CLOSE-FIT LINING

OVERVIEW

The use of liners that are deliberately deformed prior to insertion, and then reverted to their original shape once in position so that they fit closely inside the host pipe, is often known as `close fit lining ` or `modified sliplining'. Such techniques are a logical development of basic sliplining described in the Sliplining Section, and can be applied to both gravity and pressure pipes.

Cured-in-place lining may also be referred to as `close fit', but is covered separately in the Cured-in Place Lining Section of these Guidelines.

Modified sliplining often takes advantage of the in-built memory of some polymeric pipe materials: it two principal forms, both of which are intended to produce a close-fit liner which maximises the liner bore and obviates the need for annulus grouting. One form entails temporarily reducing the liner diameter by a die-drawing or roller compression process - sometimes referred to as `swaging' - so that it can be inserted into the existing pipe, and then pressurising the liner to restore it to its original size. Because of the limitations in the size reduction that can normally be achieved, the technique is better suited to pressure pipelines than to sewers with dimensional irregularities.

The second involves folding the liner into a `U' or `C' shape prior to insertion, and then using heat and/or pressure to restore circularity. This technique is often described as `fold-and-form'. The liner diameter and wall thickness are the main limitations to this process, but variations are available in polyethylene and PVC for both pressure pipes and gravity sewers.

In addition to the two main types, there are techniques involving liners folded into other configurations, and those which use reinforced materials or thermoplastics capable of expanding to a close fit without prior deformation.

APPLICATIONS

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

(A) There are proprietary systems aimed specifically at the renovation of sewers, using folded liners which are then reverted, or spirally wound liners whose diameter is

increased after insertion. Swage lining techniques are not, however, generally suitable for sewers.

(B) Approval of the relevant regulatory body is needed for all materials in contact with potable water.

(C) All bends add to the friction between the old and new pipes during installation, and so reduce the length of liner that can be pulled in without overstressing the pipe.

(D) Folded liners may be able to conform to some non-circular profiles when reverted. Swaged liners are intended for circular pipes.

(E) Swaged and folded liners are not able to accommodate significant variations in host pipe perimeter, but expanded, spirally wound liners may be suitable. Folded liners can sometimes be used in pipes that have become deformed.

(F) Subject to pipe diameter, internal reconnection may be possible using robotic equipment, although for pressure pipes it is more common to excavate.

(G) Some close-fit lining systems are intended for use in large diameter pipelines (including man-entry pipes), whilst others are aimed principally at the smaller sizes.

(H) Subject to the liner material being compatible with the chemicals.

SWAGED LINERS

There are close-fit lining techniques which entail temporarily reducing the diameter of the liner so that it can be pulled into the host pipe, and then reverting the liner to its original size. They rely on the fact that polymeric materials have a `memory', and tend to regain the size and shape at which they were initially extruded, although in practice the reversion process is aided by the application of internal pressure.

The techniques were developed for the gas industry, although they are suitable for most types of pressure pipes including potable water mains. Because the diameter reduction is limited by the properties of the material, these processes are not commonly used in sewers which have displaced joints or other dimensional irregularities. A material with a higher flexural modulus than most swaged liners is also preferable for gravity pipes with high external loading.

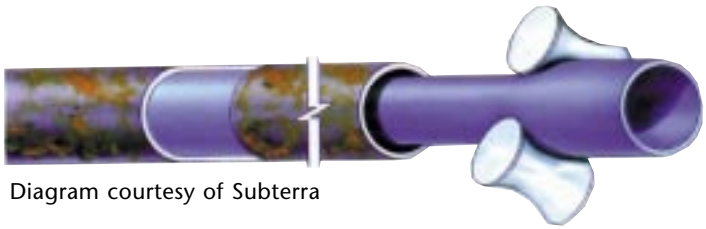


Diagram courtesy of Subterra

The pipe is reduced in diameter by passing it through rollers or dies, and is reverted to its original size after insertion

The liner pipe is made from polyethylene which not only has suitable physical properties for the diameter reduction process but is also an approved material for both gas and potable water applications. The diameter of the liner is reduced by feeding it through a system of rollers or dies within a hydraulically driven machine. This may be done on site as an integral part of the installation process, or in the factory prior to shipment of the pipes.

After winching the reduced-diameter liner into the host pipe and sealing both ends, pressure is applied to revert the liner to its original size. The technique can be applied to fully pressure-rated pipe, or to thin-walled non-structural liners for corrosion protection and leak sealing, and liners can be installed around gradual bends. Systems are commonly available in diameters from 100-600 mm, but the technique has been used in diameters up to 1100 mm.

