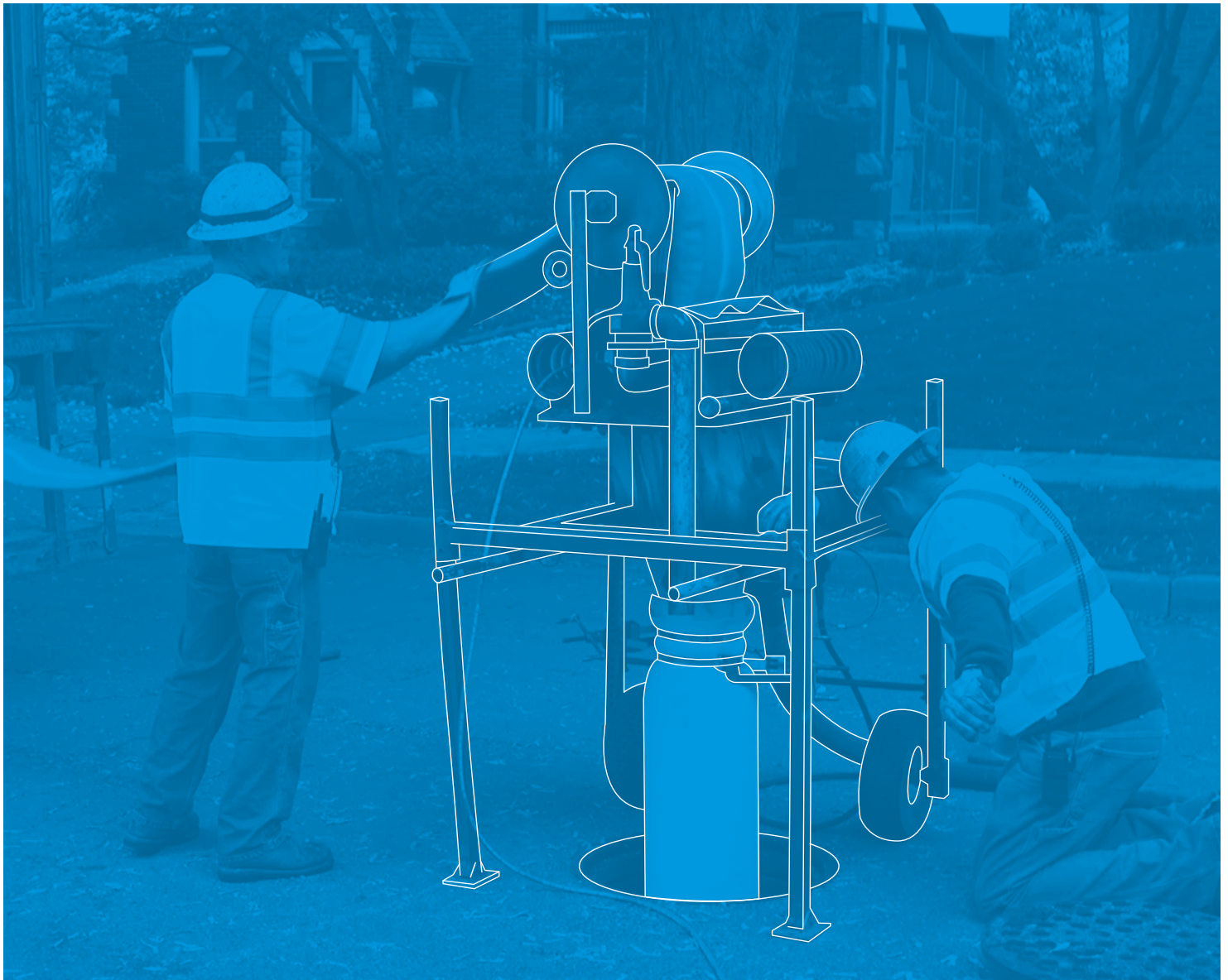
