INTERNATIONAL SOCIETY FOR TRENCHLESS TECHNOLOGY	TRENCHLESS TECHNOLOGIES INFORMATION CENTRE	
	TRENCHLESS TECHNOLOGY GUIDELINES	THIRD EDITION
	ON-LINE REPLACEMENT	LAST UPDATED MARCH 2009

1. OVERVIEW

On-Line replacement technologies use the existing pipe as a route for installation of its replacement. The available technologies can be classified as follows: (To view the full Guideline for each technique click on the highlighted name e.g. PIPE BURSTING)

Operation Type		**Pipe Material**	**Technique**
Existing pipe destroyed	Pieces left in the ground	Brittle pipes	PIPE BURSTING
		Ductile pipes	PIPE SPLITTING
	Pieces removed	Most (Inc reinforced)	PIPE EATING PIPEREAMING
Existing pipe extracted		Lead and some Plastic	PIPE EXTRACTION
Existing pipe retained as conduit for new		Any	SLIPLINING (see note following)

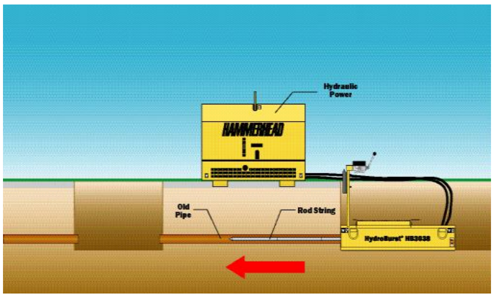
NOTE:

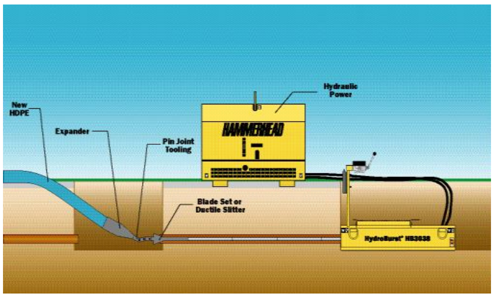
The inclusion of Sliplining in this group is open to question. If the annulus between the host pipe and the liner **is not** grouted, the liner is structurally independent from the existing pipe and can be considered as a true on-line replacement. If the annulus **is** grouted, the liner can transfer internal pressure loads to the host and is interactive. It might then be considered as a fully structural renovation technology as described in Section 5. As the Sliplining technique is described elsewhere in section 5 it will not be repeated here.

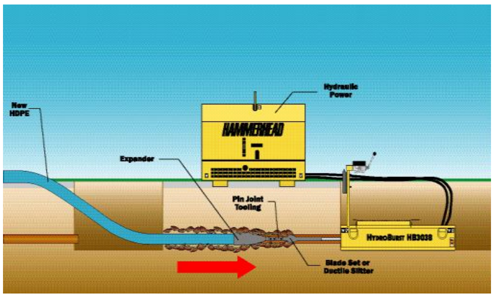
iSTT INTERNATIONAL SOCIETY FOR TRENCHLESS TECHNOLOGY	**TRENCHLESS TECHNOLOGIES INFORMATION CENTRE**	
	TRENCHLESS TECHNOLOGY GUIDELINES	THIRD EDITION
	PIPE BURSTING AND SPLITTING	LAST UPDATED MARCH 2008

1. OVERVIEW

Pipebursting technology was developed in the UK in the early 1980s, originally for the replacement of old cast iron gas mains. Following widespread use, including in the UK water industry for the replacement of small to medium diameter cast iron potable water systems and sewer pipelines, pipebursting now has an increasing market worldwide. Pipebursting is referred to in certain countries as ‘pipe cracking’. In its earliest forms pipebursting comprised the use of percussive tool (usually a modified impact mole) or a hydraulic expander to break out the existing pipe with a new pipe being pulled or jacked in behind. Using the correct equipment, the original pipe size can be increased to a certain extent allow the capacity of the new system to be greater than that available with the old one. More recently however there has been a significant shift away from these systems towards those that rely entirely on axial jacking or pulling forces acting on a specially designed, often tapered or shaped, bursting head. This system tends to be referred to as Hydraulic Rod Bursting.







