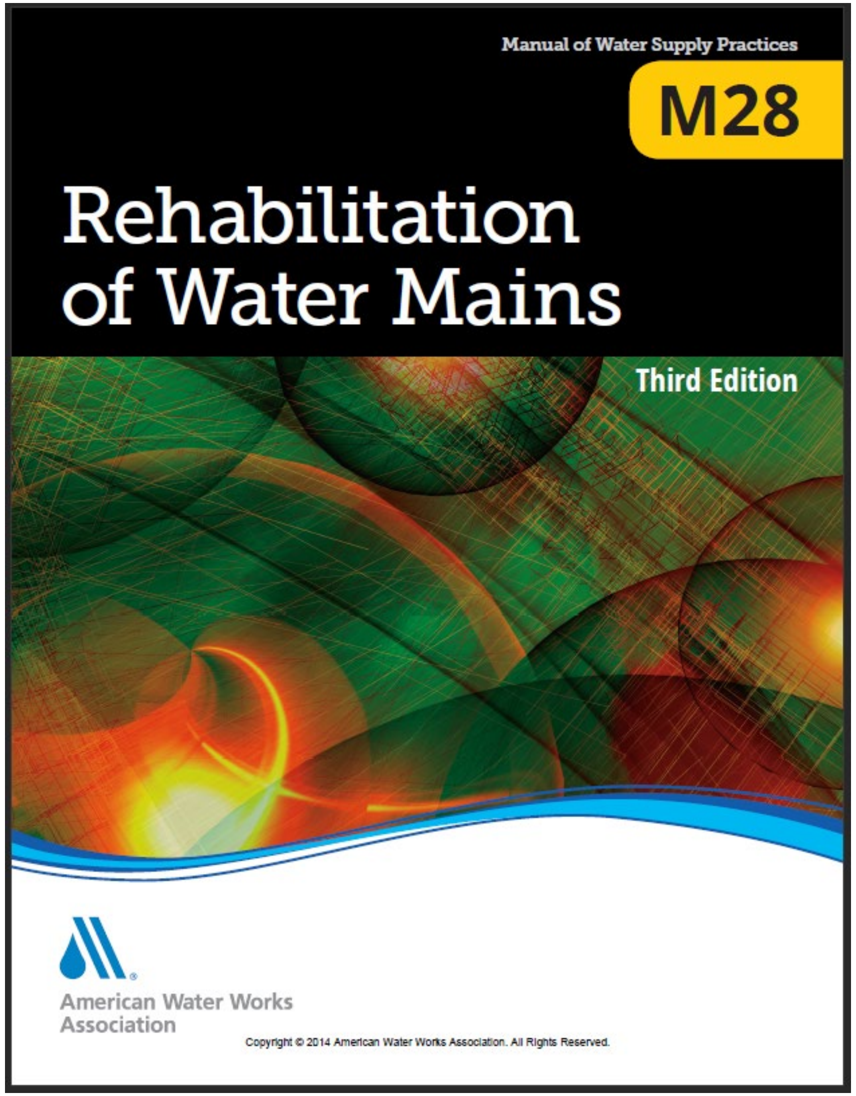
Pipe bursting
A method of fracturing the host pipe and pulling in a new pipe that is equal to or greater in size

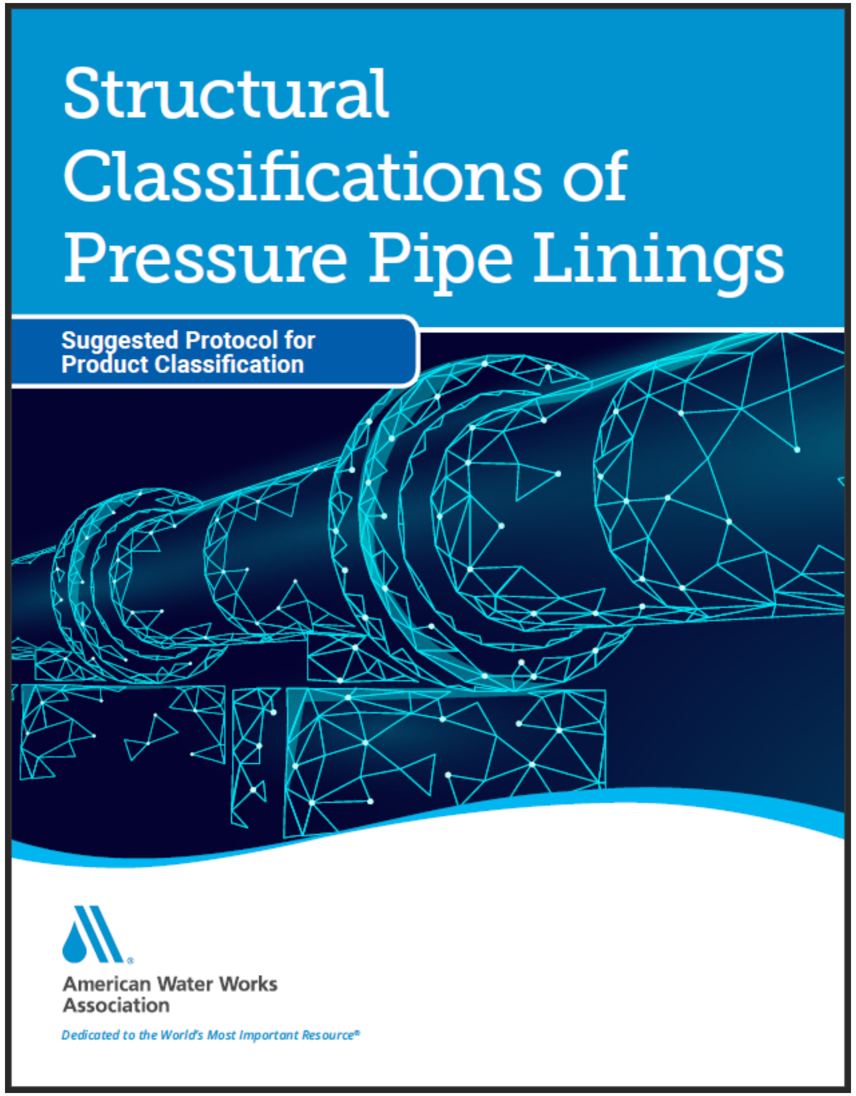
Directional Drilling
Installation of new pipe through a bored hole under an obstacle

Hose Lining
A modified type of sliplining that involves installing a high-pressure hose product inside a larger host pipe