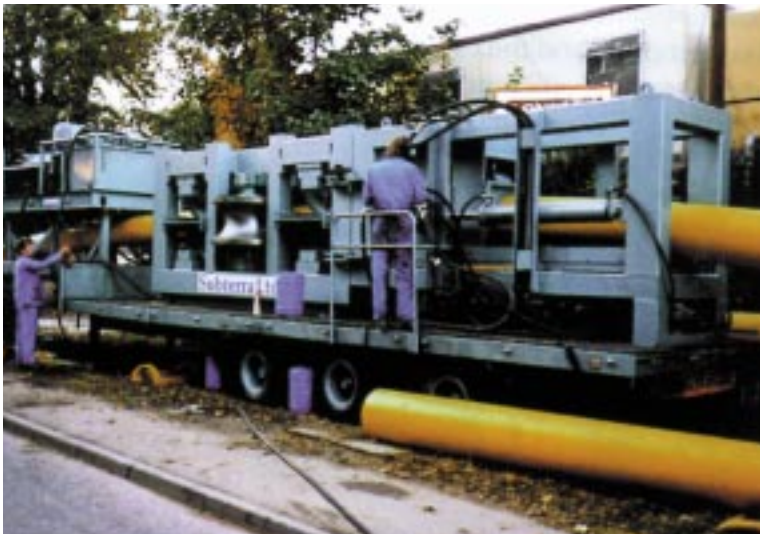


Photo courtesy of Subterra

Machine for simultaneously reducing the diameter of a PE pipe and inserting it into the host pipeline

FOLDED LINERS

Folded liners are sometimes known as `fold and formed pipeliners' (FFP), and most involve forming the liner pipe into a `U' or `C' shape prior to installation. As with reduced-diameter liners, the principle of folded liners is to reduce the effective size of the liner during insertion, and then to revert it to its original shape to produce a close fit within the host pipe. Folded liners are available for both pressure and gravity pipelines. Polyethylene is generally used for pressure applications, whilst PVC folded liners are available for gravity pipes.

In some systems, the liner is folded in the factory and delivered to site in coils. It is then winched into the host pipe. PE liners, especially thin-walled ones, may be reverted by pressure alone, but PVC liners require heating. In other systems, PE liners are folded on site as part of the insertion process. Factory folded PE liners for pressure pipes are available in diameters up to 450 mm, whilst liners folded on site can extend to 1600 mm diameter.

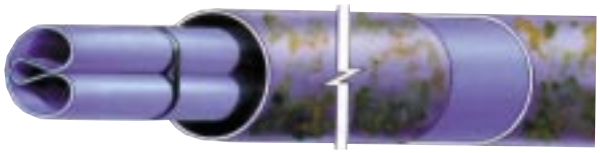


Diagram courtesy of Subterra

The folded liner is inserted into the host pipe, and then reverted to its original shape

As an alternative to folding the pipe prior to delivery, there is a close-fit lining technique for thin-walled liners in which a circular PE pipe is pushed through a forming machine on site. The technique uses standard PE pipe which is folded into a `U' or `C' shape for insertion into the existing pipe. The shape is retained by temporary straps which break when the installed liner is pressurised during the reversion stage. The liner can be installed in long lengths (over 1000 metres), and around bends subject to pipe diameter and other factors.

Thermoplastic PVC liners are often pre-heated before insertion to increase flexibility, and once in place are heated internally to create a uniform temperature throughout the material. Reversion can be achieved progressively by inserting a rounding device into the upstream end of the liner, which is propelled by steam pressure to the downstream end. As the device progresses it expands the liner against the wall of the host pipe, and also forces out any liquids between the liner and the pipe. When flexible, the liner moulds to the shape of the host pipe, and usually forms dimples at lateral connections. Pressure is maintained while the liner cools to a rigid state, after which the ends are trimmed and laterals reopened. A typical installation takes approximately five hours. It should be

noted that groundwater infiltration may adversely affect the ability of the liner to reform to the shape of the host pipe, and the use of an alternative technique may be desirable under such circumstances.

Photo courtesy of Insituform Technologies

Folded PVC liner for sewer renovation, showing close fit after reversion

Folded PVC liners are available in diameters from 100 to 350 mm, and are made from a type of PVC which is modified to accommodate the folding and reforming process. The degree of modification varies greatly between different products - some have a relatively high flexural modulus of between 2000 and 2500 MPa, whilst other highly modified compounds attain values of only 900 to 1100 MPa, a figure similar to polyethylene. This must be taken into account in the structural design of the liner.

Close-fit renovation of small diameter pipelines with a pressure-rated polyethylene replacement can be achieved using cross-linked polyethylene (PE-X) whose properties include shape memory. This allows pipes to be extruded at a given diameter and subsequently reduced in size by about 25%, the product then being coiled into long lengths for delivery to site. The size reduction allows the negotiation of constrictions and offset joints.

