

Non-Metallic Materials

Update on EPRI Observations and R&D



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Industry/NRC materials Technical Exchange Meeting
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Buried Pipe Non-Metallic Repair & Replacement Options



HDPE

High Density Polyethylene



CFRP

Carbon Fiber Reinforced Polymer



SIPP

Spray-in-Place Piping

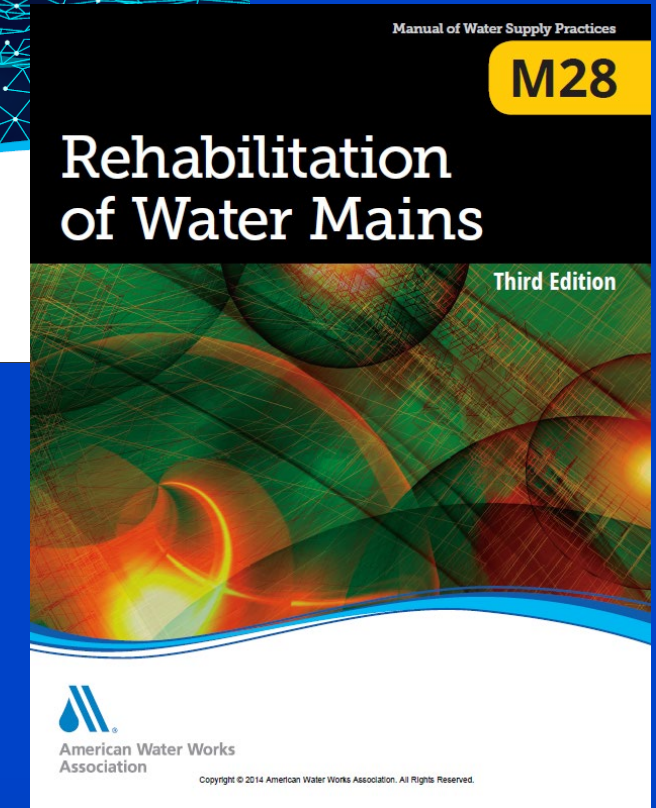
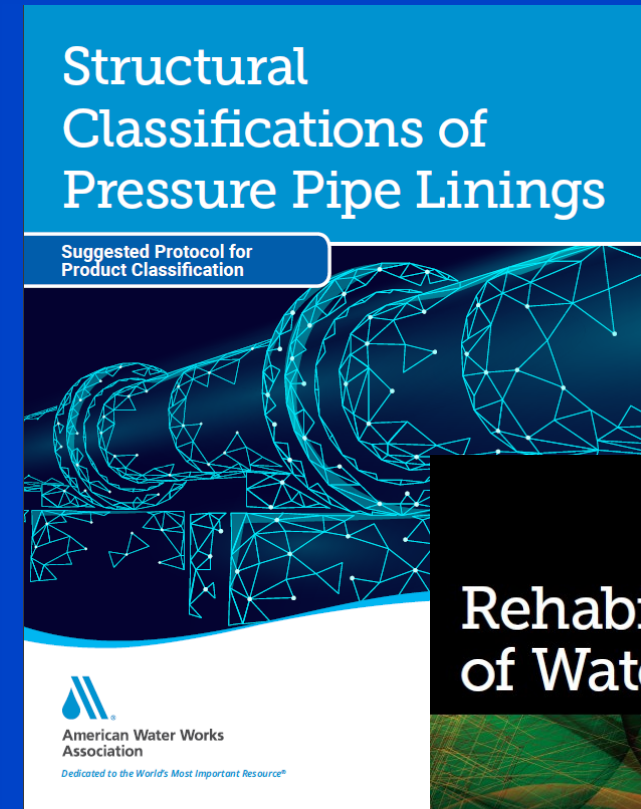


CIPP

Cured-in-Place Piping

Structural Classification of Linings / Repairs

- AWWA defines four (4) classifications of internal repairs to buried pipe
 - Class I
 - Protect pipe surface from corrosion
 - Non-structural
 - Class II
 - Semi-structural
 - Adhere to pipe
 - Sustain pressure at holes/gaps in pipe wall
 - Class III
 - Semi-structural
 - Some ring-stiffness
 - Class IV
 - Fully-structural; host pipe no longer credited with any loads