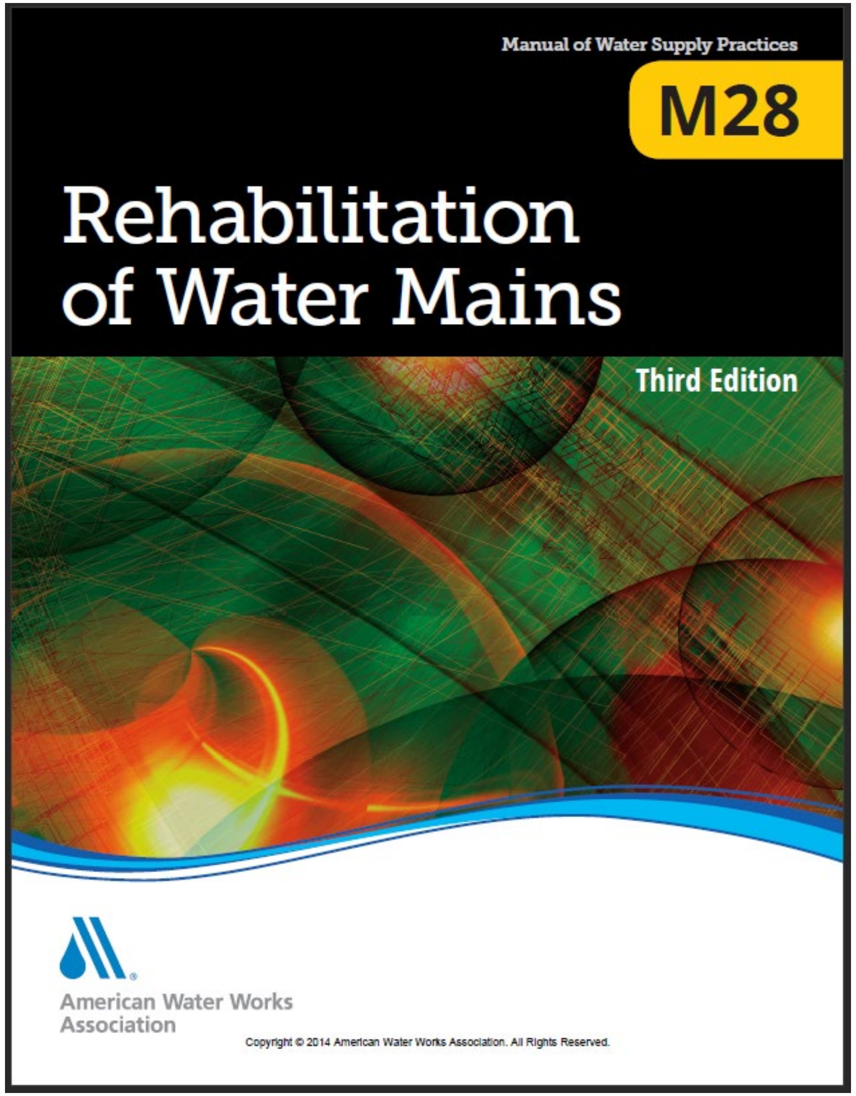
AWWA Structural Classification of Pressure Pipe Linings

AWWA Publications





M28 – Rehabilitation of Water Mains



What does this publication provide?

- Problem definitions
- Trenchless technology overviews
- Planning and delivery considerations
- Common approaches to pipe preparation for lining technologies
- Matching problems to technology
- *No* standards for design
- *Qualitative* not *Quantitative* overview of structural lining

Qualitative Classification

Table 1: *General Structural Classifications Objectives*

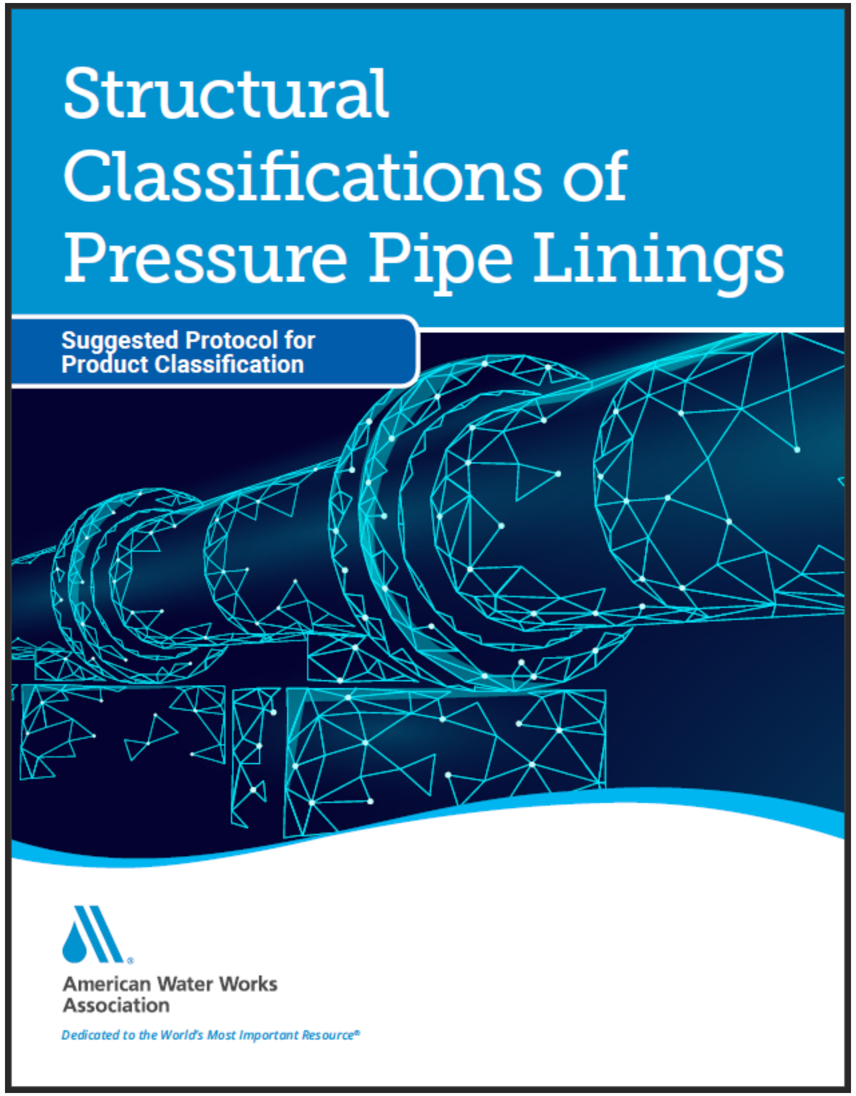
Lining System Characteristic	Non-Structural	Semi-Structural (Interactive)		Fully Structural
	Internal coating	Hole span	Hole span + ring stiffness	Structural resistance for all specified loads (internal & external)
	Class I	Class II	Class III	Class IV
Internal corrosion protection	✓	✓	✓	✓
Long-term adhesion to the host pipe	See Note 1 Below	✓	See Note 2 Below	See Note 2 Below
Hole span at MAOP		✓	✓	✓
Inherent ring stiffness (hydrostatic pressure or vacuum loads only)	See Note 1 Below	See Note 1 Below	✓	✓
Water tightness (positive connection to service taps and sealed at termination points or other discontinuities)		✓	✓	✓
Inherent ring stiffness (all static and dynamic external, hydrostatic, and vacuum loads)				✓
Pressure rating of lining ≥ MAOP of host pipe				✓
Lining survives anticipated host pipe failures				✓

1 The owner/engineer must specify whether vacuum loads exist. This is addressed through reliable adhesion to the host pipe, which is a characteristic of all Class II and some Class I linings, or inherent ring stiffness.
2 For Class III and IV linings, adhesion is not required to develop ring stiffness. However, it may be necessary to achieve a watertight seal (for example, at services and lining terminations). There are also situations where adhesion is not desirable, such as applications with broad temperature swings and in Class IV linings where the host pipe is anticipated to experience brittle failure modes.

Qualitative concept is based on:

- Intended function of the lining technology
- Degree of interaction of lining technology with the host pipe
- Type of loads the lining was intended to resist

Structural Classification of Pressure Pipe Linings



What does this publication provide?

- Takes qualitative concepts to a quantitative format
- Guidance on design and product selection for all lining products.
- Aligns product considerations to design objectives
- Initial thoughts on recommended quality assurance processes during construction
- Discussion on necessary evolution of design for technologies with a proven track record
- Provides illustrative examples of sound engineering judgement to go beyond current design code

Quantitative Classification - Type Testing

Table 2: *Type Testing*

Note: In order for a lining technology to be categorized under a specific Structural Classification, one or more test methods listed for each property must be documented and all applicable acceptance criteria met.