Hydraulic Rod Bursting is a multi-stage process as illustrated here. The process is explained in detail in the following. *Pictures courtesy of HammerHead.*

In addition to gas and water main renewal, pipebursting is becoming one of the leading no-dig technologies for the replacement of old, deteriorated and undersized sewers. Significant increases in size have been achieved, such as the installation of a 600 mm diameter plastic main through an old 375 mm concrete sewer. Sewer bursting operations are typically in the diameter range 150 to 375 mm, but pipes of 800 and 900 mm diameter have been replaced by this method, and bursts of up to 1,200 mm diameter have been achieved.

Because of the outward expansion of the old pipe, it is necessary to disconnect laterals and service pipes before using pipebursting and most other on-line replacement techniques. Although remote disconnection techniques have been developed, the most common method is by means of a small excavation, increasingly using vacuum excavation techniques, from which the lateral or service pipe can subsequently be reconnected to the new main. The number and frequency of laterals or service connections can be a determining factor when assessing the economics of trenchless replacement against traditional open-cut methods.

2. PERCUSSIVE PIPEBURSTING

Disclaimer: This document is provided for historical reference only. This guideline has been replaced by the new Trenchless Technology Charts and Descriptions on the website. Be aware that some links may no longer work. Use this information at your own risk.

Pneumatic moles, otherwise known as 'ground-piercing' or 'earth-piercing tools', are described fully elsewhere in Section 3. Basically, they comprise a steel cylinder within which a pneumatically driven hammer repeatedly strikes an anvil at the nose of the tool, causing the cylinder to be driven forward. Numerous configurations are available with various designs of nose cone and internal mechanism.

Many types of pneumatic mole can also be used for pipebursting, where the mole travels up an existing pipe, breaks it out and forces the fragments into the surrounding ground. A new pipe is simultaneously drawn in behind the mole, and a cable or rods attached to the mole nose to augment the percussive force whilst also helping to keep the mole on the correct line.

A range of pneumatic bursters. *Picture courtesy of Earth Tool Inc Hammerhead.*

Pipebursting using a pneumatic mole relies on a percussive fracture mechanism, and is therefore aimed at brittle materials such as cast iron, spun iron, clayware, un-reinforced concrete and possibly the more 'brittle' types of plastic pipe such as PVCu. The technique was at one time by far the most popular method for the size-for-size replacement and upsizing of pressure pipes, and has been used in diameters from less than 100 mm to over 500 mm.

The original systems comprised a pneumatic hammer, which was pulled through the old pipe by a steel cable attached to a winch. The nose of the burster was fitted with fins to assist in bursting the pipe and collar. The new pipe, usually polyethylene pre-welded to the required length, is drawn in immediately behind the burster unit. In some cases an intermediate jacking force may be applied to the pipe string, rather than relying entirely on the pull from the bursting head at the front or the jacking force from the rear.

Whilst start and reception pits are more often than not used with these tools some manufacturers do supply shorter versions of the impact hammers which might, in the right circumstances, be used from existing manholes.

One of the main disadvantages of the system is that during the bursting operation impact shock is transmitted into the soils which can cause vibration into adjacent properties or stress on adjacent buried plant. This problem has been in part at least reduced by the adoption of the system described in the following.

Also there is the potential on shallower installation for heave to occur at surface during the bursting and expansion process. This can also apply to other pipe bursting methods and should be borne in mind when investigating the potential for use of pipe bursting as it may negate use of the technique.

Disclaimer: This document is provided for historical reference only. This guideline has been replaced by the new Trenchless Technology Charts and Descriptions on the website. Be aware that some links may no longer work. Use this information at your own risk.