Comparison

	HDPE	CFRP	SIPP	CIPP
In-Situ Repair / Rehab	✗	✓	✓	✓
Requires Excavation	✓	✗	✗	–
Fully Structural	✓	✓	–	–
Partially Structural		✓	–	–
Non-Structural		✓	✓	✓
Complex Geometries (elbows, tees)	✓	✓	–	✗
Common Systems	SW, FP	SW, CW	SW, FP, CW, drains	SW, FP, drains, yard drain
Diameters	Variable, < 60 in. (1.5 m)	>30 in. (760 mm)	Variable	2 – 110 in. 5 cm – 2.8 m

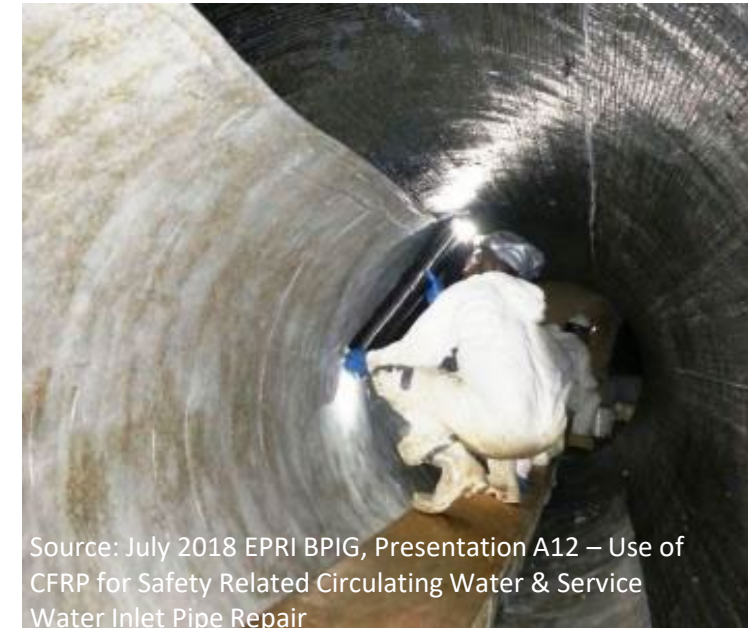
Carbon Fiber Reinforced Polymer (CFRP) Composites

What is it?

Composite system comprised of multiple layers of carbon fiber fabric, saturated in a polymer resin and hand applied to pipe

How Used?

- Can be installed on inside or outside of piping
- Applicable to multiple pipe material substrates, including carbon steel and concrete
- Used to reinforce or structurally replace the existing pipe



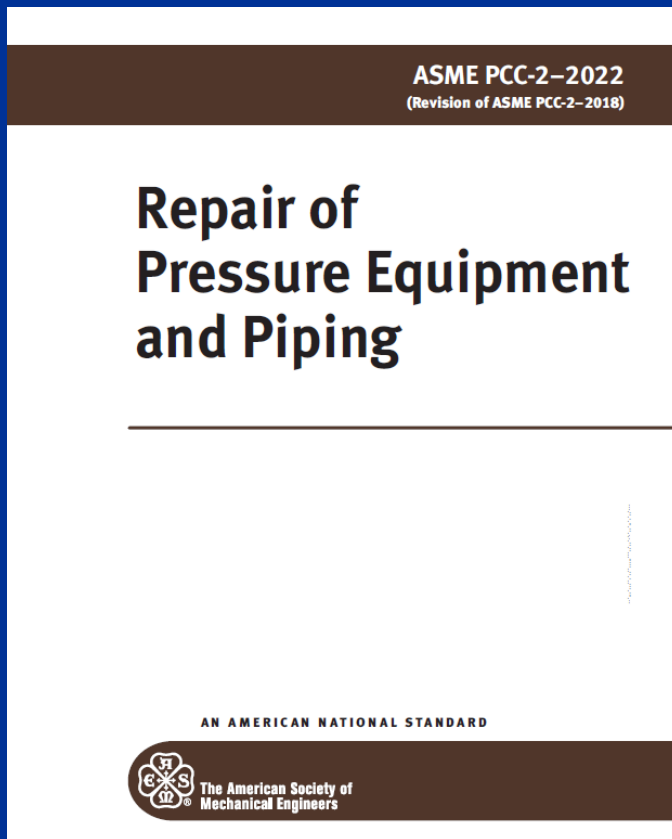
Source: July 2018 EPRI BPIG, Presentation A12 – Use of CFRP for Safety Related Circulating Water & Service Water Inlet Pipe Repair



