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## CURED-IN-PLACE PIPE – MINIMIZING RISK BY DEFECT CODING

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**ABSTRACT:** As the cured-in-place industry advances in their methods of installation and curing, engineers and owners need to be more aware of the different installation methods. Water inversion/curing has the longest track record, but air inversion and steam curing is a method that can be of great benefit for contractors, impacted residents, and utility owners. However, there are risks that must be addressed prior to installing a liner. Contract drawings often show which pipe segment is to receive a cured-in-place liner with approximate length and diameter. Sometimes, lateral locations will also be shown. Occasionally, temporary construction areas and means of access will be delineated. Rarely do drawings communicate all the known information that drove the decision to line the pipe.

This paper addresses the need to be aware of the potential drawbacks and benefits and what engineers and owners need to call out in their construction documents in order to minimize risks for all parties.

### INTRODUCTION

The benefits (trenchless, long design life, jointless, speed of installation, etc.) of cured-in-place pipe lining make it a very attractive rehabilitation technique. However, as in any construction project, there are risks to Owners, Engineers, and Contractors alike. On projects that involve substantial excavation, for example, Owners and Engineers can minimize risk to all parties and obtain better bids by performing geotechnical investigations during the design phase and making this information available to bidders (usually in the form of geotechnical data or baseline reports). By having as much data as possible about potentially unknown subsurface conditions, Contractors are better equipped to understand the time and equipment required to get the job done, and therefore the need to put as much additional “contingency money” into their bids is reduced. Owners get tighter and more competitive bids, and there is much less risk for change orders or project overruns.

In the same way, Owners should make as much information as possible available to bidders on CIPP projects. By having this information available, bidders can anticipate locations where specialized techniques, particular equipment, or significant time and labor are required. This is particularly true for areas that require substantial work to preparing pipes for receiving CIPP, for areas of possible insertion difficulties, and for locations of potential curing problems.

### CIPP INSTALLATION METHODS

When discussing risk in CIPP projects, it is important that Owners and Engineers understand the products that are used and how they are installed. Similar to understanding problems and difficulties

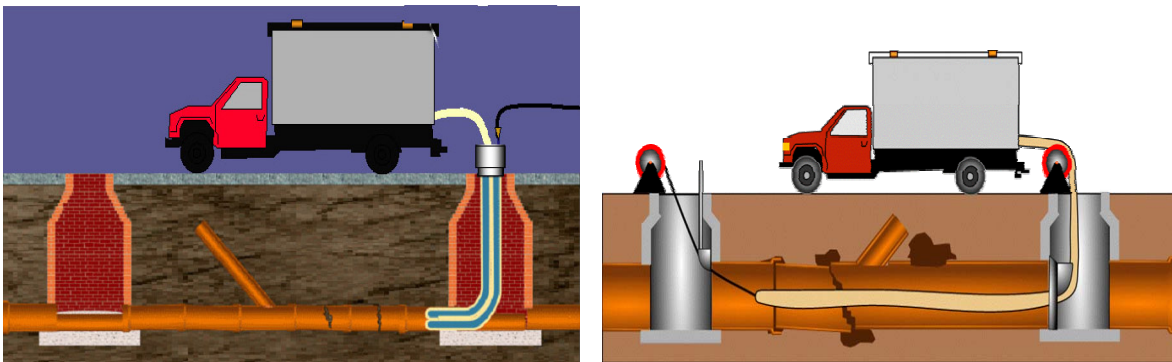
when boring and jacking a pipe underneath a road, recognizing the limitations and risks when curing a resin-impregnated flexible tube inside an existing (and most likely damaged) pipe will help in the design of CIPP projects.

There are several methods used when installing CIPP. Each method employs a means to insert the resin-impregnated tube into the existing pipe and a means to cure the pipe.

#### Inserting and Curing the CIPP

Cured-in-place pipe is typically inserted into the existing pipe in one of two ways:

1. By pulling the resin-impregnated flexible tube into place (as outlined by ASTM F1743, Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe),
2. By inverting the resin-impregnated flexible tube under pressure (as outlined in ASTM F1216, Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube).



**Figure 1.** Insertion of CIPP (left: inversion process; right: pull-in-place process).

Each method of inserting the CIPP has benefits and drawbacks from a design perspective. It is useful to understand these benefits and drawbacks when preparing to use CIPP as a means to rehabilitate pipelines; the condition of the existing pipe may lend itself towards one insertion method over the other.

The pull-in method involves impregnating a coated lining tube with resin and pulling it into the existing pipe. The liner is then expanded, generally by inflating a bladder with water or air, and the resin is cured by applying heat (usually steam, hot water, or recently by pulling ultra-violet lamps through the liner). Pull-in liners typically have exterior and interior coatings to hold the resin in the flexible tube during the impregnation process and to prevent losing resin during the insertion.

#### **Major Benefits of Pull-in-Place:**

1. Exterior and interior coatings prevent the loss of resin during insertion.
2. Less pressure on liner during the insertion process, reducing possibility of liner stretching.

#### **Major Drawbacks of Pull-in-Place:**

1. Exterior coating prevents resin migration through pipe joints.
2. Liner is “deflated” during insertion and prior to curing, allowing for debris to get caught under the liner or water to fill sags and create possible heat sinks during the curing process.

The inversion method involves inverting the resin-impregnated tube through the pipe. The liner essentially pushed inside-out using water or air pressure. The outside of inverted liners are coated to hold the resin, but during the installation the coating is inverted with the liner and serves as a coating on the inside of the liner with the wet resin now on the exterior of the liner. The setup will vary depending on whether water or air pressure is used to invert the liner. Curing is typically performed by circulating hot water through recirculation hoses in the liner or by introducing or circulating controlled steam.



**Figure 2.** Inversion liner (left: flexible tube with coating on “exterior” (prior to inversion) of the liner; right: liner as it is be inverted in the pipe).

#### Major Benefits of Inversion:

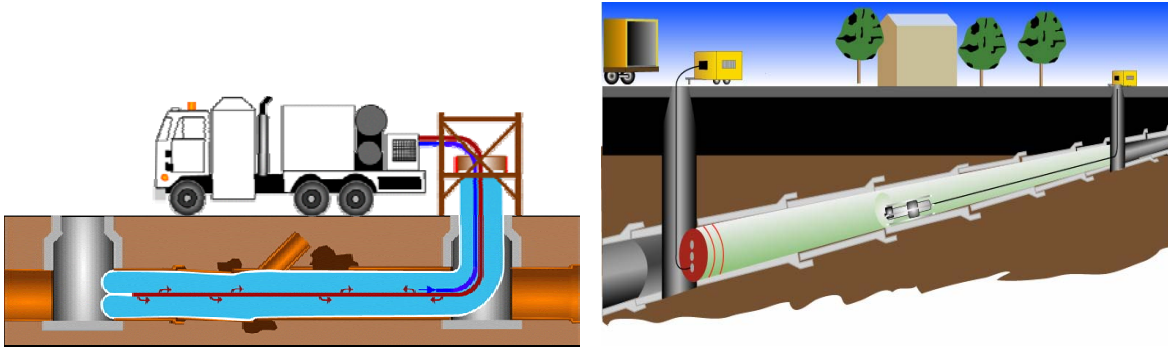
1. Inversion allows for resin to interface with the interior of the existing host pipe, allowing for resin migration in pipe joints. Resin migration aids in preventing water migration and root intrusion into the annular space between the liner and host pipe.
2. Water inversion (and some air inversion processes) keeps the liner expanded from the beginning of the insertion all the way through curing, pushing water and debris ahead of the liner during insertion. This reduces the chances of debris from being caught under the liner and allowing pockets of water to become heat sinks during curing.
3. Air inversion and steam curing is a relatively fast process.

#### Major Drawbacks of Inversion:

1. Wet resin on the exterior of the liner during inversion can lead to resin washout.
2. Pressures during inversion must be controlled to prevent stretching of the liner.
3. During most air inversion processes, the liner is “deflated” during insertion and prior to curing, allowing debris to get caught under the liner or water to fill sags and create possible heat sinks during the curing process.
4. Steam curing leads causes the rapid emission of VOCs (i.e., styrene) that may lead to resident complaints.
5. Water inversion may require a much more invasive setup, depending on the pressures required to invert the liner.



**Figure 3.** Inversion liner (left: difficult water inversion setup; right: typical roadway air inversion setup).



**Figure 4.** Curing methods (left: hot water recirculation and curing; right: ultraviolet light curing).

## DEFECT CODING – DESIGN AND BIDDING CONSIDERATIONS

When digging up and replacing a pipe, engineers typically show the line but do not usually call out the defects in the existing pipe. The assumption is that, during the process of replacing the pipe, the key factors that need to be considered are the conditions surrounding the existing pipe (e.g., soil and other geotechnical conditions, presence of groundwater, access to the existing pipeline, etc).

For many engineers and designers of CIPP, this rationale has been carried over to CIPP design and contract documents. Because the existing pipe can be used as a conduit for the CIPP, CIPP is in essence a replacement pipe. When designing CIPP, many factors are taken into account. However, the factors are normally the parameters required by the equations in Appendix X1 of the ASTM F1216 standard for circular CIPP design (e.g., soil and other geotechnical conditions, height of groundwater anticipated over the pipe, other live loads, etc). There are only two main parameters that require any information about the existing pipe, (1) inside diameter, and (2) ovality.

Many engineers and specifiers of CIPP inspect the existing pipe before determining that it should be rehabilitated using CIPP. The condition of the existing pipe is generally known before the contractor arrives on site. The CIPP industry has generally adhered to a rough rule-of-thumb: if a CCTV camera can pass through the pipe, a liner can also pass. So if the CCTV camera passes through and the decision is made to line the pipe using CIPP, the contract documents will show the pipeline to be rehabilitated and the size of the pipe. But significant defects that may hinder the actual installation of the liner are generally not shown. Listing such defects will minimize risks to contractor and minimize the risk contractors build into their bids. Below are examples of defects that should be called out on the plans.

### Ovality

Some contract documents put the design requirement on the contractor. The contractor is responsible for taking available information and determining the thickness of the CIPP that will be used to rehabilitate the existing pipe. Most of these types of contract documents refer to the ASTM F1216 equations. However, very few contract documents refer to the fact existing pipes cannot use ASTM F1216 if the ovality is greater than 10% (when designing for a fully deteriorated condition). Once the pipe has sections of greater than 10% ovality, the design must be done by non-ASTM design equations, such as the British Water Research Centre's (WRc) Sewerage Rehabilitation Manual design equations<sup>1</sup>. Non-circular pipes generally require thicker CIPP liners than circular pipes; in addition to the thicker liners potentially requiring additional pressure if inversion is used, the ovality may make the installation of these thicker liners even more difficult.





**Figure 5.** Example of pipe with a greater than 10% ovality.

*Areas of ovality greater than 10% should be called out and provisions should be made in the contract documents requiring the Contractor to use non-ASTM design equations, when appropriate.*

<sup>1</sup>Unlike the ASTM F1216 design equations, the WRc Sewerage Rehabilitation Manual design equations do not account for soil and other live loads in their design equations. Specifiers should account for this omission when designing fully deteriorated CIPP using WRc methodology.

#### Heavy Cleaning

Preparatory cleaning is a necessity for CIPP. Unless otherwise specified in the measurement and payment specification section of the contract documents, most contractors will bid their jobs assuming a minimum level of cleaning. If there is a large variation in the type of cleaning that will be required, this should be called out on the plans. If there is no mechanism in the contract for heavy cleaning or large object removal, bidders may add more “risk” into their bids or contractor may attempt to receive compensation using change orders.

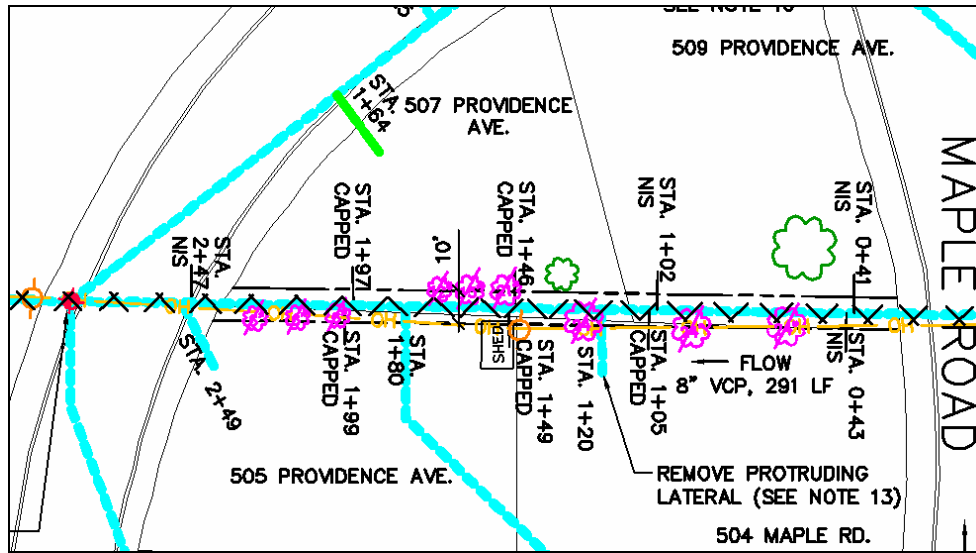


**Figure 6.** Example of heavy debris in line.

*Where known, areas requiring heavy cleaning, significant object removal, or other preparatory cleaning activities should be called out on the plans.*

#### Reinstatement of Active Taps

Many contract documents put the responsibility of confirming active taps on the contractor. Depending on the stance the Owner decides to take, reinstating a non-active tap can have expensive consequences. If lining is done primarily to reduce infiltration and inflow (I/I), cutting a hole in a new monolithic liner now opens up a pathway for I/I running between the liner and host pipe to enter the system. The typical repair is using a cured-in-place point repair, and if done correctly, with hydrophilic end seals to prevent the migration of water between the point repair and CIPP.

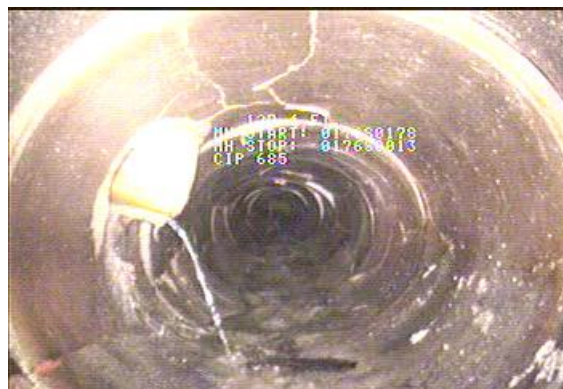


**Figure 7.** Example of plans highlighting multiple non-active taps.

*All taps should be called out and, where known, non-active taps should be highlighted. If possible, the contract should provide for payment to confirm if unknown taps are indeed active so the contractor does not build the risk into the bid.*

#### Removing Intruding Break-In Taps

Intruding break-in taps are an issue for CIPP. They restrict flow, may prohibit an easy installation of the liner, and create a weak point in the liner due to the loss of hoop strength (i.e., buckling is more likely to occur in the non-round portions of the CIPP). Break-in taps should be removed, and most contract documents specify these locations. However, many break-in taps have also caused significant structural problems at the location of the break-in. Contractors may be unwilling to take the risk of removing the break-in tap without appropriate measures, especially at critical locations (e.g., underneath major roadways or along pipelines with difficult access).



**Figure 8.** Example of break-in tap with structural defects.

*Plans should point out locations where break-in taps are to be removed and should highlight if there are defects that would restrict equipment access (e.g., large offset joints, broken pipe, etc.) or if there are severe structural defects that may worsen during removal of the break-in taps. The Owner can also minimize bids by highlighting locations where work may be done on a time and materials basis or work that may be paid for by contingency allowance.*

#### Removal of Roots

Roots are found in many sewer pipes slated for rehabilitation. Removal of these roots is a common practice prior to installation of CIPP. But, like cleaning, locations where heavy root cutting may be additional work that is not clearly covered by the contract documents and may open the owner up to change orders. Additionally, similar to break-in taps, major root issues may be problematic in structurally deficient areas or where root cutting equipment access is limited.

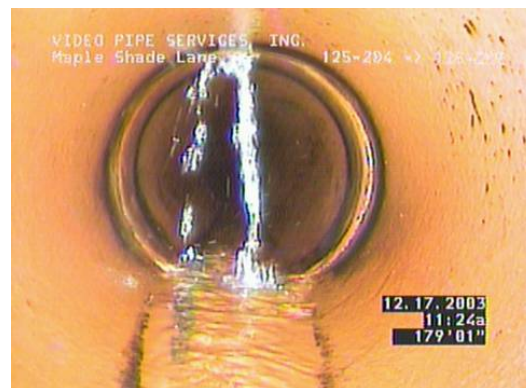


**Figure 9.** Example of roots in a broken pipe.

*Plans should point out pipe sections that are heavily inundated by roots. Plans should also highlight if there are defects that would restrict equipment access (e.g., large offset joints, broken pipe, etc.) or if there are severe structural defects that may worsen during removal of the roots. The Owner can also minimize bids by highlighting locations where work may be done on a time and materials basis or work that may be for by contingency allowance.*

#### Infiltration

Heavy infiltration may be problematic during the installation of CIPP. In addition to infiltration potentially causing resin washout on inversion installations, active infiltration can lead to heat sinks during curing, either at the location of the leak or by filling up sags in the pipe (usually something quantified as a runner or gusher, per the NASSCO Pipeline Assessment Certification Program). As infiltration is often a seasonal or weather-dependent variable, it is more difficult to call out.



**Figure 10.** Example of heavy infiltration.

*Where known, locations of active infiltration runners or gushers should be made called out. In addition, some mechanism in the Contract Documents should provide the contractor for payment of stopping the infiltration through a predetermined method such packer-injection grouting.*

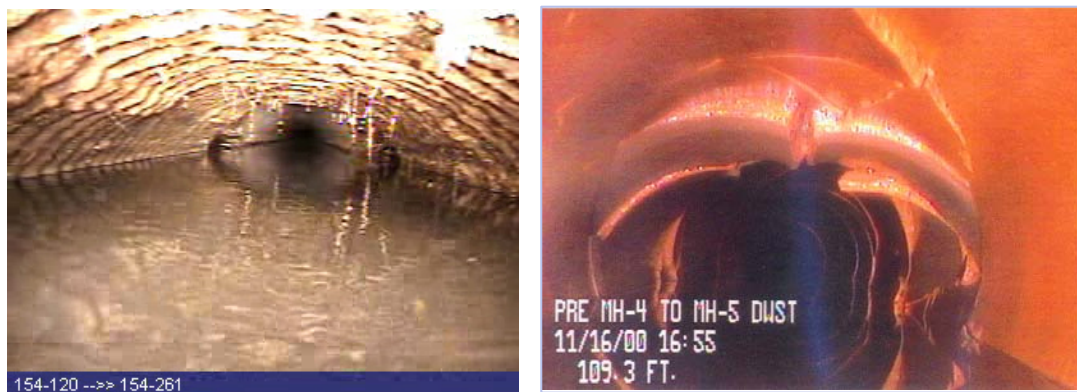
#### Structurally-Unstable Locations

The structural condition of host pipes makes some CIPP installation methods inappropriate. Exerting pressure on the pipe during air inversion may weaken an already unstable section of pipe, and if the liner is then deflated in order to switch over to the curing process, the pipeline may collapse. Similarly, the

hooks and winch cables used for pulling-in-place a liner may destabilize the already precarious structural condition of the pipe. A CIPP installation where the liner is inflated and remains inflated, such as a water inversion/hot water cure or certain air inversion/steam cure methods, are much more appropriate.

In the case of concrete pipes, the corrosion process caused by hydrogen sulfide being converted into sulfuric acid often leaves a layer of calcium sulfate (gypsum) on the exposed portion of the sewer pipe. Gypsum forms a pasty mass that is loosely bonded to the concrete aggregate. Since gypsum has no structural strength, this process weakens the sewer (USEPA, 1985). Without careful inspection, this layer of gypsum can sometimes appear as the original inner wall.

Very clearly, pipe segments should be further investigated to determine if gypsum is masking the true structural condition of the pipe. In these types of pipe segments, cleaning of line (e.g., running a jet nozzle through flowing water at 1500 psi) is a very risky proposition.



**Figure 11.** Example of unstable structural conditions (left: corroded pipe with rebar exposed; right: broken pipe).

*Pipelines of unstable structural conditions should be clearly called out and certain activities, such as preparatory cleaning, should be restricted. In addition, these pipelines may be locations where the Owner may want to specify the installation method.*

### PACP

The use of a standardized coding system reduces potential confusion over the exact nature of the defects that are called out on the plans. In the sewer industry, the National Association of Sanitary Sewer Companies (NASSCO) has developed the United States' only standardized coding system for defects in sewer lines. This standardized coding system provides consistency of reporting and simplicity of description of defects, eliminating confusion. For example, a break in the crown of clay pipe at the location of the 2-inch intruding tap is coded as a "B, 10 o'clock to 2 o'clock" adjacent to a "TBI-2, 2 o'clock". The break is clearly defined and possible interpretation of the break as a multiple fracture or a collapsed pipe is greatly reduced. PACP allows for shorter coding that is consistent to all parties.

In the design phase, owners and engineers can specify that the investigatory CCTV work be done in accordance with PACP. By doing so, all relevant defects will be coded using a national standard and, if PACP-certified inspection software is utilized, these codes will be available in a database format. Mining of the defect codes for transference to contract documents becomes that much simpler.

## **CONCLUSION**

When designing and specifying CIPP projects, owners and engineers normally take into consideration a number of issues that lead them to the decision to line the pipe. There is often a great deal of information



that is available that does not make its way onto the actual bidding documents, and in doing so, risk is often assigned to the Contractor. However, by adding a small fraction of the design effort by coding defects, clearly highlighting the locations of these defects to prospective bidders and contractors, and structuring the contract documents to share the risk between the contract parties, owners can obtain more competitive bids with the end result of projects with less change orders and fewer delays.

#### **REFERENCES (in alphabetical order)**

National Association of Sanitary Sewer Companies (2006). Pipeline Assessment Certification Program (PACP) Reference Manual.

Water Research Centre (2001). Sewerage Rehabilitation Manual, 4<sup>th</sup> Edition, Vol. 2.