CURED-IN-PLACE LINING

OVERVIEW

The main alternative to sliplining and its variants is cured-in-place lining, sometimes referred to as `insitu lining', `soft lining' or `cured-in-place-pipe' (CIPP), which has dominated the non-man-entry sewer renovation market in many countries for over twenty years. For brevity, these Guidelines refer to all cured-in-place lining techniques as CIPP systems, although it should be noted that not all providers of such systems use this term.

Although several competitive systems are now available, the common feature is the use of a fabric tube impregnated with polyester or epoxy resin. The tube is inserted into the existing pipeline and inflated against the pipe wall, then cured either at ambient temperature or, more commonly in all but the smallest diameters, by re-circulating hot water or steam. Some variations use ultra-violet light to cure the resin.

CIPP systems create a close-fit `pipe-within-a-pipe' which has quantifiable structural strength and can be designed to suit various loading conditions. The ring-stiffness of the liner is enhanced by the restraint provided by the host pipe and the surrounding ground, but systems designed for gravity pipelines do not rely on a bond between the liner and the substrate. Systems which rely on the host pipe for some measure of structural support are sometimes known as `interactive lining' techniques.

Multiple fractures in a clayware pipe - this is representative of the most severe damage that can be renovated using cured-in-place lining techniques

As well as minimising bore reduction, an inherent advantage of cured-in-place liners is their ability to conform to almost any shape of pipe, making them suitable for relining non-circular cross-sections. Provided that the liner perimeter has been correctly measured and that the material does not shrink significantly during cure, a close-fit liner should result. Their main limitation is the wall thickness, and hence the quantity, weight and cost of material, which may be required for larger sizes or for severe loading conditions, particularly in non-circular pipes.

Laterals can be re-opened remotely after lining, but care must be taken during installation to ensure that surplus resin does not enter branches. CIPP systems are also available for lining laterals from within the main pipe.

The major disadvantage of CIPP lining systems is the need to take the host pipe out of service during installation and cure. In gravity pipes, where flows are very low, it may be possible to plug any incoming pipes and to rely on the storage within the system. In other cases flow diversion or over-pumping will generally be required.

Some CIPP systems are suitable for use in large diameter (man-entry) pipes – see Renovation of Large Diametre Pipes and Chambers.

APPLICATIONS

Sewers	✔
Gas pipelines	✔ (see note A)
Potable water pipelines	✔ (see note B)
Chemical / industrial pipelines	✔ (see note C)
Straight pipelines	✔
Pipelines with bends	✔ (see note D)
Circular pipes	✔
Non-circular pipes	✔
Pipelines with varying cross-section	? (see note E)
Pipelines with lateral connections	✔
Pipelines with deformation	? (see note F)
On-line replacement (upsizing or size-for-size)	✘
Pressure pipelines	? (see note G)
Man-entry pipelines	✔ (see note H)

(A) Certain types of CIPP system have been designed specifically for use in gas pipelines rather than gravity sewers.

(B) Approval of the relevant regulatory body is needed for all materials in contact with potable water. Most CIPP systems are not intended for the renovation of potable water mains, but there are some which have been designed or adapted and approved for this purpose.

(C) The correct resin formulation must be chosen to resist unusually aggressive effluents and/or high temperatures.

(D) Wrinkling of the fabric may occur on the inner face of the bend, depending on the bend radius, the type of fabric used and the liner thickness.

(E) Some CIPP systems allow the fabric tube to be tailor-made to match changes in the circumference or perimeter of the pipeline within a manhole-to-manhole section. Other systems use a fabric which can stretch to accommodate small variations in cross-section. It should be noted that, since CIPP liners are flexible prior to cure and can conform to almost any shape of host pipe, the critical measurement is that of the pipe's circumference or perimeter.

(F) A widely accepted rule is that sewers with less than 10% deformation can be lined without any prior re-rounding. Ovality reduces the ability of the liner to withstand external loading such as hydrostatic pressure, and should be taken into account in the design.

(G) Most CIPP systems were originally intended for gravity pipelines, but certain proprietary techniques are available for pressure pipes. See also notes A and B above.

(H) Although used mainly in non-man-entry pipelines, some systems are also suitable for the renovation of large diameter sewers and culverts. The liner wall-thickness, weight and cost are the main limitations.

DESIGN & SPECIFICATION

Because liner specifications and design procedures vary from country to country and are subject to periodic amendment, it is outside the scope of these Guidelines to include reference to all national standards.