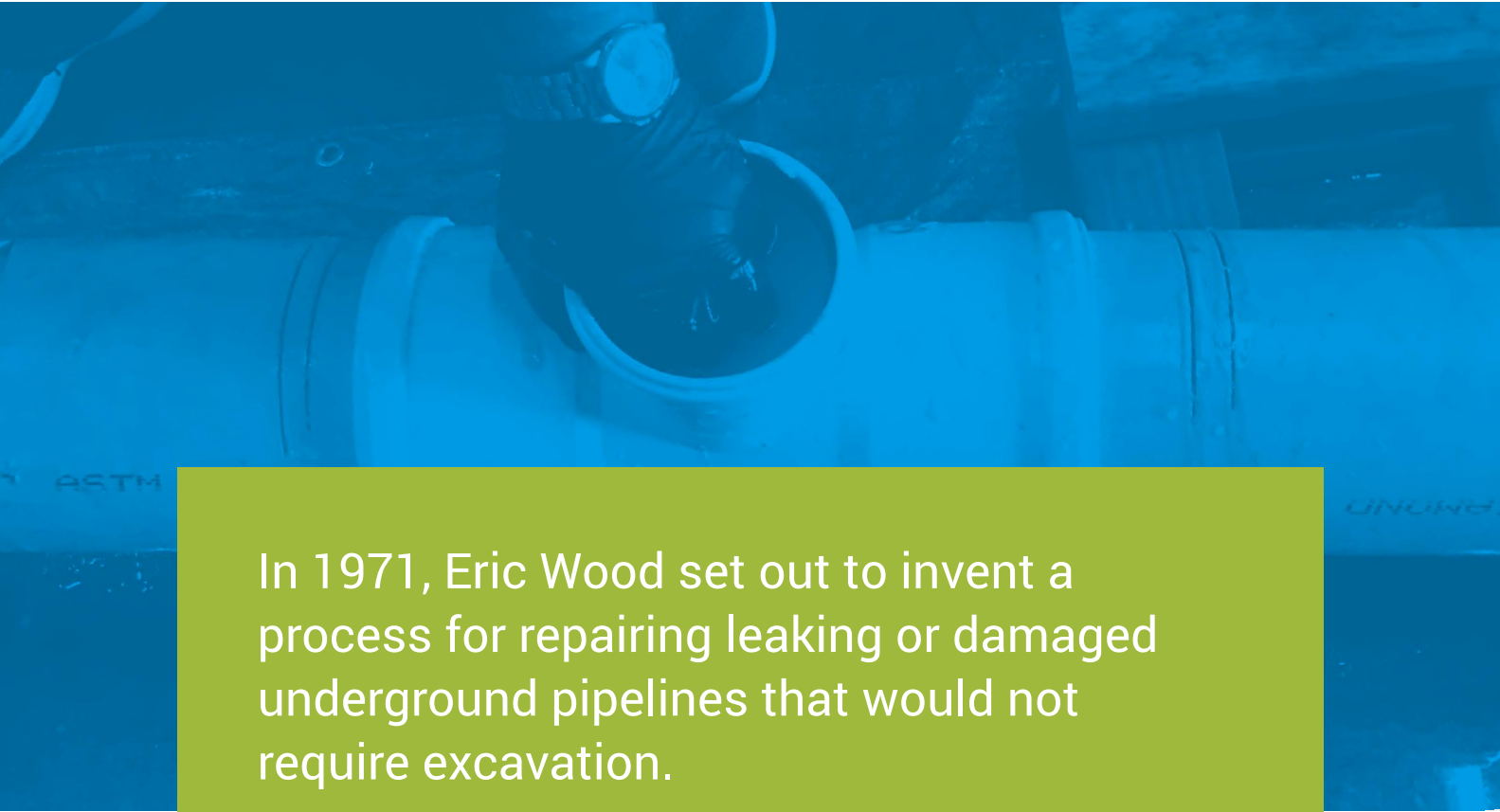