	Property	Technology	Test Method(s)	Acceptance Criteria
Class I	Potable Water Certification	All	NSF/ANSI 61 (potable water)	PASS
Class I	Material Properties	CML	ASTM C143 (slump test)	ANSI/AWWA C602, Section 4.4.3, Figures 1 & 2
Class I	Lining Thickness	All		Per manufacturer's guidelines
Class I	System Hydraulics	All		Minimum C value
Class I	Adhesion	Some Class I	ASTM D4541 (metal substrate) ASTM D7234 (concrete substrate)	Demonstration test: Pull strength ≥ negative pressures + thermal stresses + shear stresses where relevant (as established by the owner/engineer)
	All Class I attributes PLUS:			
Class II	Adhesion	All Class II	Per Class I	Per Class I
Class II	Hole Span @ MAOP	All Class II	Any or all of: ASTM D790; ISO 178; ISO 11296-4, Annex B (initial flexural properties, 3-pt bending)	Test values = short-term flexural properties For anisotropic materials, flexural properties should be obtained in the hoop and axial directions
Class II	Hole Span @ MAOP	All Class II	Any or all of: ASTM D2990; ISO 899-2; ISO 11296-4, Annex C & D (flexural creep)	Test values = long-term flexural properties
Class II	Water Tightness	All Class II	Supporting test data from end seal and fittings manufacturers, as applicable	End seals, service connections, hot taps and fittings: Pressure Rating ≥ MAOP Demonstration test(s) by the manufacturer as directed by the owner/engineer
Class II	Hydrostatic Integrity at Services	All Class II		Demonstration test(s) by the manufacturer as directed by the owner/engineer

	Property	Technology	Test Method(s)	Acceptance Criteria
	All Class I & II attributes PLUS:			
Class III	Adhesion	Some Class III	Per Class I, as required	Per Class I, as required
Class III	Ring Stiffness	All Class III-IV	Any or all of: ASTM D2412; DIN EN 1228; ISO 7685 (initial ring stiffness)	Per owner/engineer requirements
Class III	Ring Stiffness	All Class III-IV	Any or all of: ASTM D2990 (flexural creep, hoop direction); DIN EN 761; ISO 7684 with ISO 10468 (flexural creep, full ring)	For full ring tests, samples must be round, reflect the finished quality and geometry of the installed product, and tested independently of the host pipe

	Property	Technology	Test Method(s)	Acceptance Criteria
	All Class I, II & III attributes PLUS:			
Class IV	Adhesion	Some Class IV	Per Class I, as required	Per Class I, as required
Class IV	Resists all internal and external pressures	All Class IV	Any or all of: ASTM D638; ASTM D3039; ASTM D2290; ISO 8521; ISO 8513 (initial tensile properties)	Test values = short-term tensile properties For anisotropic materials, tensile properties should be obtained in the hoop and axial directions For full ring tests, test samples must be round, reflect the finished quality and geometry of the installed product, and tested independently of the host pipe
Class IV	Resists all internal and external pressures	All Class IV	ASTM D2990 and/or ISO 899-1 (tensile creep)	Determination of long-term (50-yr) retention of tensile properties
Class IV	Resists all internal and external pressures	All Class IV	ASTM D1599 (short-term burst testing)	Test samples must be round, reflect the geometry of the installed product, and tested independently of the host pipe Test value/PRF = estimated pressure rating (straight alignment). Generally, PRF ≥ 4 but lower PRF values are permissible when documented testing, as outlined herein, has established the acceptability of a lower short-term to long-term strength ratio. Further product specific de-rating may be recommended when geometric anomalies compromise hoop integrity, or when lining through bends and offsets
Class IV	Resists all internal and external pressures	CIPP	ASTM F2994, ASTM F1216 or ASTM F1743 (CIPP impregnation)	Demonstration test: Insure proper resin mixing ratio and CIPP saturation rate; vacuum impregnation under controlled conditions; data logging of impregnation process
Class IV	Resists all internal and external pressures	CFRP[3]	ASTM D6641	Compressive strength; AWWA C305, Sec. 3
Class IV	Resists all internal and external pressures	CFRP[3]	ASTM D7616	Shear strength; AWWA C305, Sec. 3
Class IV	Resists all internal and external pressures	SL (FRP) CIPP[4]	ASTM D2992 or ISO 7509 with ISO 10928 (regression analysis)	HDB or ISO test results may be used as a comparative measure vs short-term burst and long-term tensile creep results
Class IV	Resists all internal and external pressures	SL (HDPE)	ASTM D2837 or PPI TR-3	HDB
Class IV	Resists all internal and external pressures	SL (HDPE)	ASTM D3350	Material cell classification
Class IV	Resists all internal and external pressures	SL (HDPE)	ANSI/AWWA C906	Dimensions and tolerances, bend back or elongation at break, ring tensile or short-term burst, carbon black/UV inhibitor, melt flow index, density, thermal stability
Class IV	Resists all internal and external pressures	SL (PVC)	ASTM D2837	HDB from multiple stress-rupture tests from <1 hour to >10,000 hours
Class IV	Resists all internal and external pressures	SL (PVC)	ANSI/AWWA C900 or PPI TR-2	HDB + 1000-hour pressure test; burst test; flattening test

3 AWWA C305 applies to CFRP used for the renewal and strengthening of PCCP. Alternative test methods may be implemented at the discretion of the owner/engineer for applications involving different host pipe materials.
4 HDB testing is difficult to execute for CIPP and may not be indicative of a product's long-term performance. If available, HDB test results may be used as a comparative measure vs short-term burst and long-term tensile creep results.

Type Testing:

- How we measure that products meet quantifiable measures of short and long term mechanical/chemical resistance properties

Quantitative Classification - Acceptance Testing

Table 3: *Acceptance Testing*

Note: In order for a lining technology to be categorized under a specific Structural Classification, one or more test methods listed for each property must be documented and all applicable acceptance criteria met

	Property	Technology	Test Method(s)	Acceptance Criteria
Class I	Drinking Water System Components – Health Effects	All	Bacteriological testing	AWWA C651
	Material Properties	CML, PL	Compressive strength	CML: AWWA C602, Section 5.1.2
				PL: ASTM F3182, Section 6
	Lining Thickness	CML, PL	Physical measurements	CML: ANSI/AWWA C602, Table 1
				PL: ASTM F3182, Section 8.2
	Adhesion	Some Class I	Surface preparation and dryness	Surface preparation methods shall be confirmed by the owner/engineer before proceeding with the lining installation process.
				PL: ASTM F3182, Section 8.3
			Visual and CCTV inspection	No visual leaks at ends or at services
				ISO 11297-1:2013, Section 9.8
				PL: ASTM F3182, Section 7.9
			ASTM D4541 (metal substrate)	Test values ≥ design value
				PL: ASTM F3182, Section 8.3
			ASTM D7234 (concrete substrate)	Test values ≥ design value
Class II	All Class I attributes PLUS:			
	Adhesion	All Class II	Per Class I	Per Class I
	Hole Span @ MAOP	All Class II	ASTM D790 and/or ISO 11296-4, Annex B (initial flexural properties, axial direction)	Test values ≥ design submittal
				If these criteria are not met, design compliance shall be verified using actual test values
	Water Tightness	All Class II	ASTM F1216, Section 8.3 (pressure test): 2 times MAOP or MAOP + 50 psi (3.4 bar), whichever is less,	Minimum 1-hour duration once system is stabilized; leakage allowance = 20 gal/inch diameter/mile/day (1.86 L/mm diameter/km/day)
			or ISO 11297-4, Table 7 (pressure test): 1.5 times MAOP	15 minute test duration with no leakage per ISO 7432 or ISO 8533, as applicable
Class III	All Class I & II attributes PLUS:			
	Adhesion	Some Class III	Per Class I, as required	Per Class I, as required
				CIPP: ASTM F1216, Section 8.7; tight fit, full saturation
				CFRP: AWWA C305, Section 4.5[5]
	Ring Stiffness	All Class III	ASTM D790 and/or ISO 11296-4, Annex B (initial flexural properties, hoop direction)	For anisotropic materials, flexural properties should be obtained in the hoop direction
				Test values ≥ design submittal