In countries where established local criteria do not exist, a widely-used standard is the Specification for Renovation of Gravity Sewers by Lining with Cured-in-Place Pipes contained in WIS 4-34-04, March 1995: Issue 2, published by WRc in the UK. Design procedures for determining the required wall thickness of circular and non-circular sections under different loading conditions are given in the WRc Sewerage Rehabilitation Manual.

Specifications for pressure (gas and water) applications are laid down by the relevant utility companies and approvals bodies. Most countries have strict requirements and accreditation procedures for all materials likely to come into contact with potable water.

INSTALLATION – GENERAL

As with all renovation systems, thorough cleaning and preparation are essential prerequisites. In non-man-entry sewers and other pipelines, inspection should be carried out by CCTV immediately prior to relining – old surveys can be misleading. Man-entry sewers may be surveyed by CCTV or manually.

All silt and debris must be removed completely, and a further inspection is recommended after cleaning to verify this. Care should be taken to avoid excessive pressures when using jetting equipment in damaged sewers, since this can exacerbate the defects. Intruding connections, encrustation and other hard deposits should be removed by mechanical or high-pressure water cutting equipment, followed by cleaning to remove the debris that this generates.

It is important to remove any loose fragments of pipe which may fall in as the liner is being inserted. This is particularly critical with `towed-in' liners where a broken piece of pipe may fall onto the liner as it is being winched in, and then be trapped between the liner and the pipe wall when the liner is inflated. Inverted liners tend to cause less disturbance to the pipe fabric, but problems may still occur.

Most CIPP systems require flow diversion during installation and cure. This period may be from a few hours to over a day, depending on the system and the characteristics of the pipeline. Lateral connections will be blocked by the liner until reopened, and provision should be made for removing surcharged effluent if there is insufficient capacity in the branch system. The build-up of effluent in a blocked lateral creates an external pressure on the liner, which may be significant if the sewer is deep. Measures may be required to limit the surcharge head.

Although CIPP systems are trenchless and designed to minimise disruption, vehicles and plant are needed on the surface throughout the installation procedure, especially at the entry manhole. Traffic regulation may therefore be required.

There may be short-term environmental implications with CIPP systems based on polyester resins, since the styrene solvent present in the uncured resin gives off a heavy vapour with a strong odour. However, although the vapour can be a health risk in high concentrations, such levels are not typically found around CIPP installations. Indeed, styrene vapour is detectable to humans at concentrations of less than one part per million, and the odour becomes unbearably strong at levels below those at which it represents a hazard. However, to avoid any nuisance, adequate ventilation around the work site is essential. This problem applies only until the resin has cured.

Polyester resins may be adversely affected by water until they have cured, which may be of relevance in a pipeline with infiltration or backed-up connections. In some cases, the use of a `pre-liner' (see below) can overcome problems of contamination.

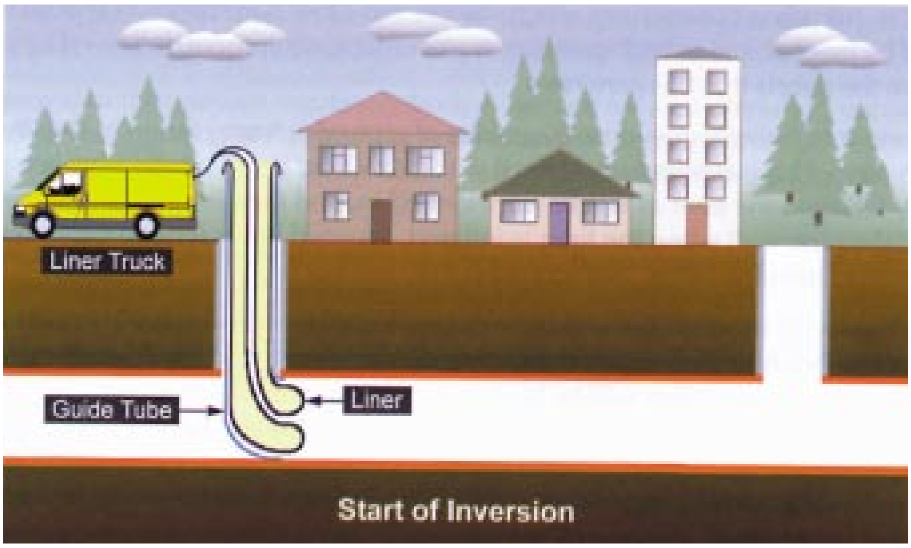
INSTALLATION IN SEWERS – THERMAL CURE

The following describes a typical process for installing thermal-cured CIPP liners in sewers. Each proprietary system has its own methodology, and the description below is intended as a guide rather than as a statement of best practice.