The Elements of CIPP:

Cured-in-Place Materials
and Processes





In 1971, Eric Wood set out to invent a process for repairing leaking or damaged underground pipelines that would not require excavation.

At that time, the only processes for trenchless pipeline rehabilitation were sliplining and grouting. Determined to invent a new trenchless repair technology, he successfully performed the first Cured-In-Place-Pipe (CIPP) installation in 1971 in London, and the process was adopted in the United States in the 1980s.

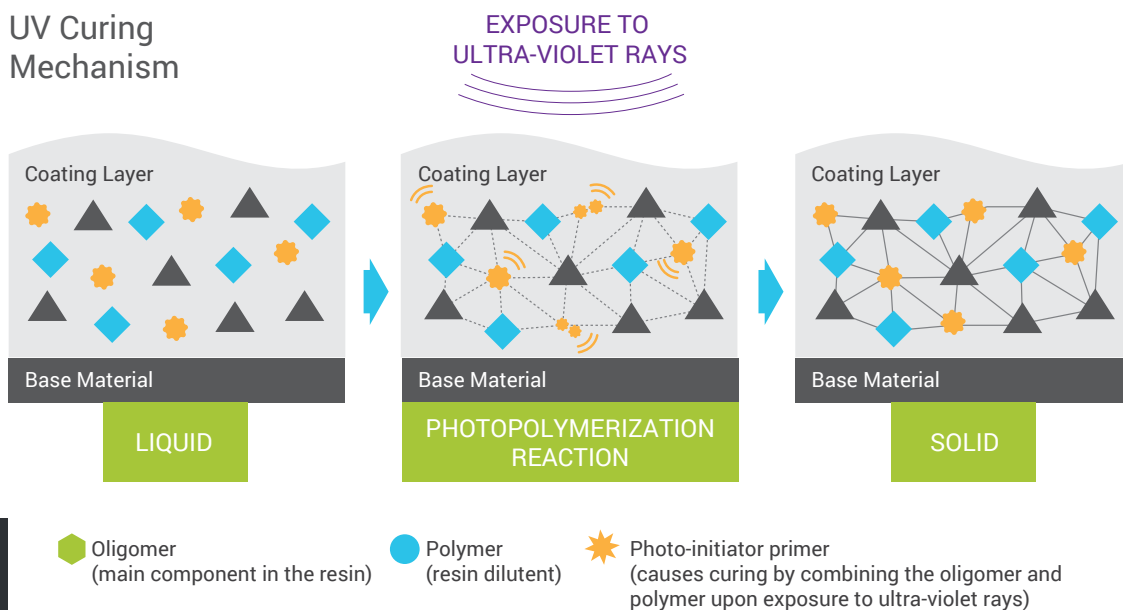
Since the invention of CIPP lining, this trenchless technology has continued to evolve and grow in popularity. According to the [2013 Trenchless Technology Pipe Relining Guide Survey](#), 84% of utilities surveyed were utilizing CIPP liners for repair. The next most popular method was sliplining with only 39% of utilities using it. To say that CIPP is a popular rehabilitation method is an understatement.

Within the category of CIPP, there are many options and combinations to choose from. First, one must choose the cure method and a resin to go with it. Then, one must choose the liner fabric. Each decision will affect what installation equipment is required, how long it takes to cure, how strong the liner is and how long it will last.

Cure Methods

There are two categories of cure method: thermal cure and UV cure. With thermal curing methods, the resin molecules cross-link and form resin chains. Heating the resin accelerates the cross-linking process and helps the resin reach an exothermic state to fully cure. Each individual resin must reach a certain temperature and remain at that temperature for a specific length of time to ensure all resin cross-linking has occurred. Hot water, steam and ambient are all options for thermal cure.

UV Curing Mechanism



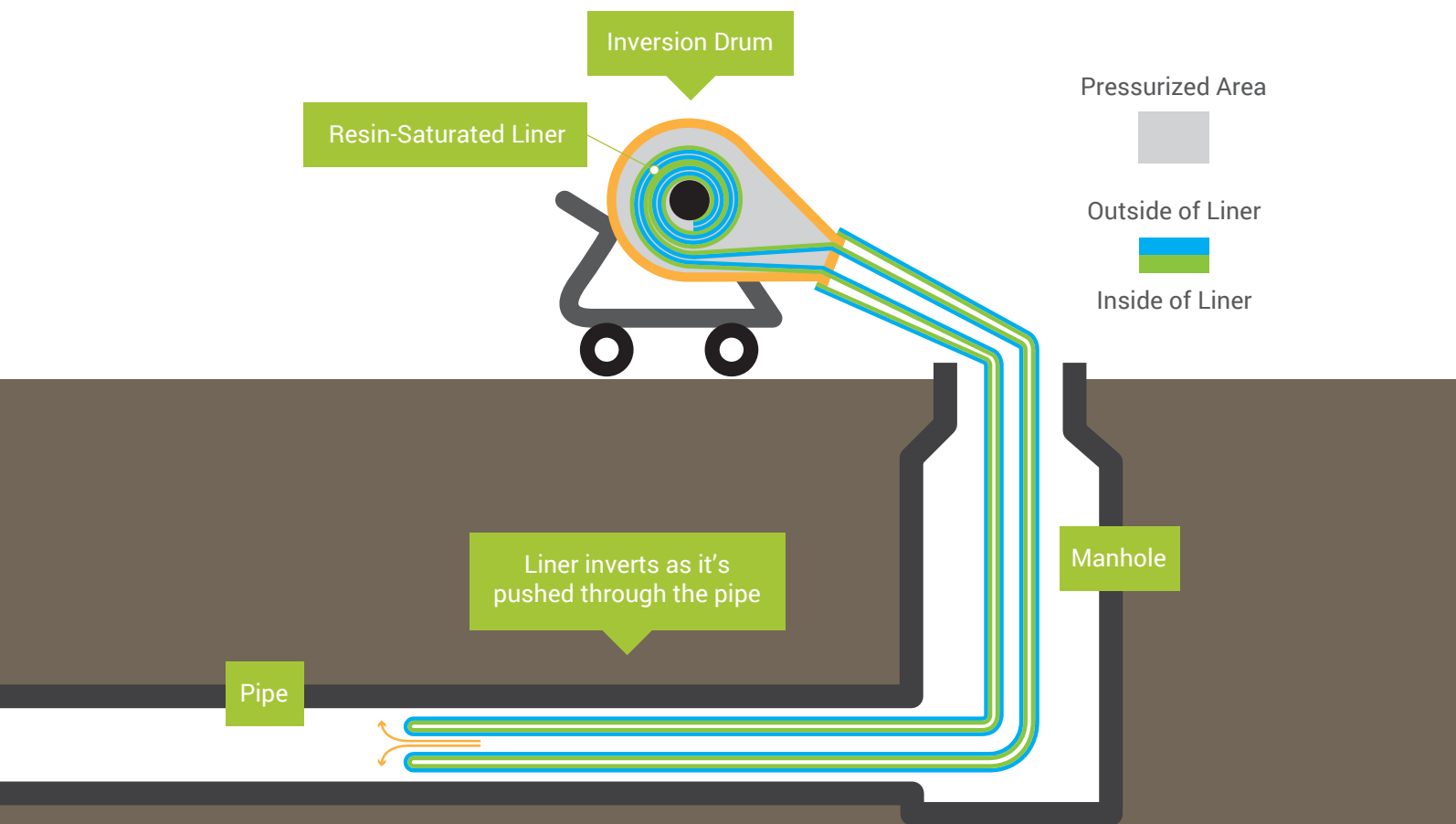
Steam cure and hot water cure are fairly similar cure methods in that both involve applying heat to cure the resin and harden the liner. Hot water was the first method for curing liners when CIPP was invented. The liner is expanded with cold water after the liner is placed in the line, then hot water is circulated inside the line to cure it. Though it is still the second most popular curing method, hot water curing is losing favor. It requires a significant investment in inversion and curing equipment and, because of how the curing equipment integrates with the inversion equipment, must remain throughout the entire curing process. This means the number of runs that can be completed in a day is lower than steam.

Steam is a slightly newer method and offers faster curing times. Steam can reach higher temperatures than water and transfers heat to the resin faster. For every 48° F increase in temperature, the resin cures twice as fast, so a smaller increase in cure temperature produces a much larger change in cure time. Another advantage to steam is that the installation and curing equipment are separate, allowing the installation equipment to move on and install other liners while the first is curing. However, steam has one major downside to water: condensate. As steam transfers heat to the liner, it cools. When it cools too much, it condenses back into water and begins pooling at the lowest point in the liner. As more condensate gathers, this can keep the bottoms of liners from reaching full exotherm and leave them soft.

Ambient cure relies on a two-part resin mixture (sometimes three-part depending on the resin manufacturer) and hardens quickly. Because of its short working time, ambient cure is most

commonly used for short lengths (short pipes or spot repairs) or small diameter lines. Essentially, the less surface area necessary to cover, the better suited a line is for ambient cure. Ambient is also a less expensive option due to fewer equipment requirements. Ambient is generally wet-out on-site, eliminating the need for a refrigeration truck, and requires no heat to cure, eliminating the need for a boiler. Ambient also cures much faster, lessening the amount of time the line must be out of service.

Finally, UV curing is one of the newest curing technologies to enter the market. Developed in the early 2000s, UV curing typically involves a single part resin which is activated by UV radiation to form resin chains and harden the liner. The liner is inverted into the pipe and pressurized; then the light train is pulled through the liner to cure. UV offers faster curing and stronger liners, but is more expensive than thermal cure liners. According to a study performed by [Staheli Trenchless for the City of Portland, OR](#) UV liners were up to twice as expensive per foot as thermal cure liners. However, the City found that UV liners were at least three times stronger than thermal liners, withstanding over 33,000 PSI. A big detractor for many contractors is that current UV can only cure glass fiber reinforced plastic (GFRP) which is too rigid to go around bends or handle diameter changes. This limits the circumstances where UV curing is an option. However, new LED-based UV lamps have been demonstrated to cure felt liners impregnated with UV resin, which solves this shortcoming.



The Inversion Process

Most liners are installed through inversion. When manufactured, the liner is made with what will become the outside of the liner, on the interior. After the liner is wet-out, the liner is oiled and either rolled into an inversion drum or inserted into a shooter. Because inversion drums involve rolling the liner up inside the drum, they can only be used for shorter runs and smaller diameters. Exact lengths vary by liner diameter and inversion drum manufacturer. In both cases, the liner is fed through the launch tubing so the front end can be folded back over the end of the launch tube and clamped into place. A calibration tube is clamped over the end of the launch tube. The calibration tube is used to guide the liner from the inversion site to the host pipe, protecting the liner from the access trench or manhole walls. Air or water, depending on the cure method, is used to pressurize the liner and press it into the line right side out. Once the end of the liner has reached the end of the host pipe, curing can begin.

Liner Material

Some may be under the impression that the resin and the quality of the cure are what make or break a CIPP liner. However, the fabric chosen can play a big role in the strength and durability of the liner, particularly when combined strategically. The fabric chosen must be the right fabric for the resin, the curing technology and the application. Every component of the CIPP process has an effect on the strength and durability of the final, cured liner, but each component affects the end result in a different way. Fabric affects how the liner handles fluctuations in pipe diameter and changes in direction.

Felt liners, made of polyester or acrylic, are the original fabric for CIPP, but GFRP is a preferred choice because of how little it shrinks. GFRP also produces a thinner liner without compromising strength. Technology has come a long way since the process was first invented, but in general felt will produce a thicker, slightly weaker liner than GFRP. But, felt has two major advantages over GFRP: First, it remains the first choice for most lines simply because felt can be inverted into the line rather than pulled through. Pull-through liners cannot be used to reline bends, large offsets, or lines with diameter or thickness changes. Additionally, pull-through liners cannot be used for runs longer than approximately 800 feet. The second advantage of felt is the cost: felt is less expensive than GFRP.

Another option many contractors choose is a fiberglass-reinforced felt liner. These types of liners have the ease of inversion installation with the strength of GFRP. They produce thinner, stronger liners than traditional felt without requiring pull-through installation. Fiberglass-reinforced felt offers other benefits. Less resin is needed to saturate them, and they weigh less, making transportation and installation faster. However, many installers, particularly those using hot water or steam to cure, choose not to use fiberglass-reinforced felt because of the higher material cost and difficulty of resin impregnation.

Wet Out

Wetting out a liner involves impregnating the fabric material with resin. This is done either by sealing one end of the liner, connecting a vacuum hose a few inches up the liner from the seal then pouring the resin into the liner or by perforating the liner and using injection wands to insert the resin. This second method is most common with larger liners. The liner manufacturer provides an equation for each specific material to determine how much resin is needed to fully impregnate the material. For an even wet-out, the liner is run through rollers to compress the material, ensuring even resin impregnation and a consistent liner thickness after curing.

Resin Types

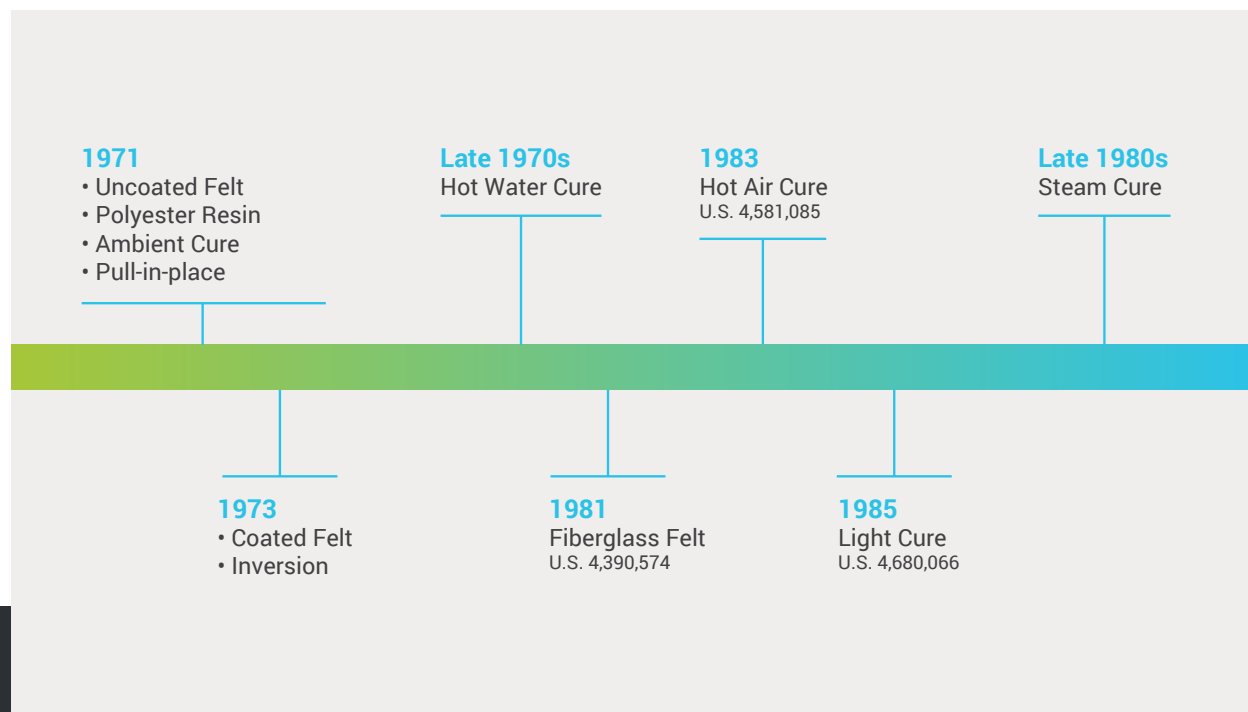
The choice in resin is dependent upon the choice of curing method; the resin must be compatible with the curing method. Thermal resins and UV resins are not interchangeable. Liner type also matters. Some liner materials provide a better result with specific types of resin. Liners also come with a coating that may or may not work with certain types of resin.

There are three main types of resin: epoxy, polyester and vinyl ester. By far, the most popular type of resin is polyester, largely due to the cost. Another advantage of polyester resin is the work time. Depending on the catalyst used, polyester resin can have a work time of a few minutes to a few weeks. This allows contractors to perform wet-out in their own facility and ship the liners to the installation site, providing for better quality control. The biggest downside to polyester resin is shrinkage. Polyester shrinks more than any other type of resin during cool down, leaving the end result more prone to leaks. Another disadvantage is the volatile organic compounds (VOCs) it emits, which necessitates adequate ventilation during installation and cure. While not an issue during most mainline installations, it can add to the cost of lateral installations when working indoors.

The second option is epoxy resin. This kind of resin has two big advantages for installers. First, it's generally the strongest type of resin, allowing it to be used in higher pressure lines. The second advantage is dimensional stability—it shrinks far less than any other kind of resin, keeping it tighter to the host pipe wall and limiting infiltration tracking. Infiltration is the leaking of groundwater into sewers. It diminishes sewer capacity and is a major issue for wastewater utilities that relining is intended to address. Infiltration tracking is when water runs along the annular space between the liner and host pipe. The more a line shrinks, the worse infiltration tracking can be, necessitating low-shrinkage resins and liner end seals to block the flow.

Epoxy also has no VOCs, so it can be used indoors without concern. The big downside of epoxy resin is the work time, which is generally limited to eight hours. This means installers must perform the wet-out onsite or at least nearby. It is also the most expensive type of resin.

The last option is vinyl ester resin. This option is a mix of polyester and epoxy components, making it highly corrosion-resistant. Some utilities and industrial companies require vinyl ester because of its corrosion resistance. However, it costs slightly more than polyester resin and has many of the same characteristics of polyester in terms of shrinkage, VOCs and storage needs.



About Styrene

One of the biggest debates around CIPP is the issue of styrene exposure. Styrene is a chemical derived from benzene and is an organically occurring compound found in many foods including coffee, tea, milk and peanuts. In trace amounts, styrene is safe; in higher concentrations, it can be dangerous to those exposed.

Most of the resins used in CIPP cause a chemical reaction that produces styrene. During the curing process, styrene gas disperses over a large area—through the line, up laterals and into residences, and throughout the vicinity of the open manholes—exposing anyone that may be around, including the installer...and area residents.

Short-term exposure to styrene can cause mucous membrane and eye irritation. The effects of chronic exposure are less conclusive. Many studies have been performed by various trade groups and government agencies. Some chronic effects (headache, fatigue, depression or hearing loss) have been conclusively demonstrated as symptoms. However, effects on the female

reproductive system and increased risk of cancer remain unproven. [One study](#) showed an increase in miscarriages and a decrease in births, but another study showed no change. However, neither study was conclusive. In terms of cancer risk, several studies have shown an association between styrene exposure and certain types of cancer, but again, the studies were not conclusive.

More recent studies have raised other concerns about the effects of CIPP. A [2017 study](#) from Perdue University analyzing seven steam-cured sites showed that the plume released from the manhole during curing, commonly thought to be just water vapor, was actually a mix of, "... hazardous air pollutants, suspected endocrine disrupting chemicals, and known and suspected carcinogens [...and] partially cured plastic, styrene monomer, acetone, and unidentified chemicals." The researchers ultimately recommended full face masks with carbon-filters and chemically resistant gloves.

Whether you decide to follow the researchers' recommendations or not, one thing about styrene cannot be denied: the smell. Styrene in high concentrations produces an overwhelming, foul odor. When using resin that emits styrene, cities and utilities often receive complaints from those nearby. For this reason, resin that causes styrene cannot be used in vertical lines inside residential or commercial buildings such as large apartment buildings, schools or hospitals.



Looking Forward

Since the invention of CIPP nearly 50 years ago, the technological advancements in its application have been impressive. Innovations in resin mixes created stronger, more durable liners; changes to fabric composition and manufacturing produce more flexible liners able to smoothly cover bends, deformations and drastic diameter changes.

But, the most impressive changes have come from the innovations in curing methods. The release of UV curing technology has produced thinner, stronger liners and given installers a simpler, faster and more reliable method for curing. Now, companies around the world are looking to be the first to develop an even better cure method. The impact CIPP has had on the municipal underground infrastructure industry is incomparable—transforming municipalities' approaches to pipe rehabilitation—saving time and money. Because this process has proven so reliable, CIPP is here to stay and will only continue to evolve.

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