3. HYDRAULIC PIPEBURSTING

Taking into consideration the effects that pneumatic pipebursting percussion can have on adjacent pipes, services, foundations and paved surfaces etc alternative techniques were developed with a view to reducing the effects if not eliminating them. One alternative is hydraulic bursting, using an expanding head with 'petals' that open and close under hydraulic pressure. Hydraulic bursters are often shorter than their pneumatic counterparts, allowing size-for-size replacement or upsizing from existing chambers without the need to excavate launch and reception pits. In general, hydraulic bursting has been used primarily for the on-line replacement of sewers and gravity pipelines, more than for pressure pipelines. Pipelines up to 1 m in diameter have been installed by this method. A more portable hydraulic pipebursting system is also available, designed to replace pipes up to 150 mm diameter and using equipment which is sufficiently compact for use in gardens, in or under buildings and in other locations with limited access.

In operation, the bursting head is first expanded to crack the old pipe, and is then retracted. Hydraulic jacks acting on the new pipe string are then used to push the pipe string forward, while tension is applied to the nose of the burster by a chain, cable or hydraulic rod system to maintain directional stability. The process is then repeated, adding further pipes to the end of the string as work progresses. The leading end of the pipe string sits inside a shield connected to the back of the bursting head. This eliminates the impact shock and stresses caused when using pneumatic busters.

The only 'shock' entering the ground then becomes that caused by the pipe fracture process, usually a much lower stress. As the petals expand the shards are pushed into the surrounding ground relatively smoothly, so further reducing peak shock stresses in the surrounding soils and adjacent plant.

A hydraulic 'expansion' bursting head. *Picture courtesy of PERCO Engineering Ltd.*

A variation on the technique is to use a very powerful hydraulic pushing and pulling machine, which acts on high tensile steel rods connected to a bursting head that is pulled through the existing pipeline. The new pipeline is drawn or jacked in behind the head. The typical pulling capacity is from 20 to 230 tonnes, depending on pipe diameter and length, and this method relies as much on the power of the pulling machine as it does the hydraulic expansion of the head itself.

Although welded PE pipes can be used in conjunction with hydraulic pipebursting, the new pipes are commonly polyethylene with joints that snap or screw together, in short lengths suitable for installation from existing chambers. Clayware pipes designed for hydraulic pipebursting applications have been used, allowing sewers to be replaced or upsized using a traditional material. These are usually jacked into the void behind the bursting head. The clayware pipes have stainless steel collars to provide enhanced shear strength at joints and, in appearance, are similar to those used with microtunnelling systems, though with a thinner pipe wall. Clayware pipes can withstand higher jacking forces than most polymeric materials, although they are heavier and may require powered systems for lifting and handling on site.

More recently special joint PVC pipes have also been developed for use in conjunction with bursting operations.

4. HYDRAULIC ROD BURSTING

A hydraulic rod bursting unit. *Picture courtesy of Hammerhead/U Mole Ltd.*

Hydraulic Rod Bursting utilises a hydraulically powered rod pushing unit which initially pushes rods through the pipe being replaced, from one access point to another. The guide rod used at the front end of the rod chain during insertion, which should prevent the rod end from snagging on any pipe unconformities. This is then replaced with the bursting head assembly comprising either a bladed head for brittle pipes or a cutting head for splitting non-brittle pipe and an expansion head, to push aside the broken shards of the burst pipe or to open out the cut pipe. The new pipe is pulled in behind the burster/expander assembly as it advances. In the burster/expander assembly the expander shell can also be of a size greater than that of the original pipe in order to upsize the service to a new larger diameter increasing its capacity. As the bursting head is pulled back through the old pipe it is burst or split, with the shards being pushed to one side into the surrounding ground. The new pipe is pulled into place into the new opening created. Once pulled through to the start pit the bursting equipment is removed, leaving the new pipe in place ready to be connected to the remainder of the existing system.

One company has extended the more common threaded end rod-based system, by replacing solid round section rods with an interlocking ladder or lattice rod design. This is designed to make rod changing easier and quicker so making the operation as a whole more efficient. There has been some question over the safety of some of the rod based system where accidents have occurred, including personal injury, when rods placed under extreme tension during a pull-back operation have snapped causing problems of recoil in the machine pit. Whilst some machine manufacturers claim their systems are safer either by virtue of the rod clamping device or with remote control of the machine with no personal access when the rods are in tension, this is something that should be borne in mind when using these systems.

