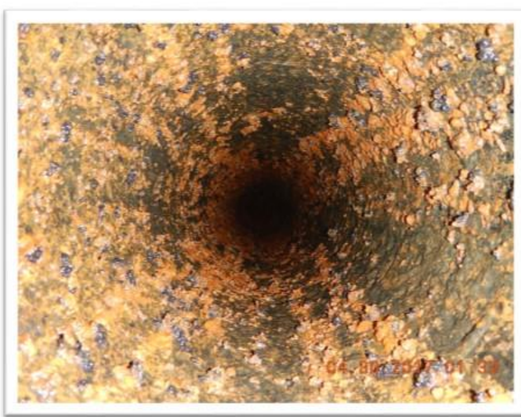
Buried Pipes Rusting? What Cured-In-Place-Pipe (CIPP) Lining Can Do for You!

As nuclear plants age, so do their pipes and the cost of replacing them can be very substantial, especially for buried piping. Several solutions exist to rehabilitate those pipes, one of them is the Cured-In-Place-Pipe (CIPP). Since its implementation in 1971, CIPP has been used worldwide to rehabilitate water distribution pipes, sewer lines, and chemical pipelines.

In commercial applications, this process is used to prevent deterioration of the pressure boundary integrity of the host pipe and to provide an internal corrosion barrier. CIPP is used extensively to rehabilitate buried piping systems because the piping can be repaired in-situ without requiring excavation. This process is very economical and piping that is difficult or impossible to replace can be repaired in place. CIPP can be a viable solution for piping in older generation nuclear units that begins to deteriorate and needs to be repaired or replaced. The Electric Power Research Institute (EPRI) has prepared a technical report, TR-103992, “Recommended Practices: Cured-in-Place Pipe Liner for Rehabilitation of Service Water Piping” [1]. This report, which was developed during a CIPP project in the service water system at the Millstone 2 Nuclear Station, contains guidance on addressing the relevant issues when using CIPP at nuclear generating facilities.



Initial Pipe Condition

Installed CIPP Liner

OVERVIEW OF CIPP

Cured-In-Place Pipe (CIPP) was first introduced in the United Kingdom in the early 70’s. The first patent [2] was granted in February 22, 1977. Since then, it has become one of the standard methods to rehabilitate piping for municipalities and industries. The CIPP process is used to ensure pressure boundary integrity of the host pipe and to provide an internal corrosion barrier. CIPP materials consist of a liner and a resin.

Liner

In pressure applications, the liner is usually a combination of three layers:

1- A barrier film that will form the inside surface of the rehabilitated pipe.

2- A felt that is impregnated with the resin

3- Fiber reinforcement layer(s)

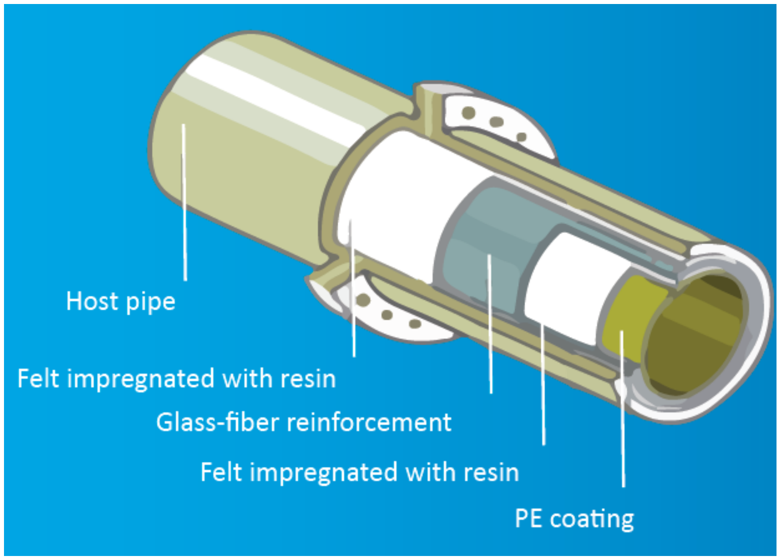


Figure 1 Schematic of an installed CIPP liner in a pipe [Error! Reference source not found.**]**