	Property	Technology	Test Method(s)	Acceptance Criteria
Class IV	All Class I, II & III attributes PLUS:			
	Adhesion	Some Class IV	Per Class I, as required	Per Class I-III, as required
	Resists all internal and external pressures	CIPP	ASTM F2994 or ASTM F1216 (CIPP impregnation)	Verify compliance during CIPP impregnation process
			Visual and CCTV inspection	Confirm fit and finish. Geometric anomalies compromising the lining system's hoop integrity shall be verified through type testing and reflected in design. Isolated circumferential fins or imperfections from lining through vertical or horizontal misalignment, offset(s) or directional change(s) shall be documented and reviewed with the owner/engineer for design compliance
			Any or all of: ASTM D638; ASTM D3039; ASTM D2290; ISO 8513; ISO 8521 (tensile properties, hoop direction)	For anisotropic materials, tensile properties should be obtained in the hoop direction
				Test values ≥ design submittal
			Wall thickness measurements: Restrained samples: ASTM F1216, Section 8.6; Measurements per ASTM D3567	Average of eight (8) measurements around circumference; not less than 87.5% of design thickness at any point (excluding coating). Although hoop tensile strength (force/unit area) is an important parameter for reinforced CIPP laminates, hoop load capacity (force/unit width) is equally or even more important. Laminate thickness can vary without changing the amount of reinforcing fibers used. As an example, the thickness may increase by adding felt material to increase the external load-resisting capacity. In this example, as the thickness increases, the tensile strength (psi) decreases. However, the hoop load capacity (lb/in.) remains the same or may slightly increase. Thus, although the hoop tensile strength decreases, the internal pressure load capacity of the CIPP remains the same or slightly increases. In this context, hoop load capacity, not wall thickness or resulting tensile strength, is a measure of pressure pipe structural performance.
				Flat plate sampling methods per ASTM F1216, Section 8.1.2 may be used in lieu of restrained samples in accordance with manufacturer's recommendations and as directed by the owner and/or engineer.
		SL (HDPE)	AWWA M55 or ASTM F2164	Hydrostatic leak test
		SL (FRP)	AWWA M45	Hydrostatic leak test
		SL (PVC)	AWWA C605	Hydrostatic leak test

5 AWWA C305 applies to CFRP used for the renewal and strengthening of PCCP. Alternative acceptance criteria may be established at the discretion of the owner/engineer for applications involving different host pipe materials.

Acceptance Testing:

- How we measure in the field that the product meets the design objectives

Emerging Trenchless Renewal Technologies for Pressure Pipe

Aegion Corporation – Stronger. Safer. Infrastructure.®

Infrastructure Solutions

Infrastructure Solutions

- Water & wastewater pipeline rehabilitation
- Structural strengthening

Corrosion Protection

- Pipeline corrosion prevention
- Oil, gas and mining

Energy Services

- Facility maintenance services

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Aegion's Pressure Pipe Products

Insituform	Pressure Rated Cured-in-Place Pipe (CIPP)
united	Tight-fit HDPE Lining Systems
FIBRWRAP®	Carbon/Glass Fiber (FRP) Systems
Underground Solutions®	Fusible PVC®
AEGION®	Thermopipe® Liner

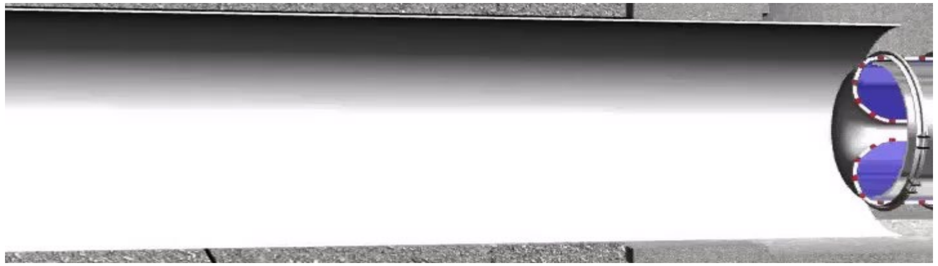
InsituMain® Cured-In-Place Pipe (CIPP)

Insituform®

What is Cured-in-Place Pipe (CIPP)?

- Resin impregnated tube with:
- Glass reinforced felt
- Inversion or Pull-in installation methods
- Hot water, steam, or UV curing methods
- Tight fitting = greater flow maximization
- Joint less, pipe-within-a-pipe that protects against corrosion, build-up, and leakage

Diameter Range	6” to 96”
Effluent Temperature	Up to 130°F
Internal Pressure Capability	Up to 250 psi (safety factor of 4)
Bends	Up to 45°
Host Pipe Material	All materials
Mechanical Properties	Exceeds ASTM F1216 & ASTM F1743
Typical Install Lengths	500 to 1,000 feet



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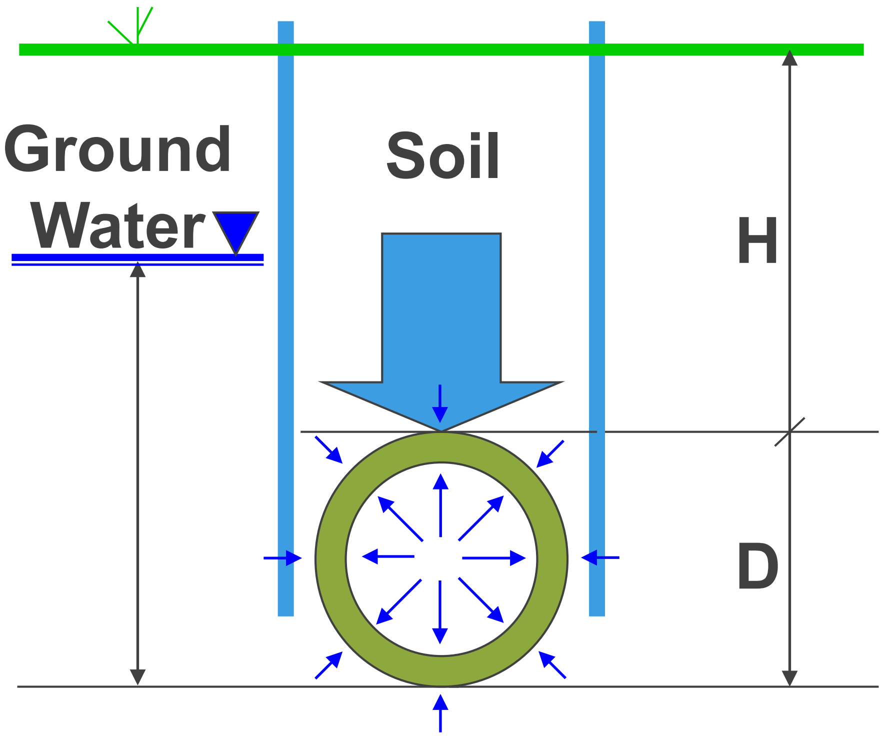
CIPP Design Parameters



- ASTM F1216 / AWWA M28
- Internal design:
  - Operating, transient and vacuum pressures
- External design:
  - Soil, groundwater, traffic, and other live loads
- Other factors:
  - Ovality, end fittings, bends and services
- Unrestrained burst testing
  - Validates safety factors

