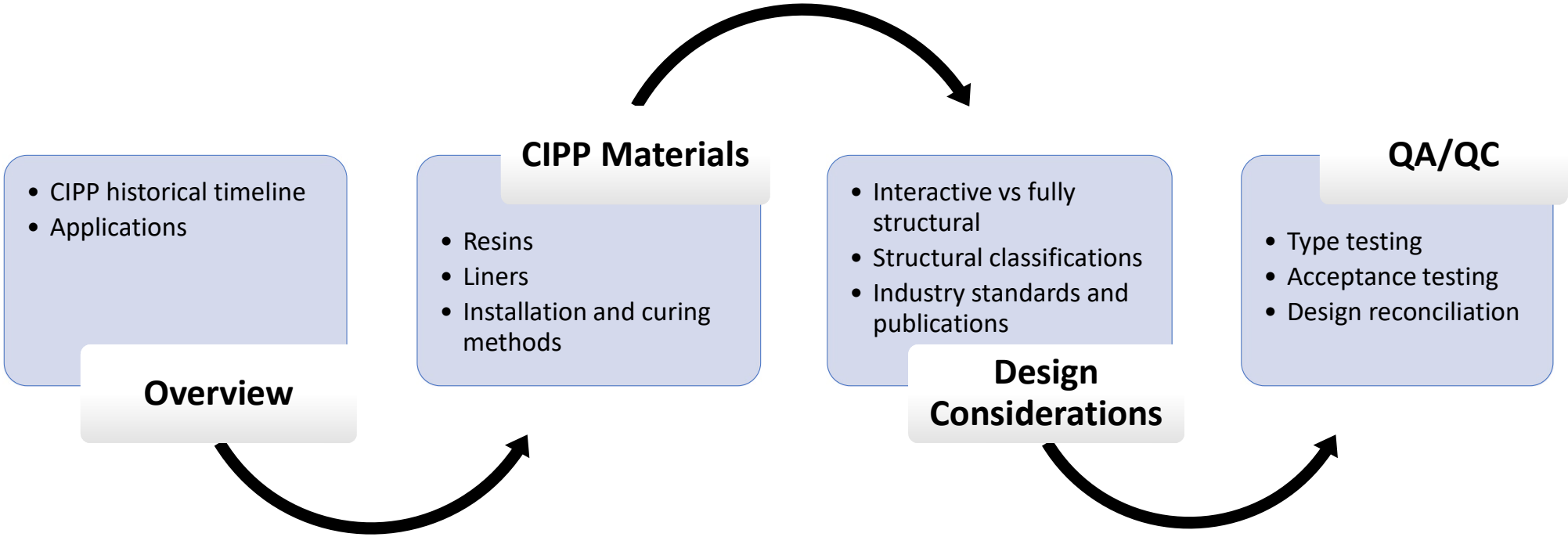
UNDERGROUND CONSTRUCTION TECHNOLOGY
The Underground Utilities Event | July 13-15, 2021 | Music City Center | Nashville, TN

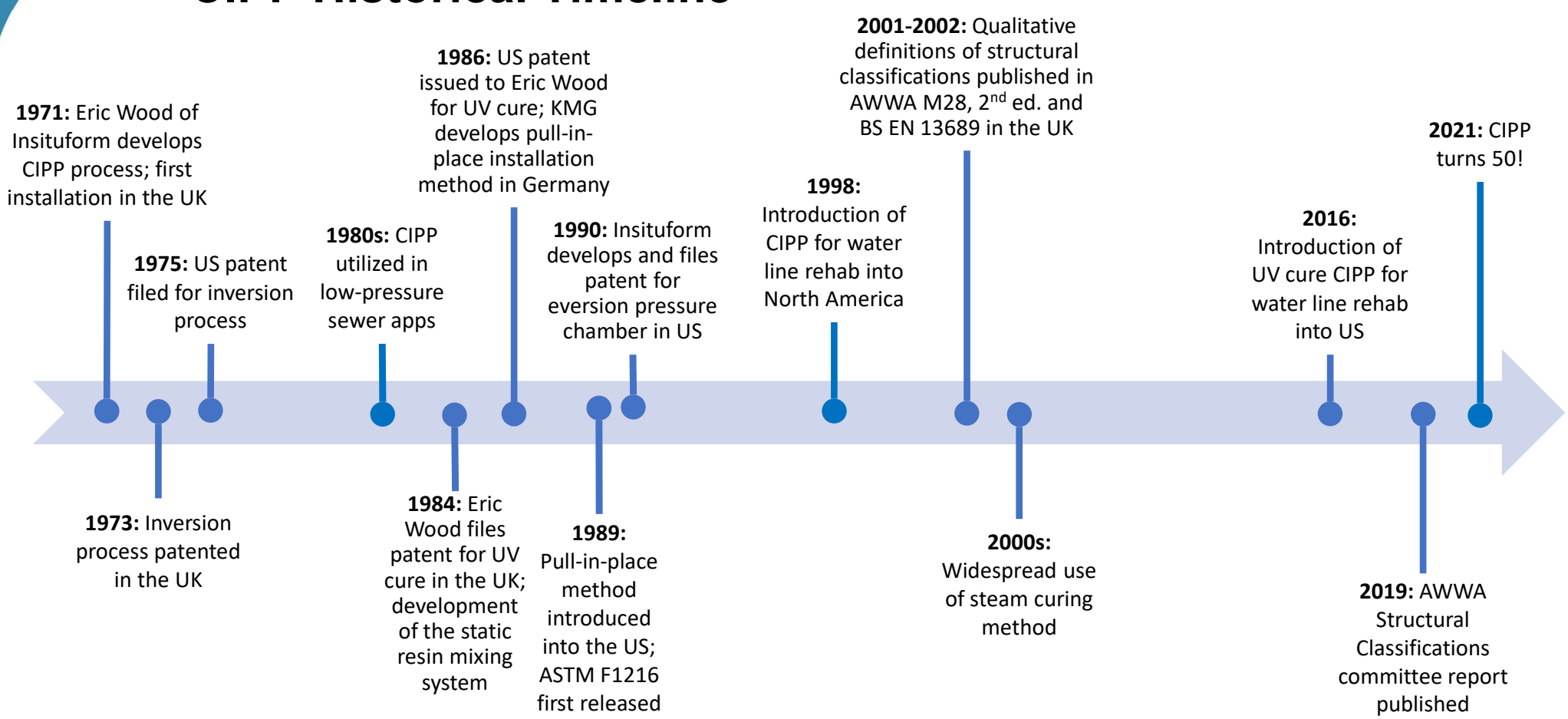
Evolution of Cured-In-Place Pipe (CIPP) for Fully Structural Pressure Pipe Renewal