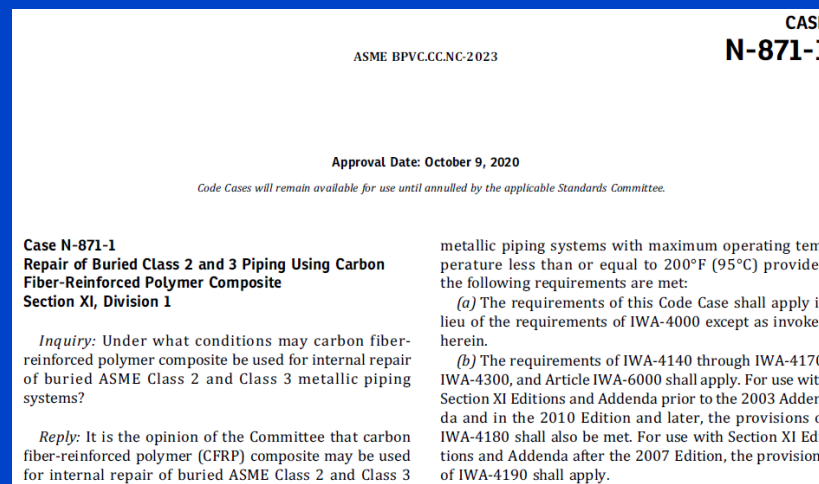
Cross-Section of CFRP Mock-up: 0.375-in. steel with 5 layers of CFRP

CFRP Industry Standards

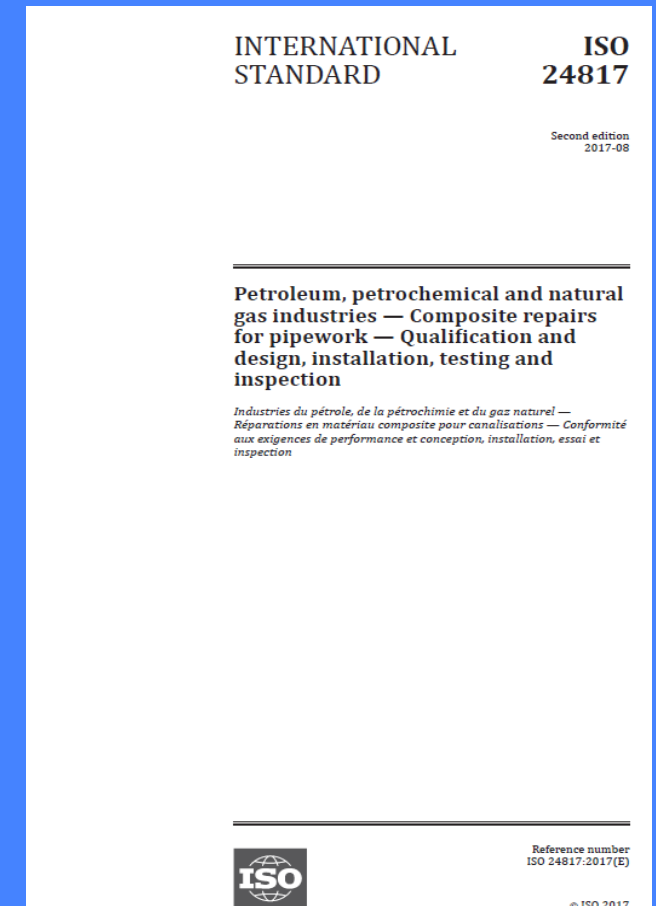
- ASME PCC-2
 - Part 4: Non-Metallic and Bonded Repairs



- ASME Code Case N-871
 - Repair of Buried Class 2 and 3 Piping Using Carbon Fiber Reinforced Polymer Composite



- ISO 24817



CFRP Industry Use

Five (5) stations have approved Relief Requests for CFRP repair of buried pipe



Surry

Approved and Installed



South Texas Project (STP)