The majority of thermal-cure liners for gravity pipelines comprise a non-woven fabric – usually polyester needle-felt – impregnated with polyester resin. Some systems use a composite material such as felt and glass-fibre. The formulation of the resin can be adapted to suit different cure regimes and effluent characteristics.

The liner fabric is usually coated on the outer face of the tube – which becomes the inner surface of an inverted liner – with a membrane of polyester, polyethylene, surlyn or polyurethane, depending on the application. The membrane serves several functions – it retains the resin during impregnation and transportation, it retains the water (or air) during inversion, and it provides a low-friction, hydraulically efficient inner surface to the finished liner. Some systems use a separate membrane rather than an applied coating, and this may be removed after installation.

Impregnation is normally carried out in the factory under a vacuum to exclude air and ensure the uniform distribution of resin. This is known as the wetting-out process. Depending on the characteristics of the resin, the liner may be delivered to site in a refrigerated vehicle, to prevent the curing reaction from starting prematurely.



Insertion into the existing sewer is usually carried out either by winching into place or by an inversion process wherein water (or sometimes air) pressure is used to turn the liner inside-out as it travels along the pipe. The following procedure is typical:-

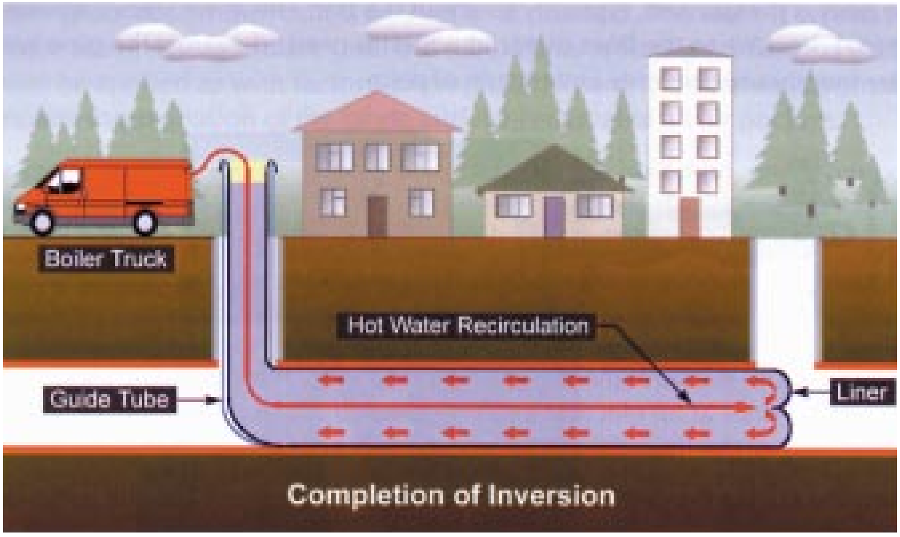
(a) A scaffold tower is constructed over the insertion manhole to provide the head of water necessary to invert the liner. In deep sewers, the tower may be unnecessary.

(b) A guide tube (which may be made from dry liner material) is installed between the inlet of the sewer and the top of the scaffold tower, with a rigid collar at the upper end to which the liner will be attached.

(c) The leading end of the liner is turned inside-out manually for a predetermined length, usually a few metres, and is then clamped to the collar of the guide tube. Attached to the trailing end is a hose which will run within the full length of the liner after inversion.

(d) Water is introduced into the turned-back section, which causes the liner to continue inverting through the guide tube and the host pipe. The pressure of water forces the liner against the existing pipe wall.

(e) When inversion is complete, the water inside the liner is circulated through a boiler unit, using the hose attached to the trailing end to ensure that hot water passes through the whole length of the liner. The rate of heat input is controlled according to the required cure regime of the resin.



(f) Temperatures at various points on the surface of the liner are monitored with thermocouples.

(g) Once cure has been achieved, the water is gradually cooled down before being released.

(h) The ends of the liner are trimmed. Sometimes a few centimetres of liner may be left protruding from the manhole wall, which provides a better seal and also mechanically locks the liner in place.

(i) If necessary, lateral connections are reopened with a robotic cutter.