David P. Kozman, P.E.
Senior Product Engineer

Introduction



CIPP Historical Timeline



CIPP Applications

Gravity-Flow:

- Sanitary sewers & laterals
- Storm sewers
- Culverts
- Roof drains
- Ventilation systems

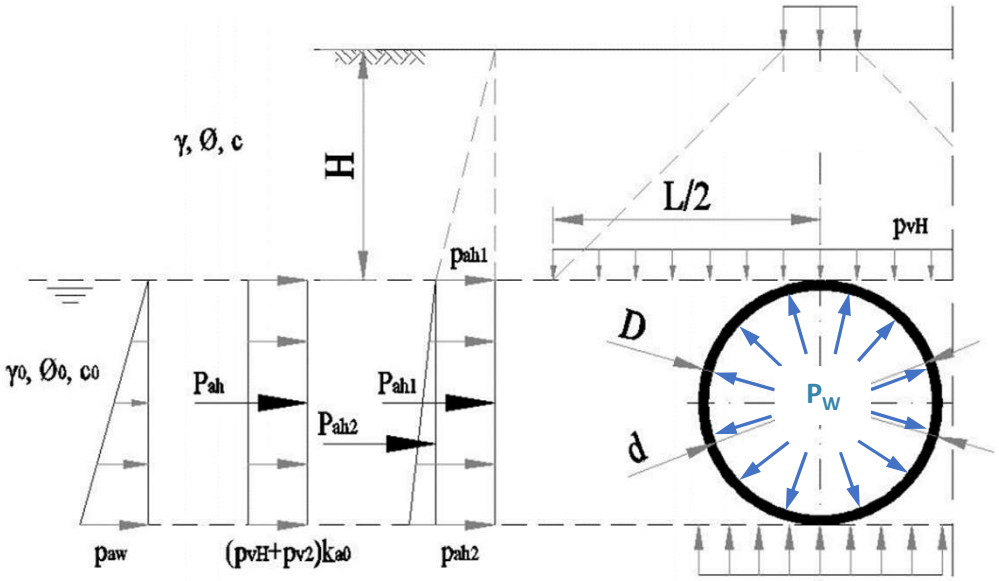
Pressure Pipe:

- Potable water
- Raw water
- Sewer force mains
- Fire suppression
- Industrial settings

CIPP Material Composition

Gravity-Flow

- Designed for external loadings:
  - Hydrostatic pressure
  - Live and dead loads
- Materials:
  - Polyester, vinyl ester or epoxy resins
  - Needled felt, felt-fiberglass or fiberglass reinforced liner with thermoplastic coating

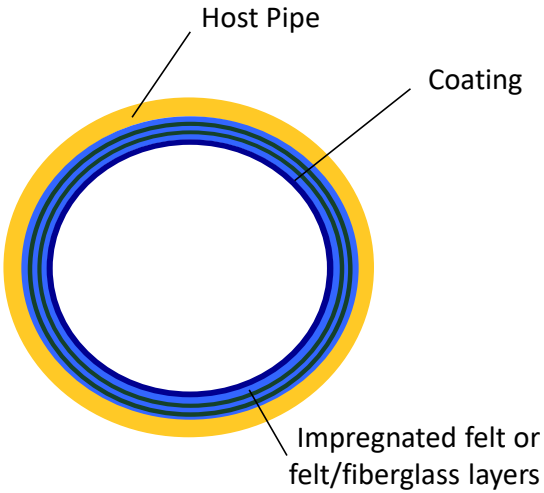


Pressure Pipe

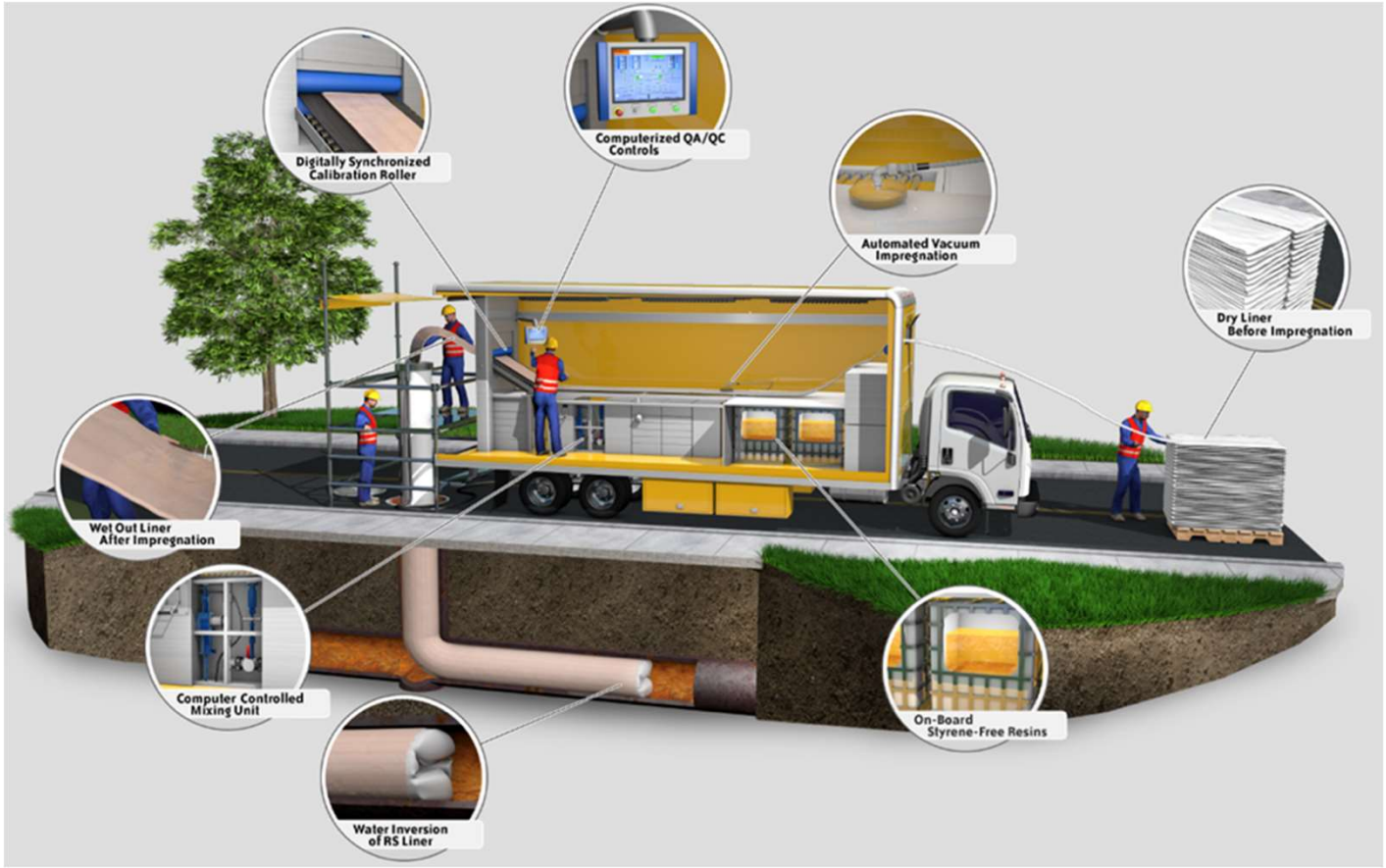
- Designed for external and internal loadings:
  - Hydrostatic pressure
  - Vacuum
  - Live and dead loads
  - Internal pressure (static and transients)
- Materials:
  - Epoxy or vinyl ester resins
  - Felt-fiberglass, fiberglass reinforced or woven hose liner with thermoplastic coating