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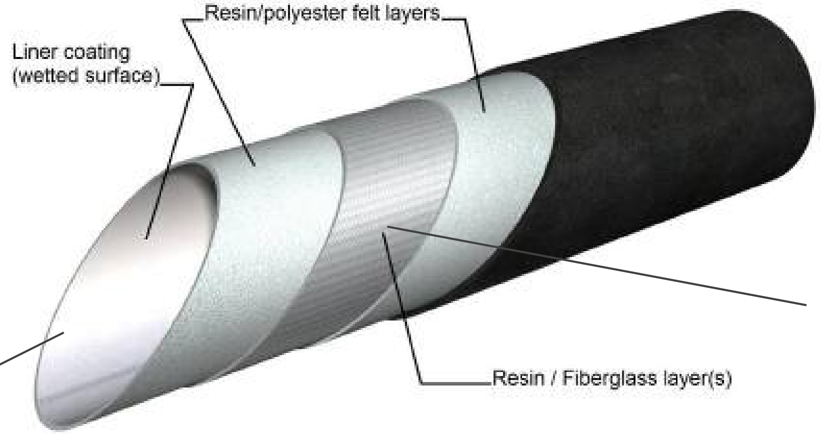
InsituMain® Glass Composite Structure

Epoxy/polyester felt structure

- Provides for external load capacity
- Layer thickness can be varied depending on loading conditions
- Utilizes epoxy resin system instead of polyester resin (drinking water safe)

Hazen-Williams Coefficient

- C=140



Epoxy/fiberglass structure

- Provides high tensile/hoop strength
- Number of layers varies depending on diameter and internal pressure

PP/TPU coating

- Water contact surface
- Coating also provides water barrier for installation processes & handling

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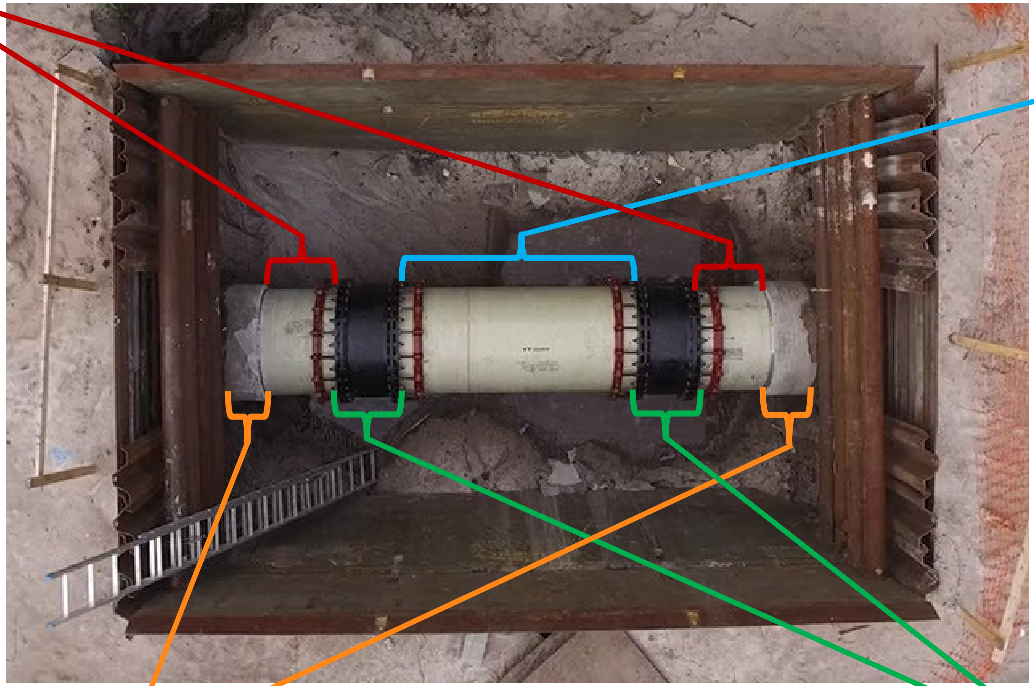
EndConnect® Mechanical Closure

Fiber Reinforced Polymer (FRP) Coupling Piece

Closure Spool Piece



Host Pipe

Mechanical Joint with MEGALUG

- Eliminates need to connect back to the host pipe
- Promotes the use of standard mechanical joint fittings

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EndConnect® Mechanical Closure

AEGION®

EndConnect® Mechanical Closure

AEGION®

EndConnect® Mechanical Closure

AEGION®

EndConnect® Mechanical Closure

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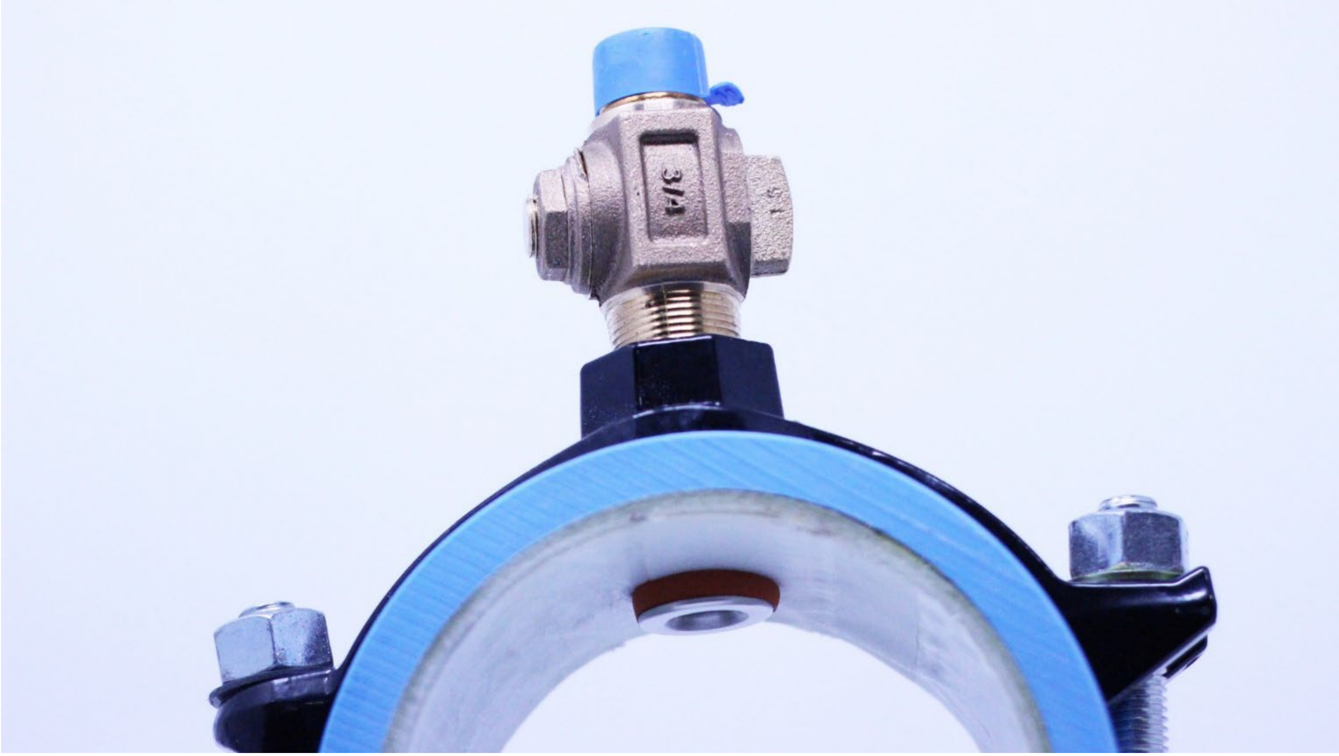
Service Connections – Adhesive vs. Mechanical

- Step 1 – Cleaning to prepare pipe surface for resin
- Step 2 – Plugging of existing service connection (prior to lining)
- Step 3 – Locating of the existing service (after lining)
- Step 4 – Drilling of the existing service (most CIPP product manufacturers/contractors stop at this step – plug and drill)
- Step 5 – Reinstatement of the existing service (via installation of the mechanical fitting)



** The mechanical reinstatement process <u>does not</u> rely on the integrity of the host pipe (long term) in order to maintain water tightness*