Some systems use a pre-liner which is installed within the host pipe before inverting the impregnated liner tube. The pre-liner is intended to stop surplus resin from entering lateral connections, and it also prevents contamination of the uncured resin by water infiltrating into the sewer or from surcharged connections.

Some systems involve winching in the liner rather than using an inversion technique. Inversion may be difficult in certain locations because of the need to create an adequate head of water (although devices are available to generate the head by a combination of air and water pressure), and towing in the liner avoids the need for scaffold towers and overhead working. However, there are limitations to the size and weight of liner which can be winched in without stretching or tearing it, and winching a heavy liner through a damaged pipe can disturb the fabric still further.

UV-CURED LINERS

As an alternative to curing with hot water, there are systems using resins which cure under ultra-violet light. The amount of plant required is generally less than for thermal-cure systems.

UV-cured liners are often made from glass-fibre or a combination of glass-fibre and polyester needle-felt, with an outer membrane and a temporary inner sleeve to protect the liner during storage, shipping and installation.

It is possible to use resins with a storage time of several weeks at ambient temperature, so refrigeration is not required. Various resin formulations are available to suit the nature of the effluent.

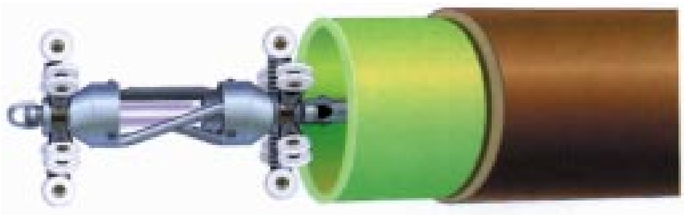
Installation generally follows the following procedure:-

(a) After the usual pre-survey and cleaning, the pre-impregnated liner is winched or inverted into position.

(b) The UV light source is inserted into the liner, and the sealing packers are inflated in each manhole.

(c) The liner is pressurised, typically to about 0.6 bar. The inner sleeve transfers the internal pressure to the liner material which is pressed against the pipe wall. The outer membrane prevents any escape of resin.

Diagram courtesy of Subterra

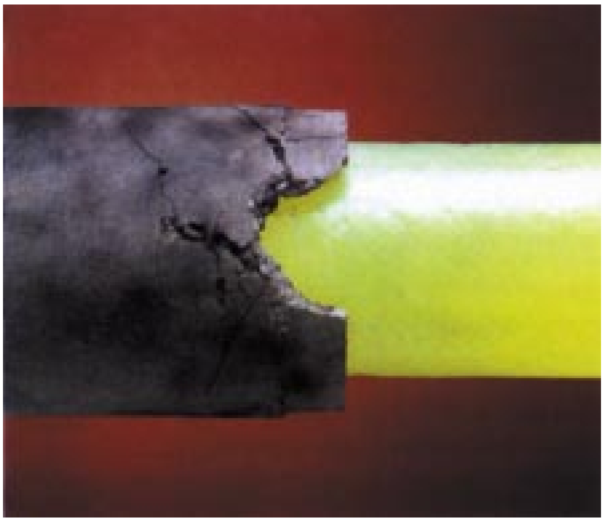


The UV light source is pulled through the liner at a controlled rate, while internal pressure is maintained

(d) While pressure is maintained, curing is effected by moving the UV light source through the liner at an electronically monitored speed dependent on the temperature of the liner during the chemical reaction.

(e) When the curing process is complete, pressure is released and the inner sleeve is removed.

Diagram courtesy of Subterra



Completed UV-cured liner

Typical curing times are between 0.5 and 0.9 metres per minute, and lengths of up to 200 metres can be lined continuously. UV-cured systems are available for pipes from 100 to 1000 mm diameter, with liner wall thicknesses from 3 to 15 mm. Variations are under development to line lateral connections.

INSTALLATION IN SEWERS – AMBIENT CURE

Ambient-cure lining systems are used mainly for the renovation of small diameter sewers, drains and other pipework, including vertical rainwater and soil pipes. They use similar fabrics to thermal-cure systems – normally a coated felt – and most use polyester resins which are formulated to cure without the application of heat.

Ambient-cure systems avoid the need for boilers or other heat sources, and therefore tend to be less expensive than their thermal-cure counterparts. The properties of the finished product may not, however, be equal to those of a thermal-cured liner, and the lack of external control over the curing cycle means that these systems are not usually suitable for pipes above 150 mm diameter, or for long lengths of pipeline.