CIPP Materials: Felt-Fiberglass Tube

Diameter Range	6”-96” (150-2400 mm)
Operating Pressure	Up to 300 psi (diameter dependent)
Liner	Felt/fiberglass composite with thermoplastic coating
Composite design	Bi-directional fiberglass-felt composite; undersized and designed to expand radially and uniformly under pressure to form a tight fit against the host pipe
Resin systems	Epoxy or vinyl ester
Impregnation method	Vacuum impregnation; resin proportionally mixed using static mixing or computer-controlled systems per ASTM F2994 at a fixed facility or at or near the jobsite
Installation method	Inversion (air or water) per ASTM F1216 or pull-in per ASTM F1743
Curing method	Controlled steam or hot water
Bends	Up to 45°
Installation lengths	Up to 1,300 LF (400 m)
Host pipe materials	All types
Short term burst pressure (ASTM D1599)	200-1,200 psi (diameter dependent)



Felt-Fiberglass Tube – Impregnation



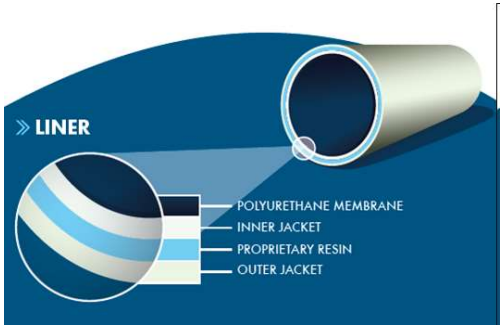
Felt-Fiberglass Tube Installation – Water Inversion

Felt-Fiberglass Tube Installation – Air Inversion

Felt-Fiberglass Tube Installation – Air Inversion

CIPP Materials: Woven Hose

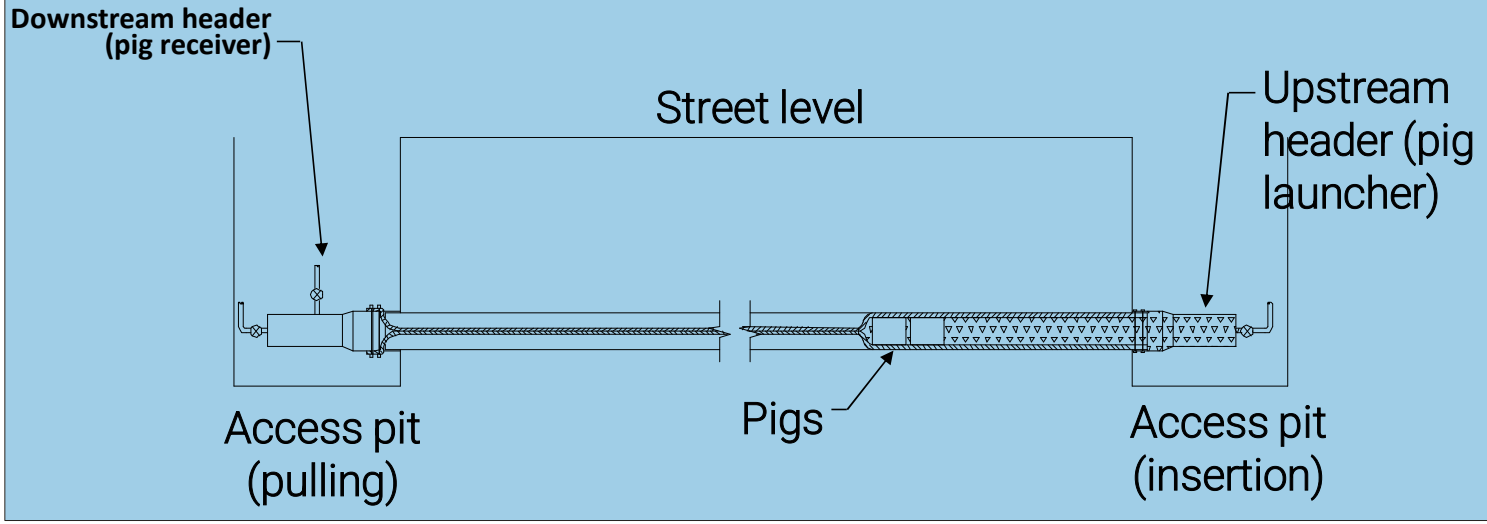
Diameter Range	6”-24” (150-600 mm)
Operating Pressure	Up to 150 psi (diameter dependent)
Liner	Woven polyester jacket with polymer coating
Composite design	Woven jacket is oversized to insure a tight fit against the host pipe
Resin system	Epoxy
Impregnation method	Resin injection; reliance on natural saturation through wicking, gravity and mechanical force
Installation method	Pull-in and expansion with progressive pig and water pressure
Curing method	Hot water
Bends	Up to 45°
Installation lengths	Up to 1,000 LF (305 m)
Short term burst pressure (ASTM D1599)	400 psi