The purpose of the barrier film is to provide an impermeable layer that will protect the resin and the rehabilitated pipe from intrusion of water. Polyethylene (PE) is a good choice for this type of application and it is widely used as a material for water pipe. One of the advantages of Polyethylene is its overall chemical resistance. The liner will be resistant to salty water (e.g., sea water) as well as to common chemicals used to treat water, such as sodium hypochlorite. Polyethylene is not a nutrient source for bacteria, fungi, spores, etc. It also presents a very smooth surface that will not promote the development of biofouling. Tests performed at a nuclear facility [1, pg 5-14] found that biofouling in a CIPP lined pipe and unlined pipe were similar. Installation of CIPP does not promote more aquatic life growth than an existing host pipe with a cement lined surface.

Felt is used primarily as a resin carrier. It contains on the order of 85% void volume for the resin to occupy.

The use of glass fiber reinforcement in polymer composites has been practiced for decades and is still the most common reinforcement for plastics. Glass fiber tensile strength per unit density exceeds that of titanium, aluminum and steel, while its modulus is similar [3]. Glass fiber is less brittle than carbon fiber and more chemically resistant than aramid or nylon fibers. Glass fibers are also less expensive than the numerous alternatives. In the present liner, the glass fibers are woven both in the longitudinal and transversal directions to provide reinforcement in both directions.

CIPP Resin

The resin choice is a very important parameter in the design of the CIPP. It will impact the mechanical characteristic and lifetime of the final product. The installation process will also be very dependent on the choice of resin. There are currently three main chemical families of resins available on the market for CIPP installation: Polyester, Vinyl Ester, and Epoxies. Each chemistry has its advantages and inconveniences. Table 1 summarizes the characteristics of each family of resins used for CIPP applications.

Table 1 Characteristics of Possible Resins for CIPP Installation

Characteristics	Polyester	Vinyl Ester	Epoxies
Safety	Initiator: peroxide	• Initiator: peroxide • Styrene present (in most cases)	_
Mixing - Ingredient proportion	Not critical	Not critical	Critical
Pot Life	Long if temperature below initiation of the reaction	Long if temperature below initiation of the reaction	Not as good as polyester and vinyl esters. Pot life can be increased by cooling.
Reaction	Exothermic, self-accelerating	Exothermic, self-accelerating	Exothermic
Cure	Multiple heating levels	Water inversion recommended.	Heating (few hours) or room temperature (over several days).
Properties	• Lower mechanical properties than other resins. • Lower chemical resistance. • Shrinkage about 7%	• Better mechanical properties than Polyesters. • High impact resistance • Better chemical resistance than polyesters. • Shrinkage < 7%	• High strength • High chemical resistance • Lower impact resistance than vinyl ester. • Shrinkage < 3%

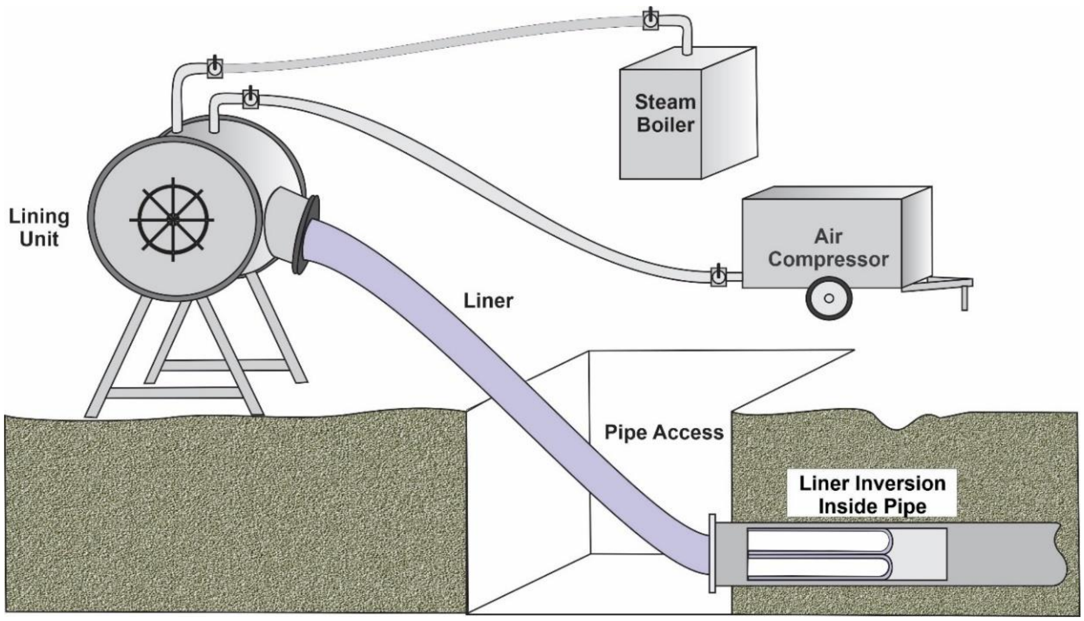
Selecting the right resin is an important step into designing a CIPP process for your application