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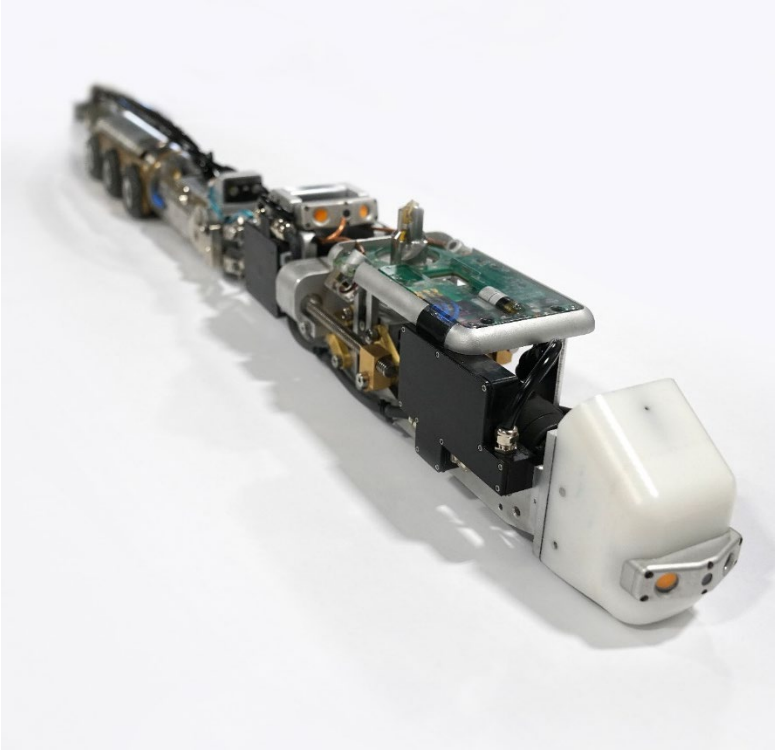
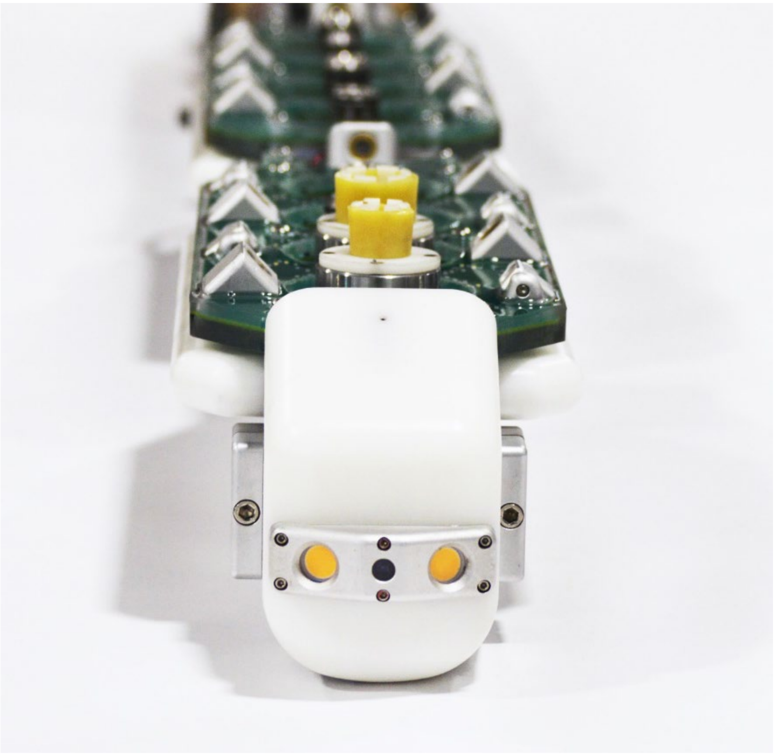
Direct Tap Mechanical Reinstatement Equipment





- One unit accommodates multiple functions:
  - Measurement of service connection diameters
  - Guidance using axial and hoop direction lasers
  - Installation of service plugs
  - Autonomous options for service plug location and drilling using magnetic sensors and cameras
  - Installation of service reconnection hardware

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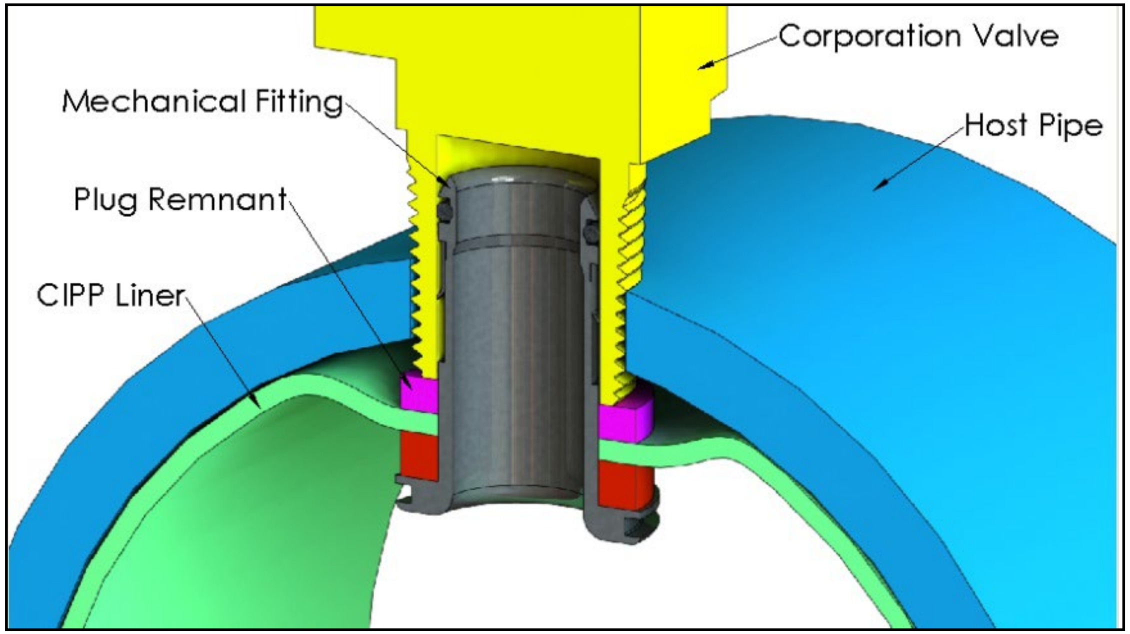
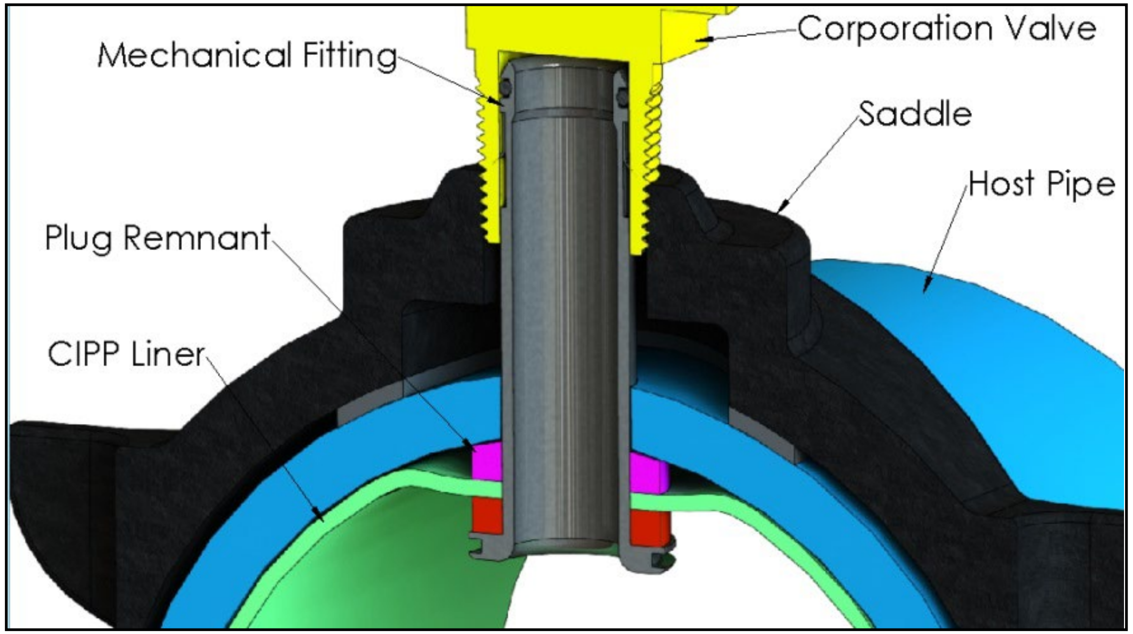
Mechanical Fitting Installation