Woven Hose – Installation Process

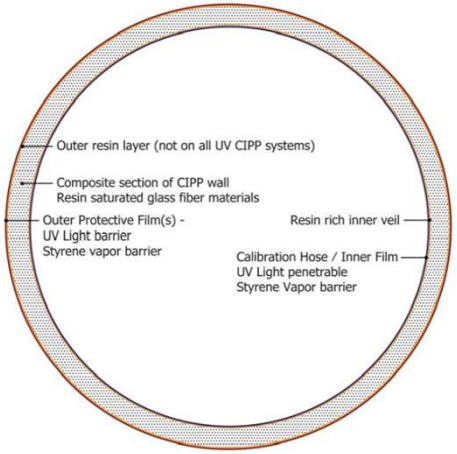
Water provides :

- *The pressure to apply the resin impregnated flexible tube against the inner surface of the host pipe;*
- *The temperature for curing of the resin and hardening of the composite material.*

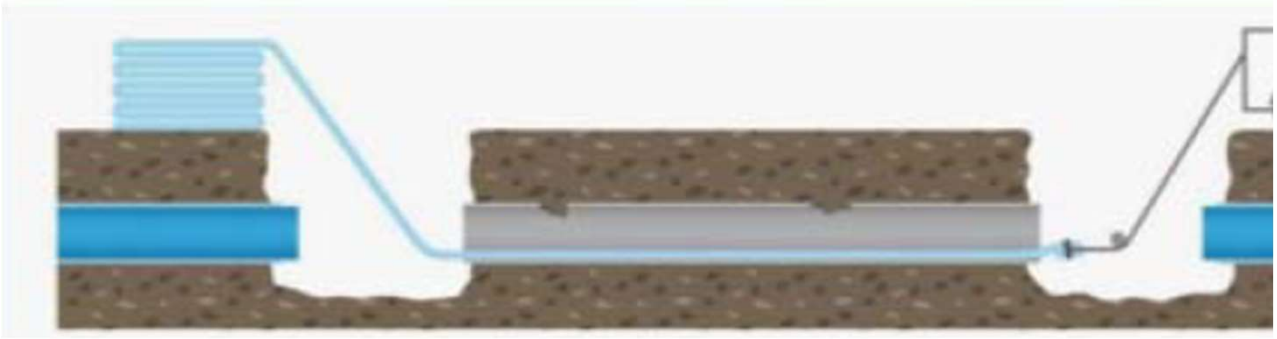


CIPP Materials: Reinforced Textile Tube

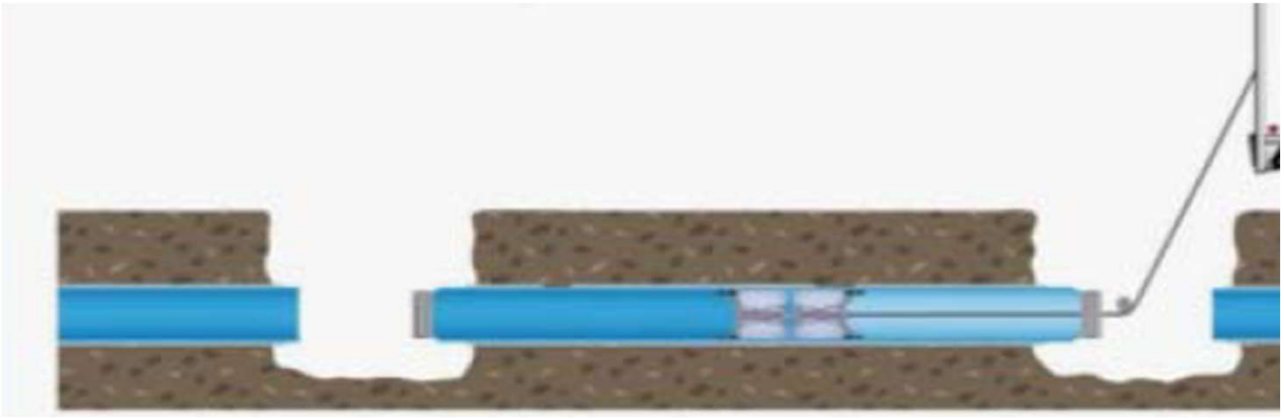
Diameter Range	10”-48” (250-1200 mm)
Operating Pressure	Up to 450 psi (diameter dependent)
Liner	Multi-axial glass fibers
Composite design	Resin-fiberglass with an outer and inner plastic film
Resin system	Vinyl ester
Impregnation method	Factory impregnation
Installation method	Pull-in-place per ASTM F2019
Curing method	Photoinitiated reaction (UV light)
Bends	Not recommended
Installation lengths	Up to 1,150 LF (350 m)



Reinforced Textile Tube – Installation Process



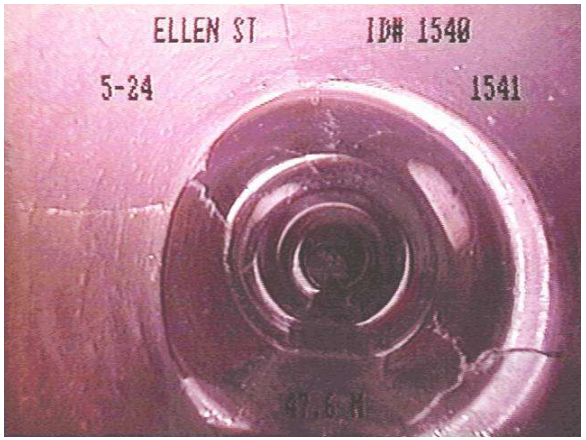
Access to the existing pipeline is made and the liner is pulled into place

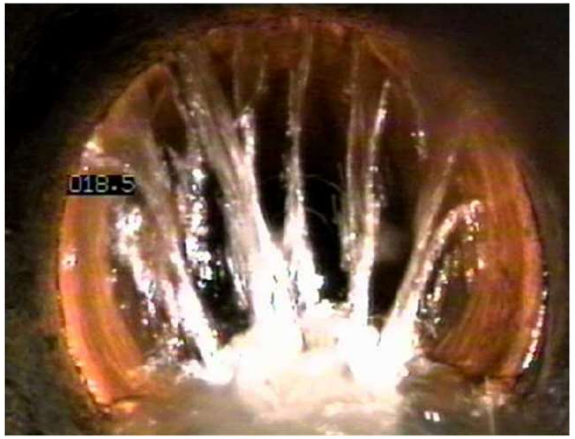


The liner is pressurized with air and cured with a UV light train

Gravity-Flow CIPP Design Conditions ASTM F1216, Appendix X1

- **Partially Deteriorated Host Pipe**
  - Infiltration
  - Root intrusion
  - Flow restrictions
  - May have longitudinal cracks and up to 10% ovality