In a more recent development, one systems manufacturer has launched a unit that addresses the problem that on pipe bursting systems occasionally the broken shards from the old pipe cause damage to the new pipe as it passes through the void created by the expander. Previously, this has been a problem that simply had either to be lived with or the problem is over-engineered out using over-sized expanders and/or a thicker walled replacement pipe to absorb the damage. In earlier years this problem was overcome by installing a casing pipe behind the bursting head into which the product pipe was the slip lined/ installed. This latter option was discarded to a large extend because research by British Gas at the time showed that shard orientation tended to be favourable and that casing installation was a costly exercise that was outweighed by the limited damage done by shards.

Alternatively some pipe manufacturers now offer specially designed pipe which has a harder protective outer skin that is designed to be sacrificial. As damage occurs to the outer skin it is ‘absorbed’ by the harder ‘wear’ layer without the shards impinging on the product pipe beneath (see Specialist Pipes below).

Disclaimer: This document is provided for historical reference only. This guideline has been replaced by the new Trenchless Technology Charts and Descriptions on the website. Be aware that some links may no longer work. Use this information at your own risk.

One newly developed system tries to overcome the 'loose shard' problem by 'gluing then into place. Whilst working in exactly the same way as traditional hydraulic rod-based pipe bursting systems, the new technique has the major difference that, using an independent grout injection system, a cement grout mix is pumped through a feed line inside the new replacement pipe. The grout is extruded under pressure via ports in the expansion head that are positioned to ensure that the grout is uniformly placed around the new pipe as it is towed in. The grout combines with the old pipe shards and the mix is pushed into the surrounding ground, 'cementing' the shards into place. This avoids interaction between the shards and the new pipe. This eliminates the need for over-engineering, so the new pipe can be designed as required for the application and the expansion head can be of the correct size and no larger. This minimises new pipe costs and eliminates the need for a more costly larger pipe bursting rig to create a larger void.

5. SMALL FOOTPRINT BURSTERS

There has also been the development of a system that is small enough, yet powerful enough, to fit into, or be used through, an existing manhole so further eliminating the need for access excavations. With increasing requirement for pipebursting application in the street to property sector of the market several manufacturers have redesigned the basic hydraulic rod burster. This design uses a smaller footprint, enabling similar power capability in a unit that has easier access to limited space conditions. As well as the rod based systems, some manufacturers have also developed cable based pulling units. This gives very small footprint units that can be utilised in an access pit as small as 619 mm x 760 mm, and to replace pipes from a little as 50 mm diameter. Production rates are also good at up to 3.5 m per minute.

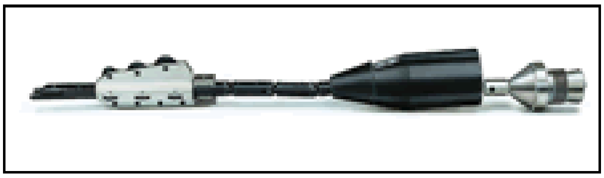
A small footprint pipe bursting unit. *Picture courtesy of HammerHead/ U Mole Ltd*

Return to Overview ▲

6. PIPE SPLITTING

Non-brittle pipe materials, such as stainless steel pipe or repair collars, ductile iron pipes or saddle clamps or polyethylene repair sections, may present problems to some pipebursting systems. If such materials are encountered, the burster may be prevented from making forward progress should it not be designed to handle these materials.

Whilst high rates of success in dealing with non-brittle materials are claimed for certain pipebursting techniques, an alternative approach is a system which uses a cutting and expanding head with the ability to cut through the wall of steel, ductile or plastic pipes or fittings.



Above: A typical pipe splitting head assembly with cutter blades at the front followed by the expansion shell. Left: A pipe splitter unit 'cutting' a ductile pipe material.