Installed Mechanical Fitting



Direct Tap Service



Saddled Tap Service

- Reduces or eliminates need for costly excavations
- ½”, ¾” and 1” diameter reinstatement options
- Pipe diameters from 6” to 12”

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CIPP Lining – West Palm Beach, FL

Project Description

- Owner: West Palm Beach, FL
- Pipe Material: PCCP
- Diameter: 48-inch
- Length: 5,700 LF
- Pressure: 25 psi
- Type: Sewer Force Main
- Project Value: $1,418,373

WPB℠
WEST PALM BEACH

Problem Statement

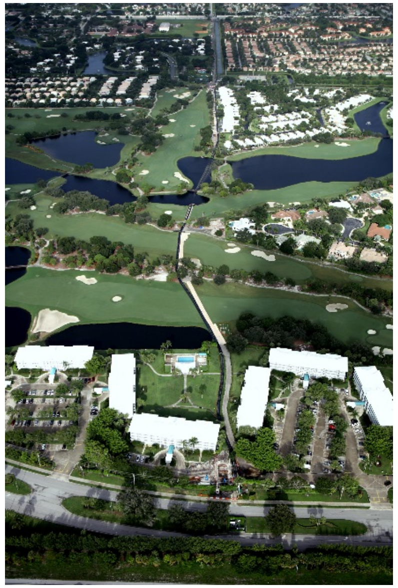
- Located near canal, county club and high-end residential homes
- High social costs
- Difficult site access
- Deteriorated pipe with pre-stressed wire breaks

CIPP Lining – West Palm Beach, FL

Renewal Technology Selection

- Fully Structural (AWWA Class IV)
- Full sewer bypass
- Long installation lengths (Averaged 1,000 LF)
- Minimal internal diameter loss

INSITUMAIN® CIPP LINING



Trenchless Technology
REHAB WINNER 2017 PROJECT OF THE YEAR

CIPP Lining – Scenic Drive Upper Conduit, UT

Project Description

- Owner: Salt Lake City, UT
- Pipe Material: PCCP
- Diameter: 48-inch
- Length: 560 LF
- Pressure: 60 psi
- Type: Potable water
- Project Value: $810,000

Problem Statement

- Gravity pipe required jointless, pressure-rated rehabilitation product
- Leakage at intermediate manhole
- High social costs to open cut pipe
- Short construction window

CIPP Lining – Scenic Drive Upper Conduit, UT

Renewal Technology Selection

- Fully Structural (AWWA Class IV)
- Span holes/joints in host pipe
- Minimal internal diameter loss
- NSF/ANSI 61 Standard
- Minimal site footprint

INSITUMAIN® CIPP LINING

Thermopipe® Liner

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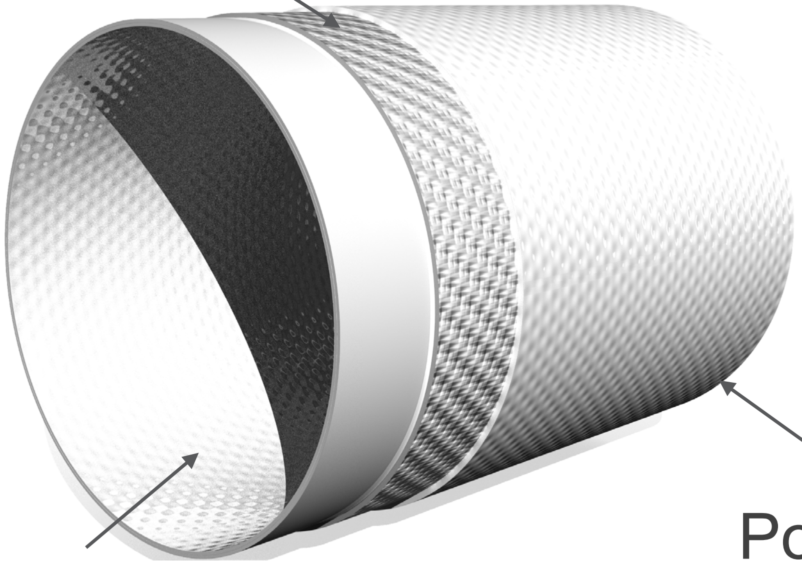
Thermopipe® Hose construction

Polyester Woven Core



Polyurethane Outer Coating

Polyurethane Inner Coating

- TPU coated (through the weave) polyester woven hose
- Stops leakage by bridging and sealing holes and faulty joints

- Hazen-Williams = 150
- Class III Solution (relies on host pipe condition)
- NSF 61 Certified

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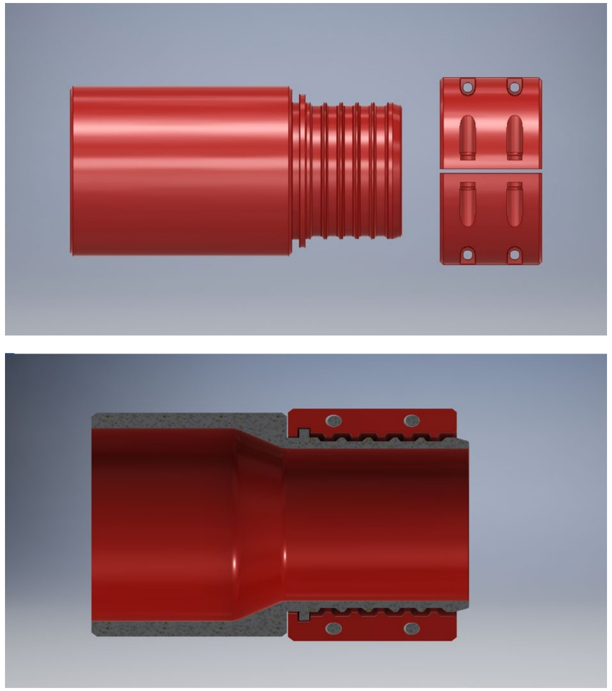
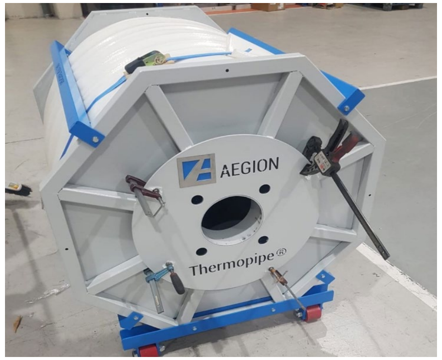
End Connection



- Epoxy Coated Steel
- Ease of Reconnection
- Plain End Connection

Installation steps



Step 1

Set up Reel on site for unwinding.

Step 2

Attach pull head, connect to cable and use winch for pull in.

Step 3

Inflate liner with compressed air to expand hose and break tape.