Gravity-Flow CIPP Design Conditions ASTM F1216, Appendix X1

- **Fully Deteriorated Host Pipe**
  - Failure is imminent
  - Missing or collapsed sections
  - Host pipe lost its original shape
  - Corrosion

Pressure Pipe CIPP Design Conditions – AWWA M28

- **Class III: Semi-Structural (Host Pipe Interactive)**
  - ➢ Host pipe structurally sound
    - Joint leaks
    - Pin holes
    - Internal corrosion

- **Class IV: Fully Structural**
  - ➢ Liner handles all internal and external loadings
    - Material degradation
    - External corrosion

Pressure Pipe Lining Design

AWWA M28 Class III?

Groundwater pressure
Hole spanning

X1.3.1 *Partially Deteriorated Pressure Condition*—A CIPP installed in an existing underground pipe is designed to support external hydrostatic loads due to groundwater as well as withstand the internal pressure in spanning across any holes in the original pipe wall. The results of Eq X1.1 are compared to those from Eq X1.6 or Eq X1.7, as directed by Eq X1.5, and the largest of the thicknesses is selected. In an above-ground design condition, the CIPP is designed to withstand the internal pressure only by using Eq X1.5-X1.7 as applicable.

ASTM F1216
Partially Deteriorated Pressure Condition

ASTM F1216
Fully Deteriorated Pressure Condition

X1.3.2 *Fully Deteriorated Pressure Pipe Condition*—A CIPP to be installed in an underground condition is designed to withstand all external loads and the full internal pressure. The design thicknesses are calculated from Eq X1.1, Eq X1.3, Eq X1.4, and Eq X1.7, and the largest thickness is selected. If the pipe is above ground, the CIPP is designed to withstand internal pressure only by using Eq X1.7.

External loads
Pipe stiffness
Internal pressure

AWWA M28 Class IV?

AWWA M28 Class II-IV?

Vacuum

X1.4 *Negative Pressure*—Where the pipe is subject to a vacuum, the CIPP should be designed as a gravity pipe with the external hydrostatic pressure increased by an amount equal to the negative pressure.

ASTM F1216
Negative Pressure

AWWA M28, Appendix A:

- **Class I:** Non-structural, corrosion barrier
- **Class II-III:** Semi-structural, host pipe interactive
- **Class IV:** Fully structural

No Correlation Between ASTM F1216 and AWWA M28

Pressure Pipe Lining Design

2019 Committee Report

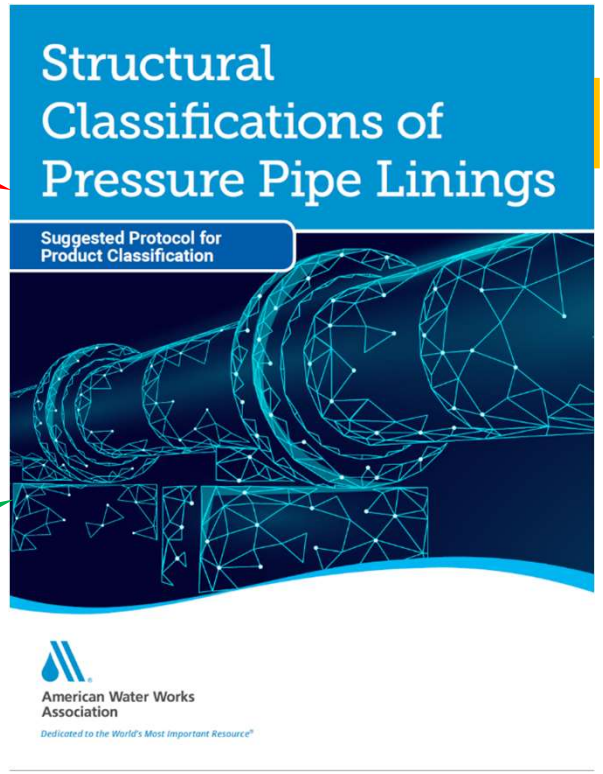
Testing

Type

Demonstration

Acceptance

Design



Content Integration

4th Edition (In Progress)

Manual of Water Supply Practices
M28
Rehabilitation of Water Mains

Addresses All Class I-IV Technologies:

- Cement mortar lining (CML)
- Spray-on polymer lining (PL)
- Cured-in-place pipe lining (CIPP)
- Close-fit lining (CFL)
- Sliplining (SL)
- Carbon fiber reinforced polymer (CFRP)
- Pipe bursting

Pressure Pipe Lining Design

AWWA SCPPL

- Establishes more concrete definitions, design, testing and acceptance criteria for Class I through IV pressure pipe lining systems
- Each structural classification presented as a sequential building block

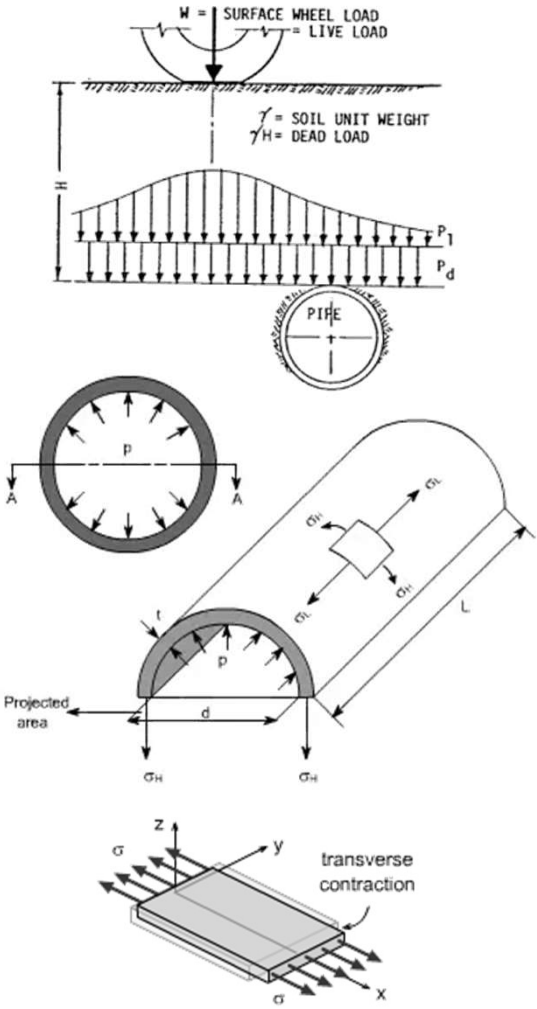
Lining System Characteristic	Non-Structural	Semi-Structural (Interactive)		Fully Structural
	Internal Coating	*Hole span*	*Hole span + ring stiffness*	*Structural Resistance for all specified loads (internal & external)*
	Class I	**Class II**	**Class III**	**Class IV**
Internal corrosion protection	✔	✔	✔	✔
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 discontinuites)		✔	✔	✔
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.*