The installation procedure is generally as follows:-

(a) Unlike thermal-cure systems, mixing of the resin and impregnation of the liner are often carried out on site. A measured quantity of the resin is mixed, with different amounts of catalyst and accelerator being added according to the temperature and the speed of reaction required.

(b) The liner, with the coating on the outside of the tube, is laid out along the road or on firm ground, and the resin is poured in at one end. The resin is worked along the tube using a heavy roller, until the whole liner is saturated. Since a vacuum cannot be applied as with factory-impregnated liners, it is essential to ensure complete impregnation of the fabric and the removal of all air pockets.

(c) The impregnated tube is pulled or winched into the host pipe, and a temporary inner sleeve is either pulled or inverted through it. This sleeve will contain the air or water used for inflation.

Installation of an ambient-cure liner in a site with difficult access

(d) Water or compressed air is introduced into the temporary sleeve, which pressurises the liner against the existing pipe wall.

(e) When sufficient time is judged to have elapsed for the resin to cure, the pressure is removed and the temporary sleeve is withdrawn.

(f) The ends of the liner are trimmed, and laterals reopened if necessary.

There are numerous variations on the above theme, including portable pressure-vessels for inverting the inner sleeve under air pressure.

Because of the low capital cost of equipment, ambient-cure relining systems have become popular with many small contractors as an alternative to carrying out drainage repairs by excavation.

CURED-IN-PLACE LINERS FOR WATER AND GAS MAIN RENOVATION

The structural characteristics required of a pressure pipe liner are quite different from those required of sewer liners. The primary loading on sewer pipes is external, and the most important structural parameters are elastic modulus and wall thickness which together provide the ring stiffness to resist buckling.

Pressure pipes, except in small diameters, fail less frequently through external loading. The most significant forces on the pipe are generally caused by the internal pressure which creates tensile stresses in the pipe or liner, and the most common pipe defects are corrosion and leakage from joints. Pressure pipe liners do not generally require as much ring stiffness as sewer liners, but they do need to withstand the bursting forces generated by internal pressure.

For this reason, the fabric used for CIPP pressure pipe liners tends to have a higher tensile strength than that for sewer liners, and, because flexural stresses are not so critical, the wall thickness of the liner is usually much less. Glass-fibre or a glass-fibre composite is commonly used, except in woven hoselinings which generally use polyester fibres.

The fabric of woven hoselinings is normally impregnated with epoxy resin, rather than polyester, which may produce an adhesive bond with the substrate and eliminates water-paths which could allow internal corrosion to continue. Epoxies may also be more acceptable in contact with potable water.

Most of the techniques aimed at pressure-pipe renovation were initially developed for the gas market, mainly in Japan, but several CIPP systems are now available to renovate potable water mains.

The installation process is similar in concept to the inversion method used for gravity pipe liners. However, because pressure pipe liners are less bulky, it is possible to contain the impregnated liner within a pressure vessel and to invert the liner through the host pipe with compressed air. Curing is achieved by introducing steam into the liner.

In addition to the thin-walled liners described above, there are also CIPP techniques using epoxy resins which do not rely on a bond to the existing pipe wall. These systems develop their strength from the composite action of the resin and fibres rather than a woven jacket, and are designed to resist both internal pressure and external loading. As an alternative to epoxy resin, vinyl ester resins are used for some industrial applications.

SUMMARY

- Most cured-in-place lining systems are intended for the renovation of gravity pipelines, though pressure pipe systems are also available.
- They are versatile, being able to accommodate non-circular sections, bends, changes of cross section, all pipe materials and various loading conditions.
- They produce a close-fit liner with a smooth internal surface, and the low hydraulic roughness often compensates for the reduction in bore.
- The liners generally used are resistant to all chemicals normally found in sewers. Special resin formulations are available for particularly aggressive effluents.

- Pipes from less than 100 mm to over 2500 mm diameter can be relined, although the economics may become less favourable in the largest sizes as the weight and cost of materials increases.

Photo courtesy of Insituform Technologies

Installation of a cured-in-place liner in a large diameter pipeline

- Lateral connections can be opened remotely from within the main pipeline.
- Lateral relining systems are available for installation either from within the main or from the upstream end of the lateral. These can provide an integral, sealed lining system for gravity sewers.
- The host pipe is blocked during insertion and cure of the CIPP liner, and flow diversion will often be required unless there is adequate storage in the upstream pipes.
- Cured-in-place techniques have a track record going back over 25 years, and their durability is well established.