INSTALLATION

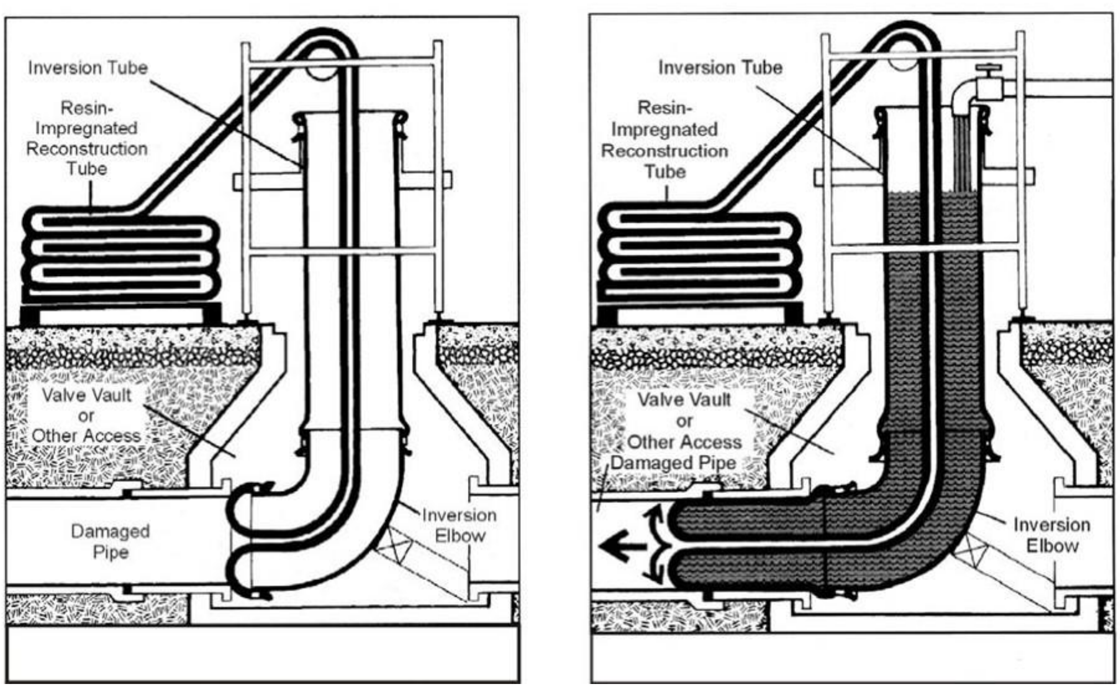
After cleaning of the host pipe, there are three main steps to proceed to the installation of the liner.

First step is the preparation of the liner. During this step, the liner is impregnated with the mixed resin. Pot life, and, temperature are important parameters at this step to assure a smooth installation of the liner in the pipe and to achieve the expected properties. The proper wetting of the liner with the resin is also an important criterium to ensure that the resin will be spread evenly throughout the length of the liner.

The second step is the installation and curing of the impregnated liner into the host pipe. Installation is an inversion process that can be achieved with either compressed air or water head pressure. The choice of one technique over the other will depend on the resin chemistry and the length of the liner being installed. Curing will be achieved by steam or hot water circulating inside the installed liner.