Approved



Arkansas Nuclear One (ANO)

Approved



Brunswick

Approved and Installed



Calvert Cliffs

Approved

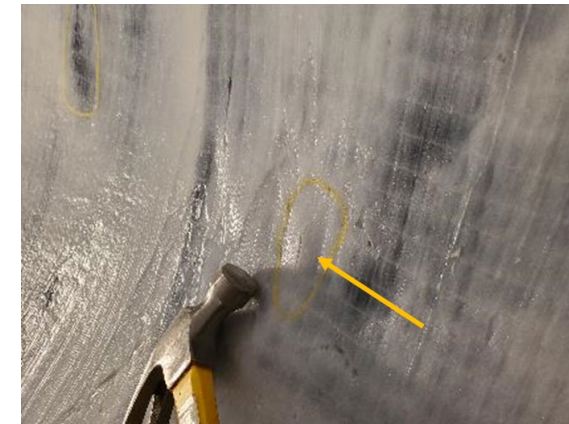
NDE of Substrates Beneath Composites (3002020823)

- Terminal ends of CFRP repairs require the substrate to meet all original minimum thickness requirements
- CFRP too attenuative for conventional ultrasonic techniques to measure substrate thickness beneath composite
- [3002020823](#) (March 2022) identified & assessed 2 viable techniques
- Results supported ASME Code Case progression



NDE of Composites

- Potential flaws in CFRP composites include: loss of adhesion, delamination, blisters
- Current inspections methods: visual, acoustic tap testing
- Report 3002032154 (2025)
 - Evaluated techniques using fabricated mock-ups using manual & automated acoustic tap testing, and UT methods
 - In collaboration with NRC & PNNL



Advanced UT for CFRP

- Overview

- Building on 3002032154 (2025)
- Exploration and assessment of advanced UT methods for evaluating the CFRP laminate material

- Approach

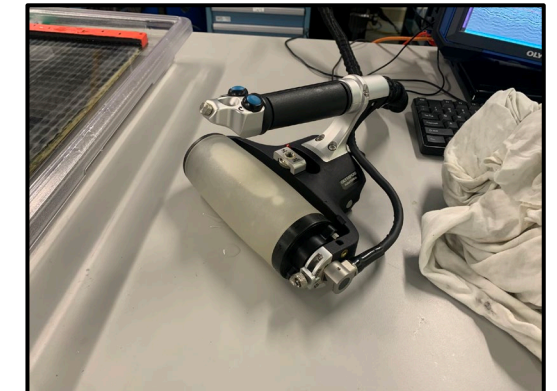
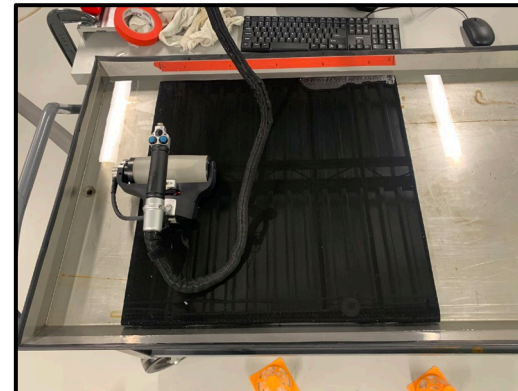
- Scan pre-existing mock-ups with state-of-the-art UT algorithms, including FMC/TFM
- Supplement mockup inventory with new samples, based on results
- Trial of optimal probe configuration based on results and vendor consultation

- Status

- 45 EPRI mock-ups have been examined
 - Two different UT instruments; linear electronic scan and FMC/FM
 - Detectability of flaws varies strongly and shows strong dependence upon vendor as well as the flaw type
- Sample of EPRI CFRP mockups provided to several vendors for in-house assessment

- Future Plans

- Targeting additional probes/techniques for 2nd half of 2026
- Considering construction of additional mock-ups by end of 2026, as needed and based on results of Phase I and Phase II
 - Consider destructive testing of select specimens for confirmation
- Technical update planned for Q4 2026




Encoded UT scanning of large plates underway

Performance of CFRP with Increasing Temperature

Three distinct regions:

1. **Below** glass transition:
 - Resin is hard and brittle
 - CFRP design assumes that operation is within this region
2. **Within** the glass transition range
 - Material behavior of the resin is transitioning from hard and brittle to soft and rubbery
 - Occurs over a range (e.g., ~54°F, 12°C)
 - Mechanical properties are variable
 - “Glass Transition Temperature” is a point within this region, the position of which is dependent on test method
3. **Above** glass transition:
 - Resin is soft and rubbery

Questions:

- What factors can affect and influence T_g ?
 - How do different methods of determining T_g compare?
 - DSC vs. DMA
 - Variability of measured values within a sample set?
- 
- **What is an appropriate amount of margin to specify between the composite's glass transition temperature (T_g) and a piping system's maximum design temperature?**

CFRP Glass Transition Temperature

Scope

- Evaluate consistency of measured T_g:
 - Within and across different material lots
 - For different vendor resin systems
 - At different applied curing temperatures
 - With variable concentrations of resin thickeners
- Evaluate variances in test methods

Approach

- Literature review of factors affect T_g
- Leverage Technical Advisory Group to inform
 - Variables of interest
 - Testing Methods
 - Sample Sizes
 - Project Priorities

Status

- 2025
 - Literature review on factors affecting T_g
 - Development of preliminary test matrix
- 2026
 - Completed Baseline Testing
 - Target 100% cure
 - Elevated cure temp and time
 - Prioritize alternate cure time and temperature testing
- 2027+
 - Additional resin suppliers
 - TAG input on priority of other variables

Future Areas of Potential Research



Critical Flaw Sizes

- Improve understanding & enhance technical basis for CFRP flaw sizes



Material Testing

- Cure temperature variables
- Mech. properties at >10k hours



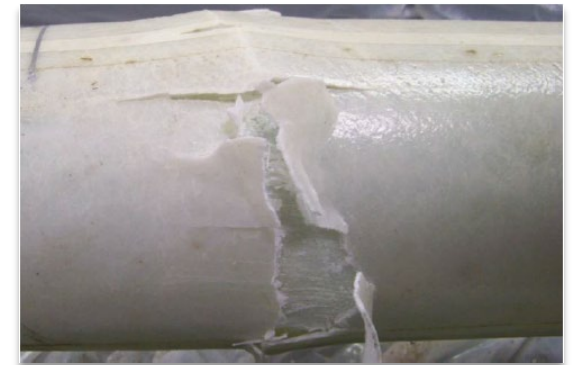
Guidance

- Owner's Guide for Design, Installation, and Inspection of CFRP Repair Systems



Performance Validation

- Address design, material, and installation uncertainties
- Validate field tests match performance predicted by design

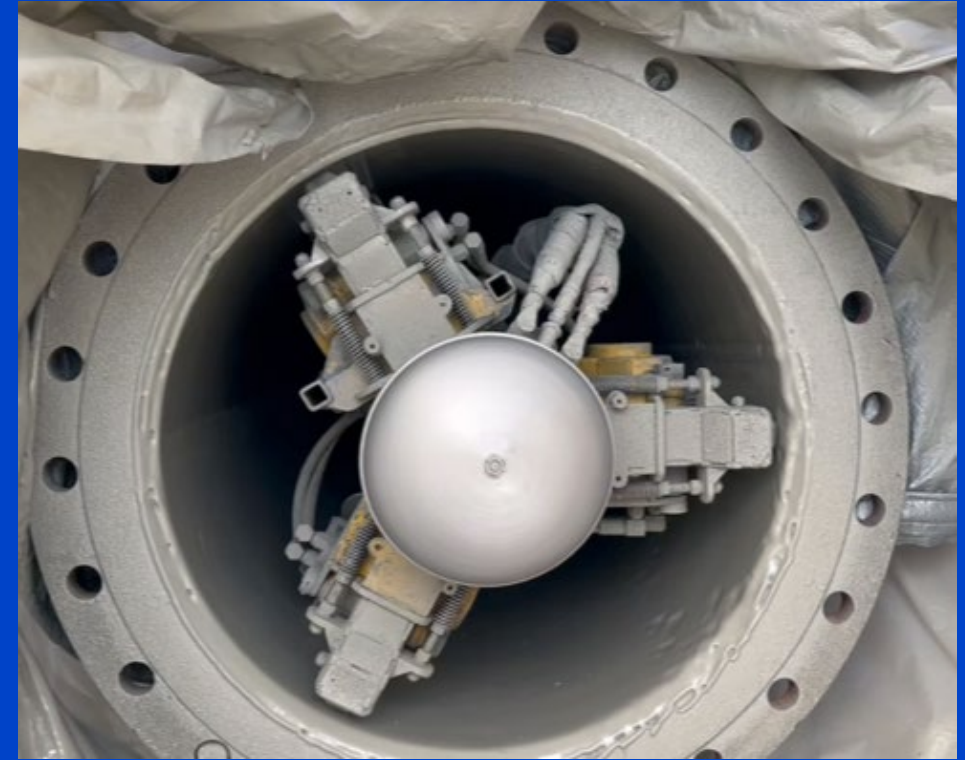




Spray In Place Pipe (SIPP)

Spray-in-Place Polymer (SIPP) Liner

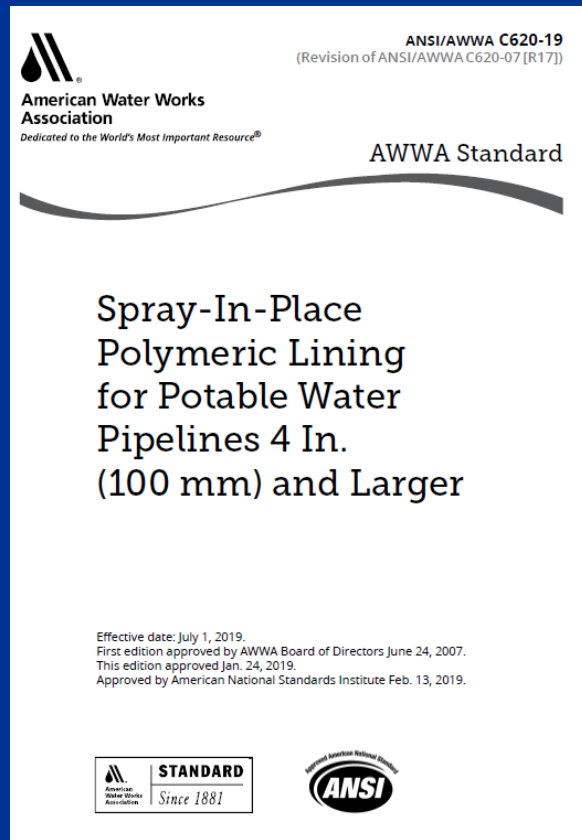
- “Trenchless” pipe rehabilitation method
- Method: manual or robotic spray equipment
- Resins: epoxy & polyurea (most common)
- AWWA Liner Classifications
 - Class I: Non-Structural
 - Class II & III: Semi-Structural
 - Class IV: Full Structural
- Significant interest within EPRI BPIG user group
 - Non-structural and structural



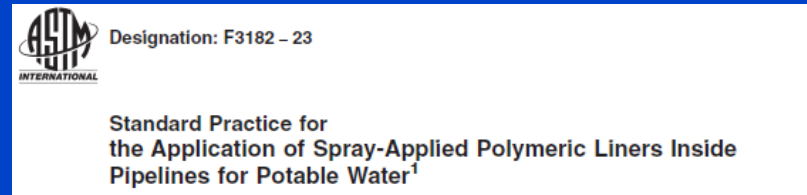
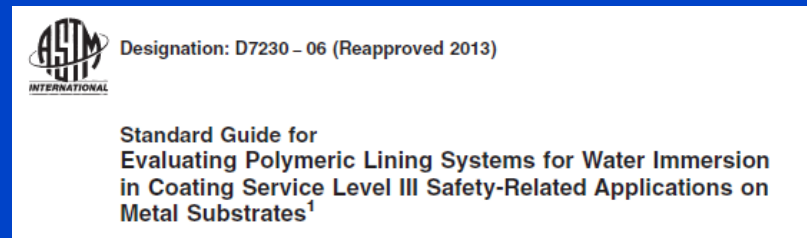
Source: 2025 BPIG meeting, B05 – Advancing SIPP Coatings and the Testing Regime for Service Level III