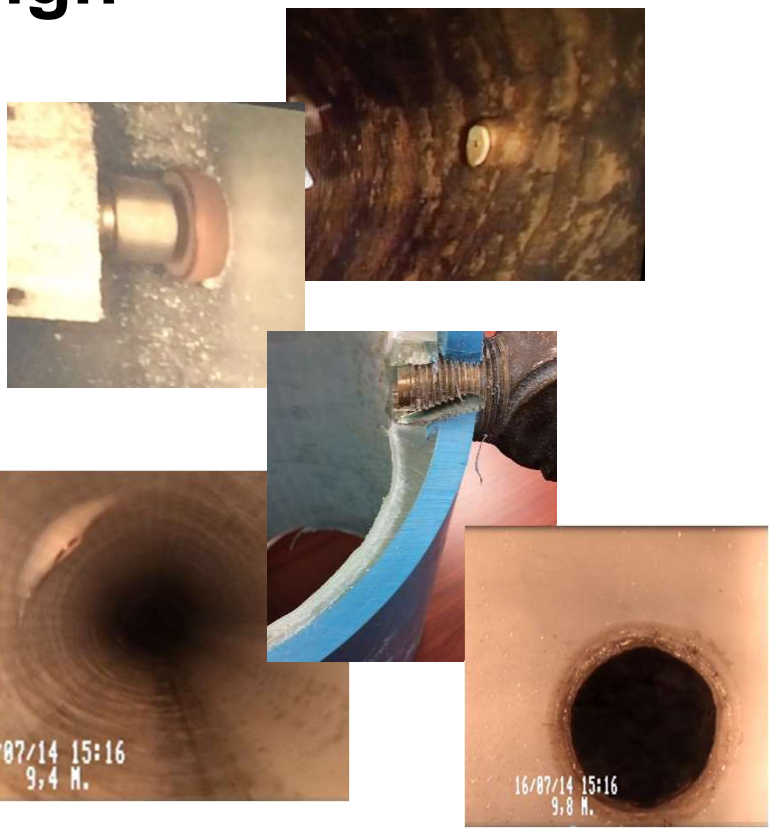
Pressure Pipe Lining Design

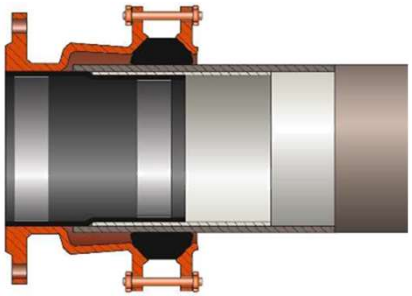
Design Check	ASTM F1216	AWWA M28	AWWA SCPPL
Hoop (Circumferential) Direction			
Working Pressure	•		•
Transient Pressure			•
Vacuum Pressure			•
Live loads	•		•
Soil loads	•		•
Ovality	•		•
Deflection Limits			
Combined Loading			
Longitudinal (Axial) Direction			
Poisson's Effect			•
Thermal Effects			•
Thrust Restraint			•



Pressure Pipe Lining Design

- **Importance of maintaining hydrostatic integrity**
  - Enhanced through reliable adhesion between liner and host pipe
    - Robotic service reinstatements
  - Use of mechanical end seals

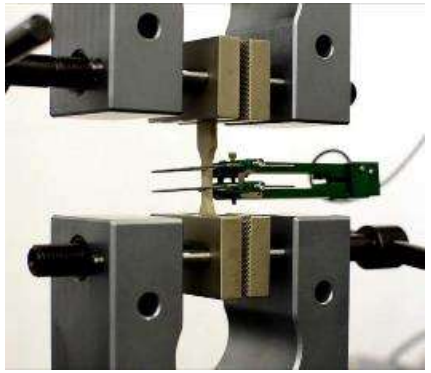




Pressure Pipe CIPP QA/QC

- **Design**
  - Short-term and long-term properties
  - Hoop vs axial directions

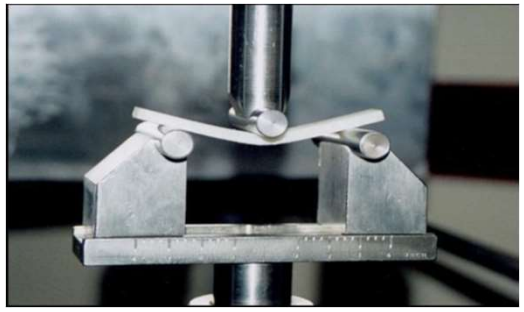
- **Type Testing**
  - Forms basis of design
  - Short-term testing (hoop and axial)
    - Tensile: ASTM D2290, D3039, D638
    - Flexural: ASTM D790
  - Short-term burst testing: ASTM D1599
    - 4:1 reduction factor to estimate MAOP



ASTM D638

ASTM D2290

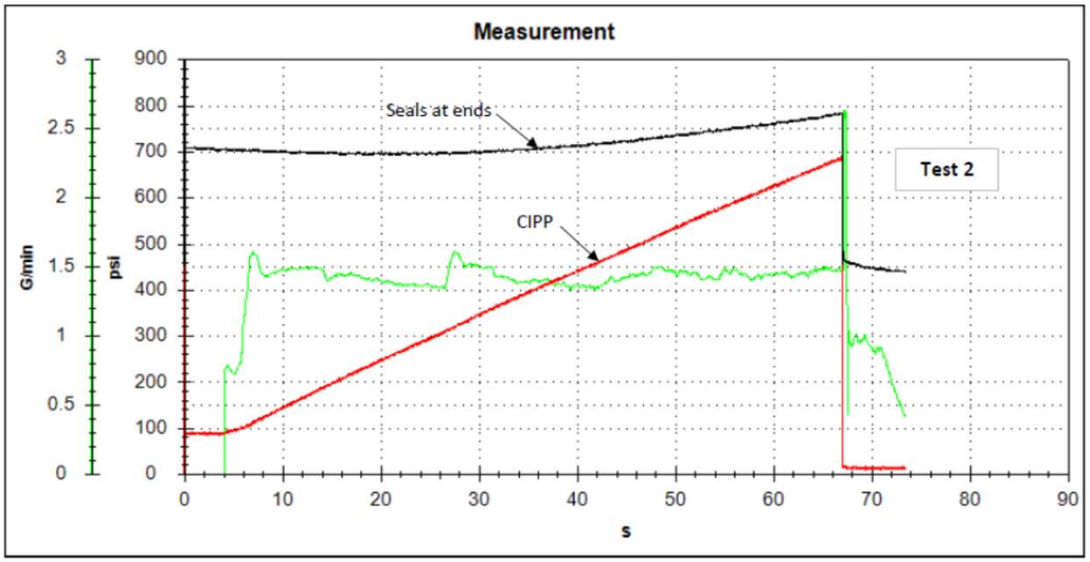
ASTM D1599

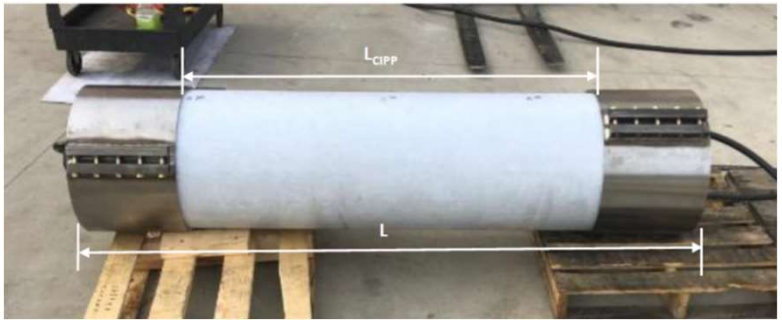


ASTM D790

Short-Term Type Testing

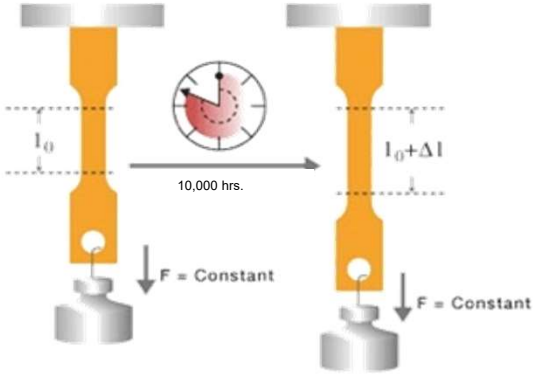
ASTM D1599: Short-Term Burst





- Short-term burst of unrestrained CIPP samples (60-70 second test duration)
- **Estimated pressure rating = burst pressure / 4**