Schematic Drawing of CIPP Installation with Air



Schematic Drawing of CIPP Installation with Water

The last step of the CIPP installation process is the installation of end seals at each end of the CIPP. Their purpose is to prevent the infiltration of water between the CIPP and the host pipe. They consist in a rubber seal covering the end part of the CIPP and the unlined end part of the host pipe. Retaining bands are installed to apply pressure on the rubber seal and prevent any water infiltration. The requirement for this type of installation is that the host pipe has sufficient structural capacity for the pressure applied during the retaining bands' installation.

End-Seal Installed in Pipe

EXAMPLE OF AN INSTALLATION

In May 2017, the repair of the A train Service Water to Emergency Feedwater cross connect piping at V. C. Summer was achieved using CIPP technology. This was the result of months of work. The goal of this rehabilitation was to prevent corrosion debris that could clog the emergency feedwater flow control valves. The 8-inch pipe was located underground in a very congested part of the plant where the possibility of rehabilitating this pipe without any excavation was a big advantage. Another advantage was that the time required to install the CIPP was minimal and was easily completed during an outage.

Prior to the installation, the teams of V. C. Summer Nuclear Station and Imperia Engineering Partners worked together to establish the feasibility of this project, define the specification of the product, select proper materials, and choose the installer. Under Imperia's 10 CFR 50 Appendix B QA program, a commercial grade dedication plan was developed. Three mock-up installations were conducted to gather data to satisfy the requirements from the commercial grade dedication plan, develop the installation procedure, prepare material for testing to verify and validate the properties of the cured liners, and to qualify the installer staff. Also, the last mockup conducted at a facility near to V. C. Summer Nuclear Station provided a good opportunity for all the stakeholders to observe and understand the challenges of this installation:

- Installation equipment access to the Emergency Feedwater end of the installation was located within a radiologically controlled area
- Access to the Service Water end of the installation required difficult personnel entry through a 20” pipe Tee with a short vertical drop

The mockup was carefully configured to accurately represent the physical space challenges that would be faced during installation.

Mockup

Installation at the plant

Pipe Access for Start of Inversion

Laboratory testing was performed prior to any mockup installations to establish the liner properties. Samples taken from the mockup and plant installations were tested to verify the mechanical properties of the cured liner. The post installation test results are reported below in Table 2. Those properties were well above the requirements established by ASTM F 1216 [4].

Table 2 Mechanical Performances of Cured Liner Compared to ASTM F1216 [4] Specifications

Sample Orientation	Tensile Test		Flexural Tests	
	Tensile [lbf]	Modulus [psi]	Flexural Stress (5% deflection) [psi]	Flexural Modulus (0.5%-1% deflection) [psi]
Axial	13,900	1,451,000	14,860	471,530
Hoop	19,340	1,277,340	19,200	575,130
ASTM F1216	3,000	NA	4,500	250,000

CIPP IN A FEW NUMBERS

Parameters	Comments
Pipe diameters	6 to 124 inches
Pipe Length	Up to 800 ft individual length Other considerations like type of resin chemistry, liner construction, and host pipe configuration need to be considered
Presence of branch connections	Solutions exist to open the branch connection after installation and prevent water infiltration behind the liner
Presence of elbows	90º can be accommodated Wrinkles at the elbow can be evaluated to confirm its low impact on flow.
Position of Pipe	Horizontal or Vertical will work
Pipe access	Manhole or similar access at both ends of the installation One end will require space for access of the installation equipment. More limited space.at the other end is acceptable.
Installation time	Can be done during an outage
Pressure limit	Up to 200 psi
Rehabilitated Pipe	Good internal corrosion performance
CIPP service life	50 years
Cost of rehabilitation	20-30% of the cost of direct replacement of Buried Pipe.

REFERENCES

1. EPRI-TR-103992, Recommended Practices: Cured-in-Place Pipe Liner for Rehabilitation of Service Water Piping, Final Report, December 1994.
2. US Patent 4,009,063; 1977
3. D.C. Slivka, T.R. Steadman, V. Bachman, “High Performance Fibers II”, Battelle, 1987, p.ii.

4. ASTM F 1216 Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube