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Waterways Experiment
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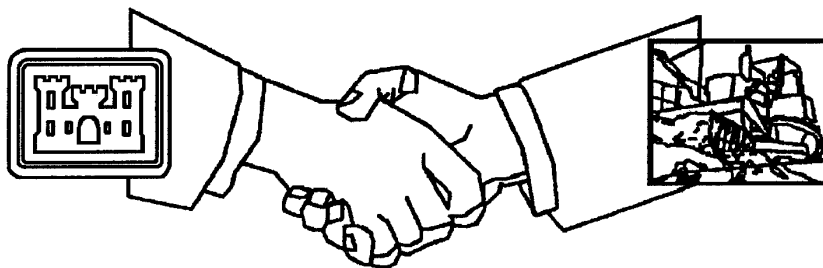
Guidelines for Trenchless Technology:

Cured-in-Place Pipe (CIPP), Fold-and-Formed Pipe (FFP),
Mini-Horizontal Directional Drilling (Mini-HDD), and
Microtunneling

by

Robert D. Bennett, Leslie K. Guice, Salam Khan, Kimberlie Staheli

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**A Corps/Industry Partnership to Advance
Construction Productivity and Reduce Costs**

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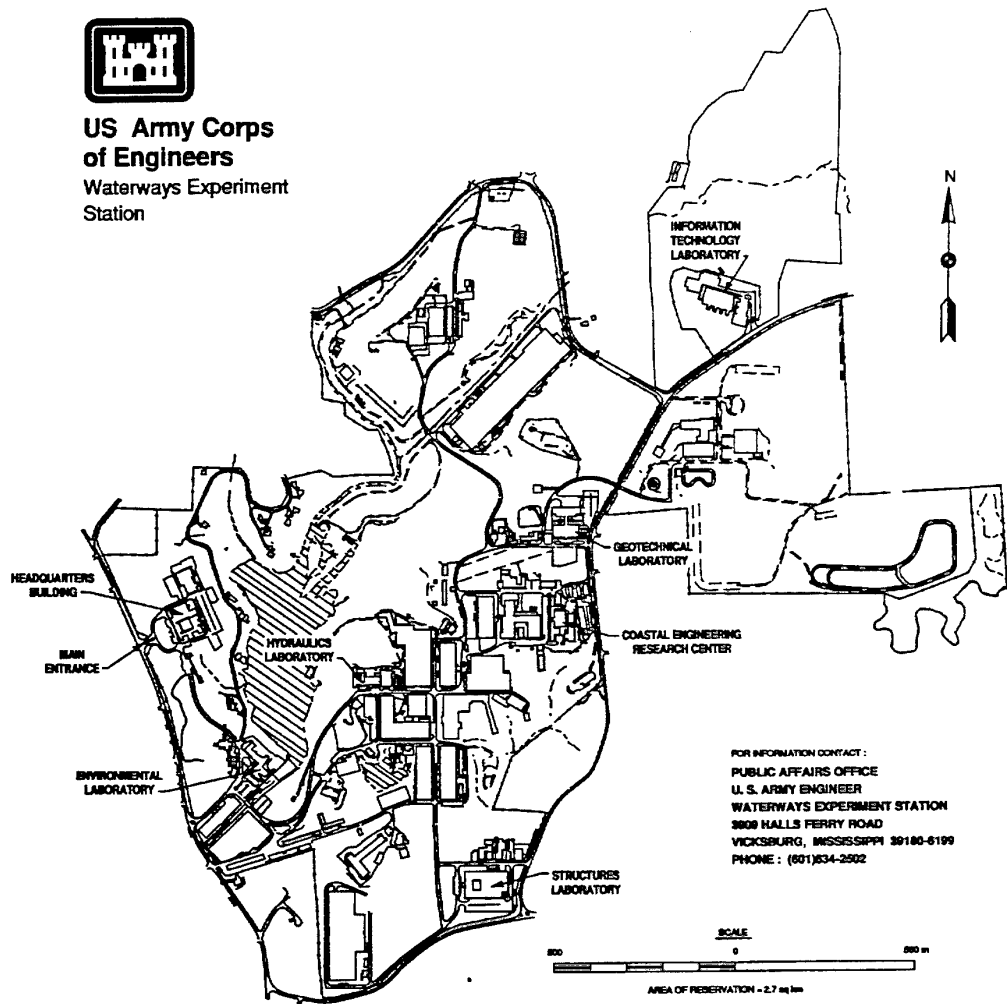
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2 Guidelines for Cured-in-Place Pipe (CIPP) and Fold-and-Formed Pipe (FFP)

2.1 Introduction

This report provides guidelines for the selection of all plant, materials, labor, and equipment needed and performance of all operations in connection with the rehabilitation of a subsurface pipeline by the cured-in-place pipe (CIPP) or fold-and-formed pipe (FFP) process. It is intended to help those who are relatively new to designing and specifying pipeline rehabilitation systems. The focus of this report is on the processes used, potential difficulties, and guidance for avoiding problems, as opposed to prescribed design procedures and specifications or even guide specifications. From this report, the engineer should obtain an understanding of what should be considered and resources for assisting in the design and specification of rehabilitation systems.

CIPP and FFP are pipeline rehabilitation techniques used to restore full service to a defective pipeline from access point to access point (typically a manhole). While CIPP can be used to rehabilitate a section of the pipeline as a point source repair, these guidelines address only complete rehabilitation. There are several rehabilitation systems in the market currently using CIPP, FFP, or related technologies.

2.1.1 Range of applications

CIPP and FFP systems can be used to eliminate or reduce inflow of storm water, infiltration of groundwater, exfiltration of pollutants, surface settlement caused by soil migration into the pipe, corrosive attack, and pipe irregularities/defects/joints in sewer collection systems. These systems can restore or increase hydraulic flow by smoothing surfaces. CIPP can be used in both circular and noncircular shapes.

While there are exceptions, CIPP and FFP techniques are normally preferred to rehabilitate pipelines under the following conditions:

- a. The pipeline has adequate flow capacity during the expected life of the liner. (Note that reductions in infiltration and inflow after pipeline rehabilitation can actually lead to significant flow reductions over conditions that existed prior to rehabilitation.)
- b. The pipe diameter and length of the rehabilitation run are within the general envelope of capabilities of the CIPP or FFP system as shown in Table 2-1.
- c. Point source repairs are not practical because of economic, social, or environmental considerations, or if they cannot adequately rehabilitate the line segment.
- d. The host pipe is not severely damaged, broken, or deformed. There are no flat surfaces or corners. There are no significant changes in pipe diameter from manhole to manhole. There are no sharp bends or tees. (Note: Liners may be used if special design considerations are given for these conditions. Also, use of CIPP liners may not be as severely restricted under these conditions as would be use of FFP liners.)
- e. Flow bypassing is feasible or unnecessary due to low flows.

Table 2-1
Typical Range of Applications for CIPP and FFP

Method	Diameter Range	Maximum Installation Range	Liner Material	Applications	Minimum Design Life
CIPP	4 to 108 in.	1,000 to 3,000 ft	Thermosetting resin/fabric composite	Gravity and pressure pipelines	50 years
FFP	4 to 18 in.	500 to 700 ft	PVC, HDPE ¹	Gravity and pressure pipelines	50 years

¹ PVC = polyvinyl chloride; HDPE = high-density polyethylene.

2.1.2 Cured-in-place pipe (CIPP)

CIPP is a liquid thermosetting resin-saturated material that is inserted into the existing pipeline by hydrostatic inversion, air inversion, or mechanically pulling with a winch and cable. These installation techniques as used in current CIPP systems are illustrated in Figures 2-1 through 2-3. After insertion, the resin-saturated material cures by application of hot water or steam to form a new pipe of slightly smaller inside diameter, but of the same general shape as the original pipe. The liner is designed to fit snugly against the wall of the host pipe.

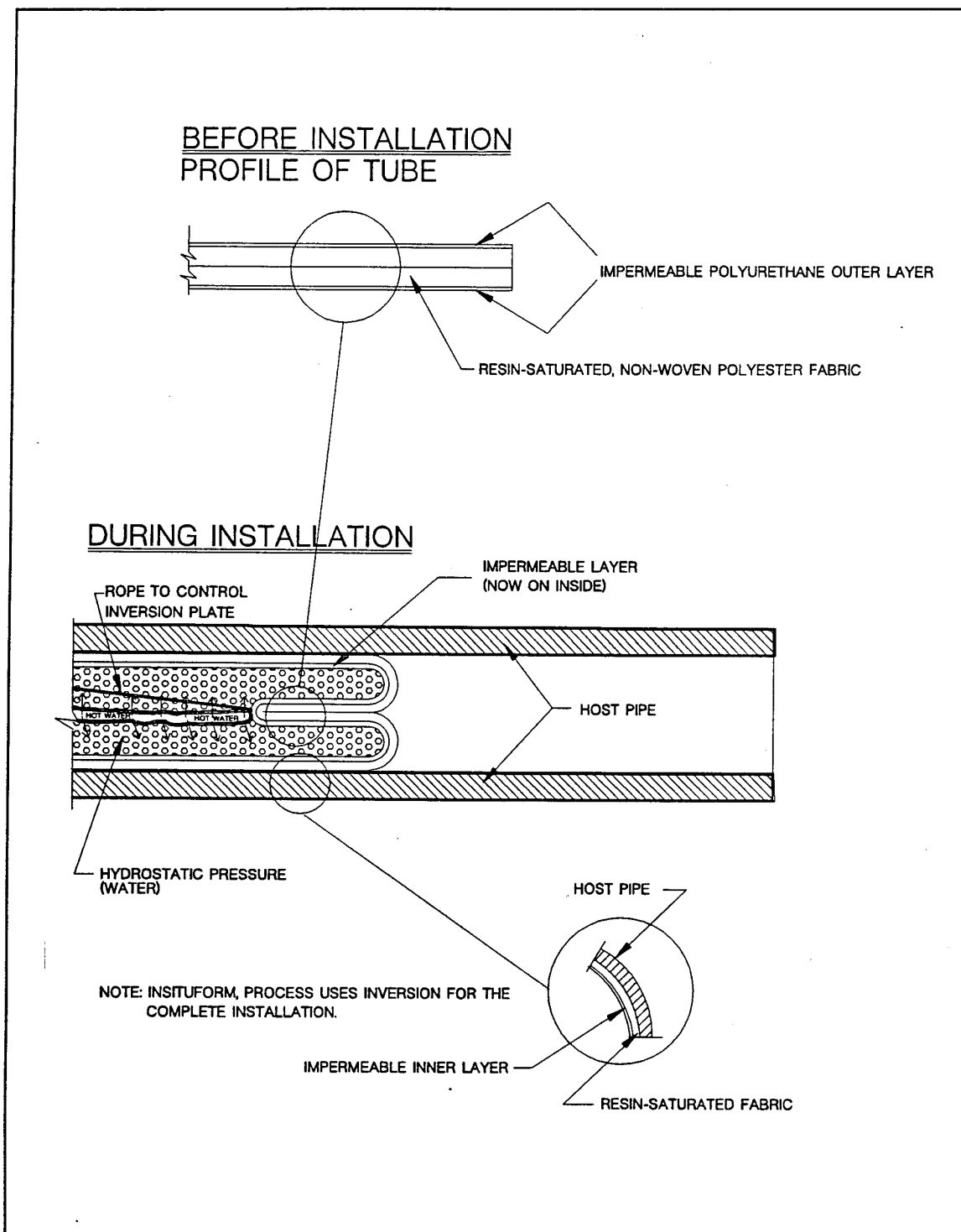


Figure 2-1. Typical CIPP installation by hydrostatic inversion (Insituform®)

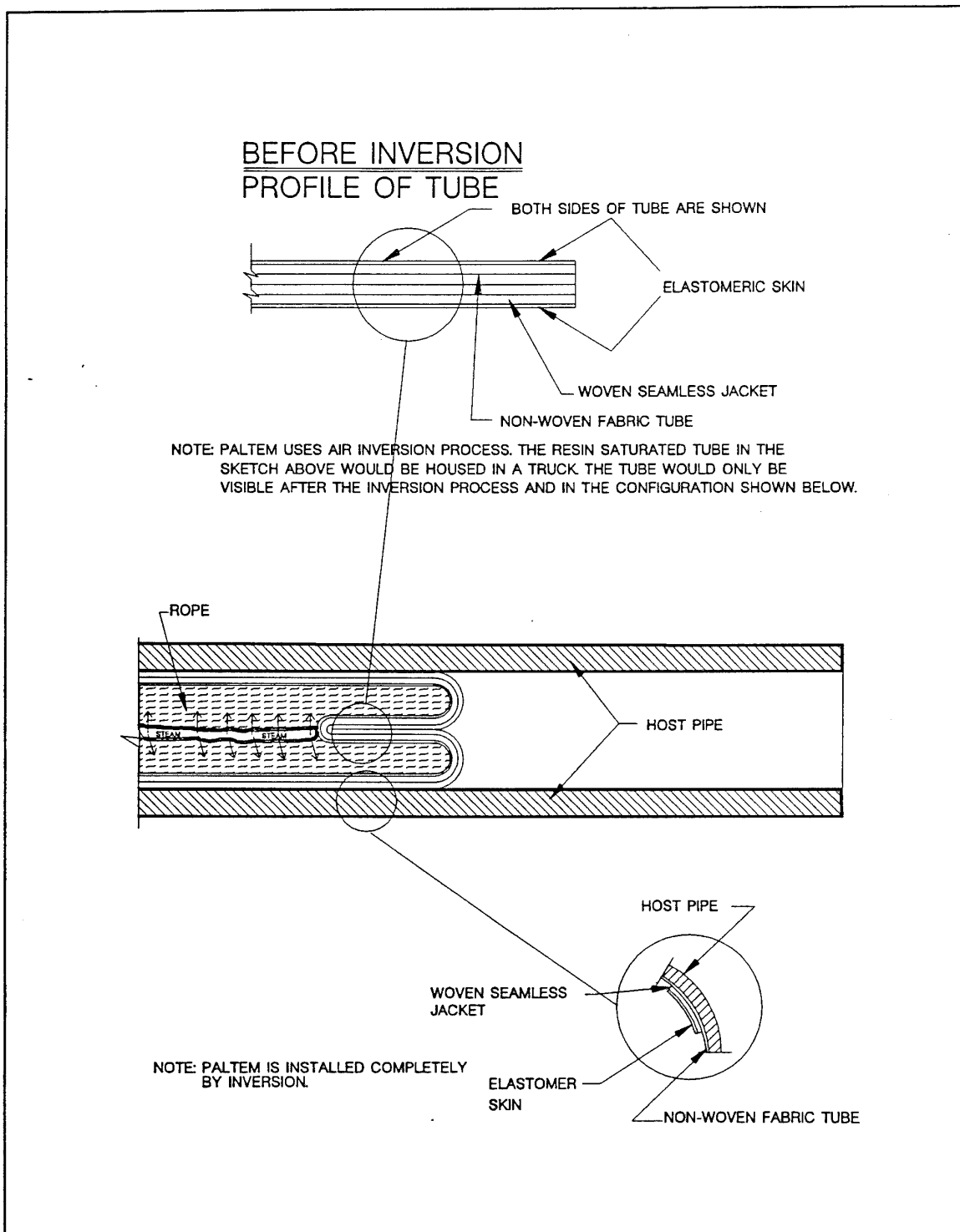
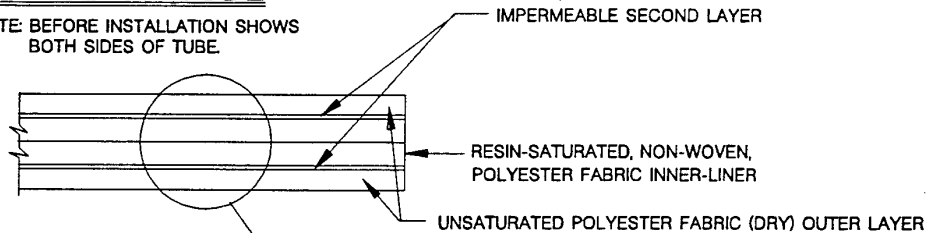


Figure 2-2. Typical CIPP installation by air inversion (Paltem HL®)

INLINER USA PROFILE OF TUBE

NOTE: BEFORE INSTALLATION SHOWS BOTH SIDES OF TUBE



INSTALLATION: RESIN-SATURATED BAG IS WINCHED INTO THE HOST PIPE. DURING WINCHING THE BAG PASSES THROUGH ROLLER CUTTERS THAT PERFORATE THE IMPERMEABLE SECOND LAYER AND ALLOW RESIN TO FLOW INTO THE UNSATURATED (DRY) OUTER LAYER. DURING CURING

CALIBRATION HOSE BECOMES INTEGRAL COMPONENT DURING CURE AND REMAINS IN PLACE

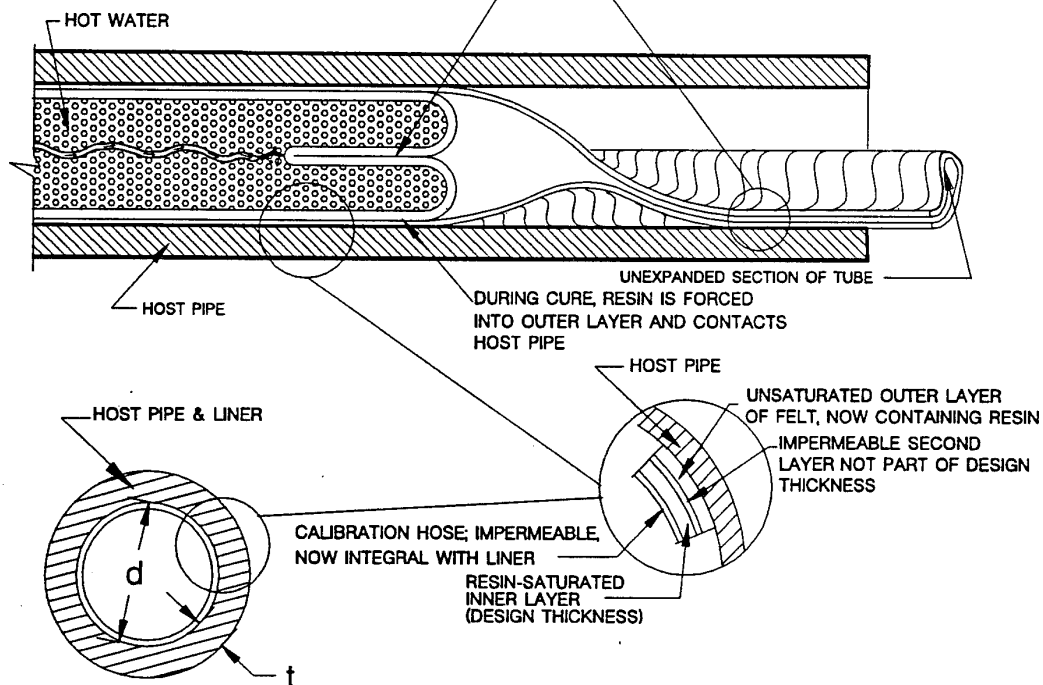


Figure 2-3. Typical CIPP installation by winching (In Liner USA®)

2.1.2.1 Basic components

The primary components of the CIPP are a flexible fabric tube and a thermosetting resin system. For typical CIPP applications, the resin is the primary structural component of the system. These resins generally fall into one of the following generic groups, each of which has distinct chemical resistance and structural properties. All have good chemical resistance to domestic sewage. The three primary resin systems used are unsaturated polyester, vinyl ester, and epoxy. Unsaturated polyester resins were originally selected for the first CIPP installations due to their chemical resistance to municipal sewage, good physical properties in a CIPP composite, excellent working characteristics for CIPP installation procedures, and economic feasibility. Unsaturated polyester resins have remained the most widely used systems for the CIPP processes for over two decades. However, at least one manufacturer currently uses vinyl ester resins for all applications.

Vinyl ester and epoxy resin systems are mainly used in industrial and pressure pipeline applications where their special corrosion and/or solvent resistance and higher temperature performance are needed and higher cost justified. In drinking water pipelines, epoxy resins are required.

The primary function of the fabric tube is to carry and support the resin until it is in place in the existing pipe and is cured. This process requires that the fabric tube withstand installation stresses with a controlled amount of stretch but with enough flexibility to dimple at lateral service connections and expand to fit against existing pipeline irregularities. The fabric tube material can be woven or non-woven, with the most common material being a non-woven needled felt. It can consist of one or more layers of felt, glass fiber composite cloth, impermeable plastic, and other materials to form the total liner thickness. Impermeable plastic coatings are commonly used on the interior and/or exterior of the fabric tube to protect the resin during installation. The layers of the fabric tube can be seamless, as with some woven materials, or longitudinally joined with stitching or heat bonding.

There are many CIPP systems in the market today. The primary differences between these various CIPP systems are in the composition and structure of the tube, method of resin impregnation (by hand or by vacuum), installation procedure, and curing process.

2.1.2.2 CIPP method description

First the existing pipe is thoroughly cleaned and internally inspected to assess existing conditions. The distance between inspection manholes is measured, and all damaged sections and service inlets are carefully noted. The purchase order placed with the CIPP manufacturer is based on these data, and the product is manufactured for insertion into a particular pipe.

Roots, grease, sediment, and debris are removed from the line. In the inversion method, the inversion head usually overcomes external water pressure, and incoming water is pushed ahead of the inverting tube so all water is expelled and none is trapped. If necessary, spot repairs may be performed prior to liner placement, and a preliner may be used if excessive filtration is evident.

After the pipeline has been cleaned, inspected, and the flow has been bypassed, the flexible fabric tube is inserted into the pipe through a manhole or another convenient entry point. Just before the installation, the flexible tube is impregnated (wetted-out) with the liquid thermosetting resin at the contractor's wet-out facility or, for large-diameter tubes, at the jobsite. It is critical that the fabric tube is totally saturated and air evacuated in order to provide consistent finished

physical properties required by design. This flexible tube is installed in the old pipe by winching mechanically or inverting it under air or water pressure.

In the inversion process, the tube is cuffed back and clamped to an inversion ring at the access point. The tube is then fed through the ring with the tube being turned inside out. Water or air pressure is then applied to continue turning the tube inside out, pushing it through the existing pipe. The pressure keeps the tube expanded against the existing pipe wall as it inverts along the installation length. With the winched technique, the wet-out tube is pulled through the full length of the existing pipe. Then an inflation bladder is inverted through the tube to expand it against the host pipe wall. Combinations and variations of these two methods are used by most CIPP systems.

Once the tube is inserted into the existing pipe and expanded, heated water or steam is circulated through the tube to initiate the curing or hardening of the thermosetting resin. This changes the resin from a liquid to a solid. After the curing cycle is complete, the CIPP is cooled and a new pipe is formed with a slightly smaller inside diameter, but of the same general shape as the original pipe.

The ends of the cured pipe are then trimmed, forming a smooth, seamless CIPP. At the service connections or laterals, dimples are normally created due to the applied pressure. In the case of pipes large enough for personnel entry, a special cutting device is used to reopen service connections at the dimple locations. In pipes that are too small for personnel entry, a robot is used in conjunction with a closed-circuit television (CCTV) camera to locate the dimples visually and reopen the service connections.

2.1.2.3 Advantages

There are several advantages of the CIPP method over other methods of trenchless pipeline rehabilitation. Grouting is not normally required due to the tight fit of the CIPP against the existing pipe. The CIPP has no joints and has a very smooth interior surface which typically improves flow capacity, despite the slight decrease in diameter. Noncircular shapes can be accommodated often without a decrease in flow capacity. The lining is capable of accommodating bends and some existing pipe deformations. Entry is possible via existing manholes or through minor excavations, and the total installation can take place rapidly. Remote-control internal lateral connection is possible. The cost of CIPP has been found to be competitive with all other methods of construction and rehabilitation, particularly for larger projects with multiple segments and where social and environmental considerations are significant.

2.1.2.4 Disadvantages

Compared with other rehabilitation techniques, CIPP liners require expertise to ensure that installations result in a quality product. A trained crew and operators with special equipment are required, which may cost more for small jobs. High set-up costs on small projects may reduce the cost effectiveness of this method. The tube or hose must be specially constructed for each project (some manufacturers provide stock materials to their licensees for small diameters, such as 8, 10, and 12 in.). The existing flow must be bypassed or plugged upstream of the section to be rehabilitated during the installation process. Sealing may be required at liner ends or cuts to prevent inflow or outflow. The curing period could take 5 hr or more under certain circumstances. The rehabilitated pipe will take the shape of the host pipe, including deformations.