Step 4

Simple mechanical end connections and reconnect with standard waterworks fittings.

- Diameter Range 4-12”
- Pressure Rating 200 psi
- Maximum Install Lengths 3,000’+
- Maximum Temperature Rating 150F

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Hose Lining – Vancouver, WA

Project Description

- Owner: Fairway Village
- Pipe Material: PVC
- Diameter: 6-inch
- Length: 300 LF
- Pressure: 140 psi
- Type: Irrigation water
- Project Value: >$80,000

Fairway Village

Problem Statement

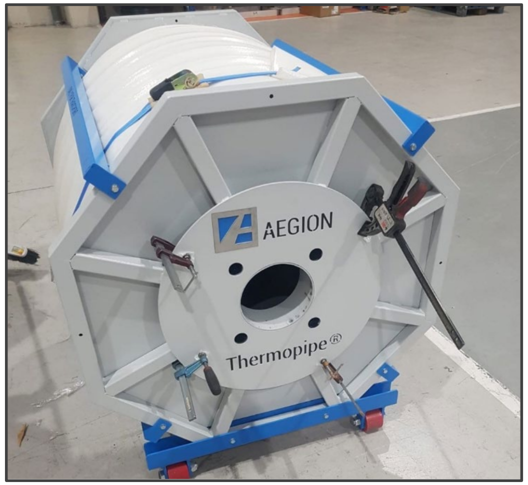
- Fully structural host pipe
- Leaking pipeline
- Difficult site access
- High social costs

Hose Lining – Vancouver, WA

Renewal Technology Selection

- Semi-Structural (Class III)
- Water tightness
- Small construction footprint

THERMOPIPE® HOSE LINING



Selecting Appropriate Pressure Pipe Renewal Technology

Which Technology Should I Consider?

CIPP

Spray Applied

Slip Lining
(conventional)

FRP

Pipe Bursting

Slip Lining
(modified)

Hose Lining

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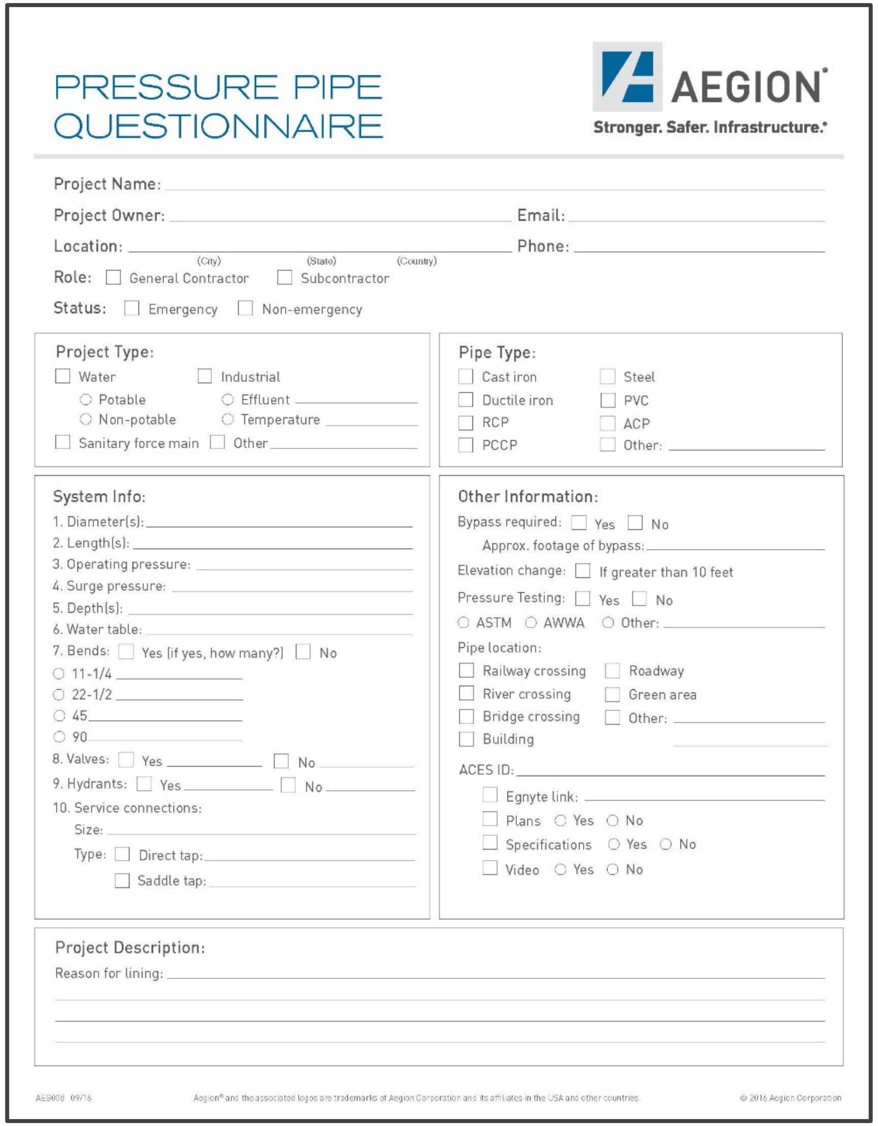
We Have to Ask the Proper Questions

- What type of problems is the pipeline system experiencing?
  - Structural or non-structural?
- How much longer do I need this asset?
  - Product/Process type as well as designs can be modified accordingly
- Do I need additional capacity in this pipeline?
  - Future commercial or residential expansion
  - Originally under designed
- Can I accept less capacity in this pipeline?
- Are there multiple services and/or bends present in the pipeline?
- Can pipeline access be created easily and cost effectively?
- What is the size of the existing pipeline?



PRESSURE PIPE QUESTIONNAIRE

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Project Name:
Project Owner: Email:
Location: (City) (State) (Country) Phone:
Role: ☐ General Contractor ☐ Subcontractor
Status: ☐ Emergency ☐ Non-emergency

Project Type:
☐ Water
○ Potable
○ Non-potable
☐ Industrial
○ Effluent
○ Temperature
☐ Sanitary force main ☐ Other

Pipe Type:
☐ Cast iron ☐ Steel
☐ Ductile iron ☐ PVC
☐ RCP ☐ ACP
☐ PCCP ☐ Other:

System Info:
1. Diameter(s):
2. Length(s):
3. Operating pressure:
4. Surge pressure:
5. Depth(s):
6. Water table:
7. Bends: ☐ Yes (if yes, how many?) ☐ No
○ 11-1/4
○ 22-1/2
○ 45
○ 90
8. Valves: ☐ Yes ☐ No
9. Hydrants: ☐ Yes ☐ No
10. Service connections:
Size:
Type: ☐ Direct tap:
☐ Saddle tap:

Other Information:
Bypass required: ☐ Yes ☐ No
Approx. footage of bypass:
Elevation change: ☐ If greater than 10 feet
Pressure Testing: ☐ Yes ☐ No
○ ASTM ○ AWWA ○ Other:
Pipe location:
☐ Railway crossing ☐ Roadway
☐ River crossing ☐ Green area
☐ Bridge crossing ☐ Other:
☐ Building
ACES ID:
☐ Egnyte link:
☐ Plans ○ Yes ○ No
☐ Specifications ○ Yes ○ No
☐ Video ○ Yes ○ No

Project Description:
Reason for lining:

AEG008 09/16

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So What Now?

- Not a one-size fits all
- Comparative analysis: scope, schedule, and budget across different technologies
  - As compared to traditional dig & replace
- Each technology will have its pros & cons

Next Steps…

- Initial Project Review – Feasible Options
- Plan & Spec Reviews
- Preliminary Pricing* (aka ROM)
- Budgetary Pricing* (Program Level Funding)

*Includes schedule information

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Any Questions?

Thank you!

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