SIPP Industry Standards

- AWWA C620

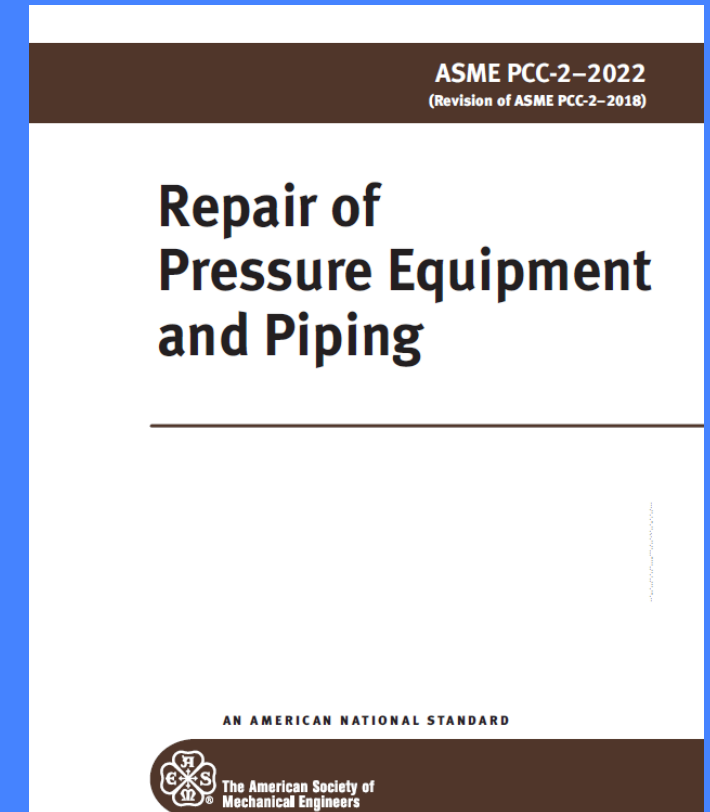


- ASTM D7230 & F3182



- ASME PCC-2

- Article 403 - Nonmetallic Internal Lining for Pipe: Sprayed Form for Buried Pipe



Technical Gaps

- Industry standards & guidance for testing to qualify SIPP installation in Safety-Related Systems (non-structural)
- Design methodologies to support semi- or fully-structural design application
- Material property performance over time (creep)
- Capacity & performance-based testing to evaluate all structural loading conditions

Proposed Research Plans

- Design and qualification guidance for SIPP as non-structural lining for safety-related piping (2025-2026 EPRI project)
- Gap assessment to identify material properties need to support structural design & Code Case development
- Accelerated aging and testing
- Long-term performance & capacity testing of SIPP as a structural repair

Non-Metallic Deliverables Summary

Product ID	Project Title	EPRI Program	Year
3002032154	Nondestructive Evaluation Performance Characteristics for Carbon Fiber Reinforced Polymer Repair Structures	NDE	2026
3002032154	Technology Assessment of Spray-in-Place Piping: Interim Report	PRR	2023
3002020823	Nondestructive Evaluation of Metallic Substrates Through Carbon Fiber Reinforced Polymer (CFRP) Composite Repair Systems	PRR	2022
3002021073	Welding and Repair Technology Center: Non-Metallic Repair of Nuclear Piping, Vessels, and Tanks	WRTC	2021
3002005334	Guidelines for Relief Request for Use of Nonmetallic Repairs of ASME Class 2 and 3 Piping	PRR	2015
1019179	Capacity Testing of Cured-in-Place Piping	PRR	2009
1013480	Design and Qualification of Cured-in-Place Liners for the Rehabilitation of ASME Safety Class 3 Piping Systems	PRR	2006
TR-106013	Cured-in-Place Piping for Structural and Pressure Boundary Integrity: Interim Report	PRR	1995
TR-103992	Recommended Practice: Cured-in-Place Pipe Liner for Rehabilitation of Service Water Piping	PRR	1994

* Including >25 reports on High Density Polyethylene (HDPE)

Summary



Increasing use of non-metallic repair & replacement options throughout the industry



Existing guidance available (HDPE, CFRP, Cured-in-Place Pipe CIPP)



EPRI research & support to ASME Codes & Standards



Material property and larger-scale performance testing



Industry guidance for design, qualification, installation, & inspection



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