The folded PVC liner is expanded using a rounding device propelled through the pipe

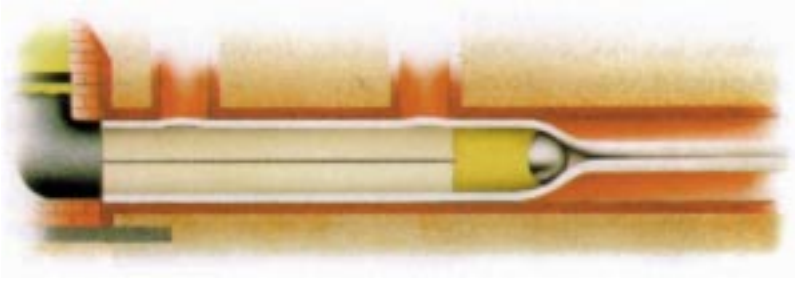


Diagram courtesy of]Insituform Technologies

Once inserted, the pipe is heated using a hot air tool, which activates the shape memory of the material and causes it to revert to the size at which it was extruded. The liner pipe expands to achieve a close fit, moulding itself to any intrusions and joints. If, prior to reversion, the host pipe is broken out at the position of branch connections, the new pipe expands to the correct dimensions for the use of standard electrofusion fittings.

A water main relining system is available which comprises a circular woven polyester jacket encapsulated in polyethylene. This flexible hose is folded in a tight `C' shape before being inserted into the host pipe and inflated using low pressure steam. The process produces a thin walled liner which can have an unsupported fifty-year burst strength of up to 23 bar depending on diameter. The system is currently available in the size range 70 to 200 mm, and lengths of up to 200 metres can be installed in one operation. The system can be used to line through bends.

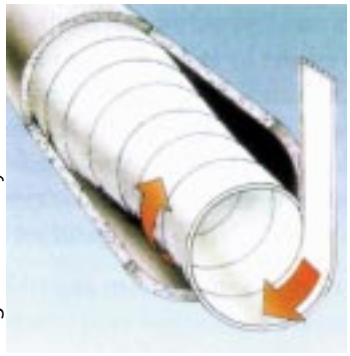
Two recently-introduced techniques for relining small diameter (12 to 18 mm) water service pipes are aimed at leakage control and the avoidance of contamination from lead pipes. In the first, a folded polyethylene film liner is wound on a reel contained within a pressure vessel. The motive force is created by air pressure acting on a small flexible `bullet' fastened to the end of the liner. Air from an oil-free compressor is released into

the pressure vessel, driving the bullet into the pipe and carrying the liner behind it. The liner is then inflated with compressed air and held in place with standard plumbing fittings, allowing the water supply to be reinstated quickly. The second involves the insertion of an undersized, extruded polyester (PET) tube which is expanded with steam pressure and secured in place with standard plumbing fittings.

EXPANDED SPIRAL LINERS

Some versions of the spirally wound lining technique for gravity pipelines (described in the Sliplining Section) offer the facility to expand the installed liner to provide a close fit within the host pipe. During installation, the joint between adjacent turns of the helix is prevented from slipping by a locking wire. Once the liner is in position, the winding machine continues to operate, and the locking wire is pulled back progressively to allow the joint to slip and the helix to increase in diameter.

Diagram courtesy of Subterra



The spirally wound liner is expanded after insertion by allowing slippage between adjacent turns of the helix

As with the standard form of spiral liners, low flows in the pipeline can be accommodated during installation without overpumping or diversion. Since there is no grouting, groundwater may enter manholes by following the path between the outer T-beams. It is therefore essential to provide a good seal between the liner and the host pipe at chambers. Sealing must also be carried out at any lateral connections.

The structural properties of the liner are governed by the need to wind the PVC strip into a helix, and spirally wound liners may not be able to resist high external loads.

SUMMARY

- Reduced diameter (swaged) liners are suitable for the structural relining of gas and water mains, producing a close-fit liner within the host pipe. They may not be suitable for pipes with severe joint displacements or dimensional irregularities.
- Folded PE liners offer an effective means of installing close-fit structural or non-structural liner within a pressure or gravity pipe. The properties of thin-walled polyethylene are not ideal for structurally unsound pipelines with high external loads.
- Folded PVC liners are suitable for gravity pipelines up to 350 mm diameter, and offer good chemical resistance and relatively short installation times. High groundwater tables and infiltration can impair the installation process.
- Folded polyester-reinforced PE liners are for use in water main renovation, and are sufficiently flexible during installation to negotiate bends.
- Small-bore folded PE membrane liners or expandable polyester liners can be used for leakage control in water services and to prevent contamination from lead pipes.
- Expanded spirally wound liners for gravity pipelines are quick to install and may not require flow diversion. Although they are close fitting, the spaces between the external ribs allow a water path which must be sealed at manholes and connections. The stiffness of the liner may not be as high as in some other systems.