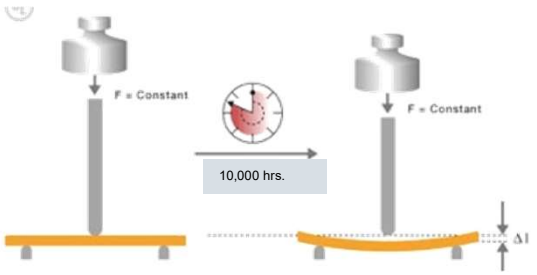
Long-Term Type Testing



ASTM D2990

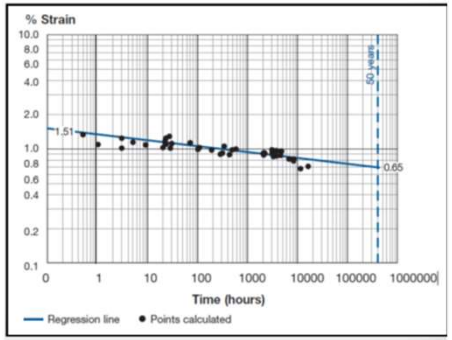
Tensile Creep

DIN EN 761



ASTM D2990

Flexural Creep

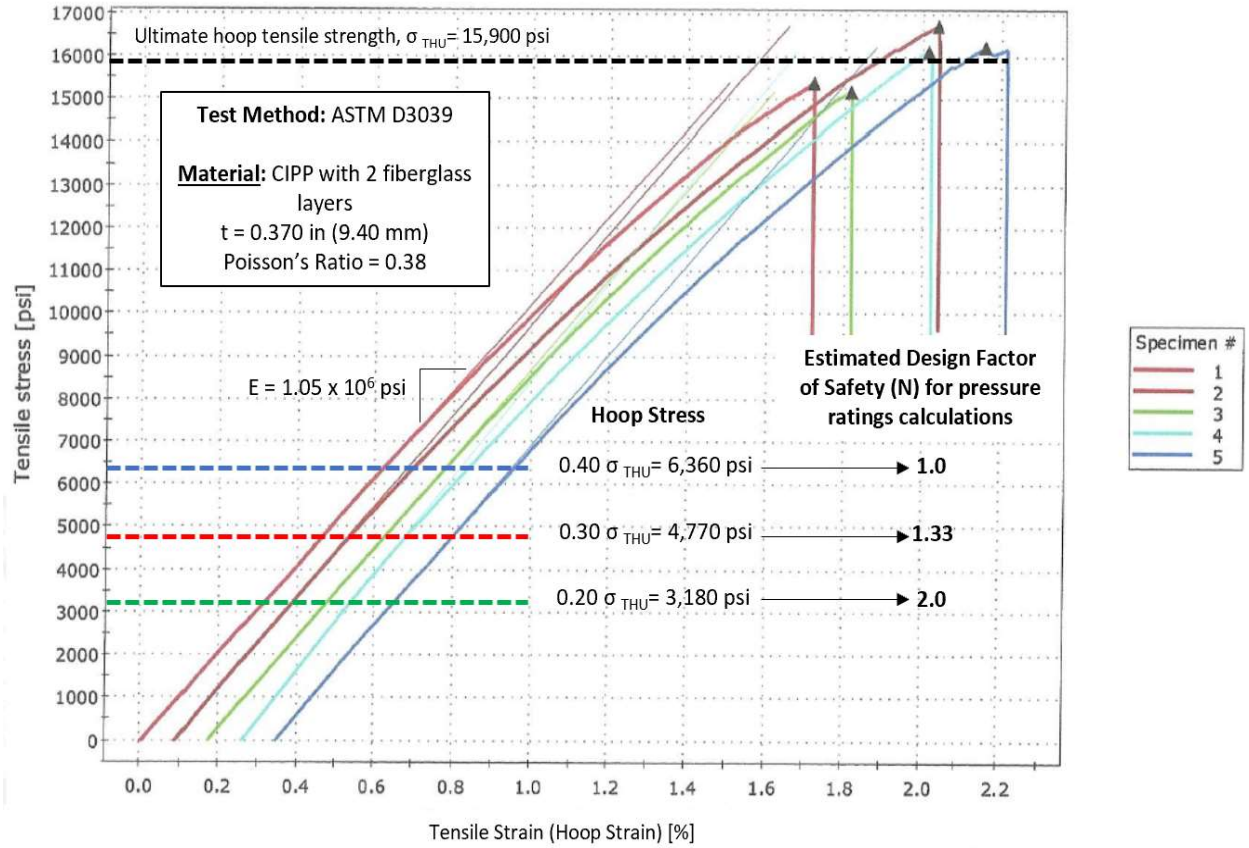


ASTM D2992

Hydrostatic Design Basis (HDB)

Long-Term Type Testing

ASTM D2990: Tensile Creep

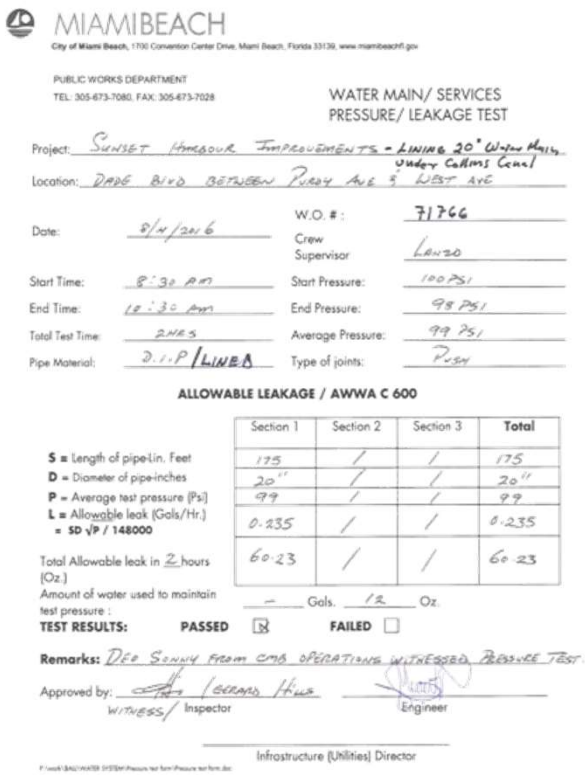


Pressure Pipe CIPP QA/QC

- **Post-lining CCTV inspection**
  - Confirm fit and finish
  - Identify any potential problem areas: fins, lifts, dry spots, discolorations

Pressure Pipe CIPP QA/QC

- **Hydrostatic Testing**
  - After end seal installations but prior to service reinstatements
  - Test individual sections
  - Eliminate trapped air
  - Establish test pressure
    - ASTM F1216: 2 times MAOP or MAOP plus 50 psi, whichever is less
    - AWWA: 1.5 times MAOP
  - Proper venting (eliminate vacuum)
- **Acceptance Testing**
  - Confirms in-place properties
  - Short-term tensile and flexural testing (hoop and axial)
    - Restrained samples or plates – must be representative of the installed product
- **Design reconciliation as required**



MIAMIBEACH
City of Miami Beach, 1700 Convention Center Drive, Miami Beach, Florida 33139, www.miamibeachfl.gov

PUBLIC WORKS DEPARTMENT
TEL: 305-673-7080, FAX: 305-673-7028

WATER MAIN/ SERVICES
PRESSURE/ LEAKAGE TEST

Project: SUNSET HARBOUR IMPROVEMENTS - LINING 20" Water Main under Collins Canal
Location: DADE BLVD BETWEEN PURDY AVE & WEST AVE

Date: 8/4/2016 W.O. #: 71766
Crew Supervisor: LAZO
Start Time: 8:30 AM Start Pressure: 100 PSI
End Time: 10:30 AM End Pressure: 98 PSI
Total Test Time: 2HRS Average Pressure: 99 PSI
Pipe Material: D.I.P/LINER Type of joints: PUSH

ALLOWABLE LEAKAGE / AWWA C 600

	Section 1	Section 2	Section 3	Total
S = Length of pipe-Lin. Feet	175	/	/	175
D = Diameter of pipe-inches	20"	/	/	20"
P = Average test pressure (Psi)	99	/	/	99
L = Allowable leak (Gals/Hr.) = SD √P / 148000	0.235	/	/	0.235
Total Allowable leak in 2 hours (Oz.)	60.23	/	/	60.23

Amount of water used to maintain test pressure : — Gals. 12 Oz.

TEST RESULTS: PASSED ☒ FAILED ☐

Remarks: DEO SONNY FROM CMB OPERATIONS WITNESSED PRESSURE TEST

Approved by: GERARD HIRE
WITNESS / Inspector Engineer

Infrastructure (Utilities) Director

Pressure Pipe Lining – Industry Publications

- Committee Report, "Structural Classifications of Pressure Pipe Linings – Suggested Protocol for Product Classification"
- Manual of Practice No. M28, *Rehabilitation of Water Mains*
- C305, *CFRP Renewal and Strengthening of Precast Concrete Cylinder Pipe (PCCP)*
- C620, *Spray-In-Place Polymeric Lining for Potable Water Pipelines, 4 in (100 mm) and Larger*
- C622, *Pipe Bursting of Potable Water Mains, 4 in (100 mm) to 36 in (900 mm)*
- Standards in progress: CIPP, sliplining, applied linings

- F1216, "Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube," Appendix X1

- NM.1 – Thermoplastic Piping Systems
- NM.2 – Glass-Fiber-Reinforced Thermosetting-Resin Piping Systems

- ISO 11297: *Plastics piping systems for renovation of underground drainage and sewerage networks under pressure*
- ISO 11298: *Plastics piping systems for renovation of underground water supply networks*

THANK YOU!

David P. Kozman, P.E.
Senior Product Engineer
(614) 832-2860
dkozman@hhtrenchless.com

HAMMERHEAD TRENCHLESS