The 'splitting' head (as it is commonly known) is pulled through the pipeline by a hydraulic rod system, and slices open the old pipe while pulling in a new pipe string behind it. The technique can be used in pipes made from steel, ductile iron, repaired cast iron, asbestos-cement, PVC and polyethylene, and has been used to install diameters of up to 305 mm under suitable conditions. Rates of progress of around 2 m/min have been achieved. One aspect of these splitting heads that has made them very popular for both brittle and ductile pipebursting operations, is that they have the capacity to 'cut' through repair fittings, so increasingly they are used for most bursting operations as the pipe being replaced more often than not will carry several such repair collars. This allows operations to proceed without the need to dig down at repair points, or to drag collars through the soil to the reception pit, a circumstance that places increased pressure on the pulling system. Before these heads were available, pulling repair collars through the ground regularly brought replacement operations to a halt as the pulling power of the rod machine was too insufficient to overcome the increased friction forces created.

7. SPECIALIST PIPES

Whilst the improvements and developments in the bursting equipment itself have been significant over the past decade or so, one of the most pressing problems with pipe bursting has only been answered in more recent times. One regular occurrence, in the early years of pipebursting, was the damage caused to the new pipe during insertion by sharp edges of old, burst pipe cutting into its surface. To overcome this problem, several clients required that thicker wall pipe be used in pipebursting works so that, even with surface damage, the remaining wall thickness was sufficient to do the job required. A rule of thumb for these installations has been that damage depth should not be more than 10% of the pipe wall thickness.

In an attempt to overcome this problem, some pipe manufacturers have developed new pipe systems that use a sacrificial skin around the main body of the pipe. The skin can of a harder plastic than the main PE body such as PVCu which will withstand scouring to a much higher degree or foamed PE which wears preferentially. The pipe design also ensures that the main pipe is of the standard required for the installation. Therefore, even if the sacrificial skin pipe is scoured completely through, the main pipe will be virtually unaffected.

8. OTHER DEVELOPMENTS

As well as the new pipe design, there have been certain other pipe system developments that have aided the growth in the pipe bursting market. One significant one has been the development of pipe coil trailers, which enable pre-determined long lengths of pipe to be transported to site so eliminating the need for pipe welding on site. This reduces the number of operations required on site. The working area needed to complete an operation is also reduced, as the footprint of the trailer-mounted pipe system is much less then that required when stick pipe is welded on site. Both this and the sacrificial skin pipe development can also be applied to HDD operations (see Section 3).

9. PROXIMITY OF OTHER SERVICES

Whilst the types of online replacement systems and their support equipment have been discussed above, there is one area of extreme importance that needs also to be covered, Proximity to Other Buried Services. This cannot be overstressed!

As will have been seen in the text above, all of the systems covered rely on breaking down the pipe material of the existing pipe, or cutting in some fashion, with the shards, or other remains, then being forced into the ground surrounding the old pipe route. This of course required that the surrounding ground is compressible in nature, which in turn means that, when the expansion of the burst pipe occurs, there will be ground movement around the route in some form or other.

Whilst the majority of the compression occurs close to the burst pipe, the effects of this compression may be felt at some distance from the centreline of the old pipe. Therefore any service sitting inside this zone of influence of the compression will naturally be affected by it. This may lead to problems, such as pipe fracture or joint failure, which in turn may give rise to leakage or other problems. Research has been and continues to be carried out in respect of the potential ground movement and its effect on adjacent services (*see Conference Papers Moscow 2008 'Effect Of Pipe Bursting On Adjacent Structures' link*).

Before starting a pipe bursting operation it is vitally important that a full and comprehensive ground survey is completed, and the potential for damage to nearby services assessed. This may even mean having to choose an alternative replacement method if the potential for 'third-party' service damage is too high. This is a factor that may be a determining one when considering the use of the pipebursting technique.

The systems available to complete a full and comprehensive ground survey are discussed elsewhere in these Guidelines.

10. SUMMARY

1. Pipe Bursting and Splitting On-line replacement offers a means of replacing or upsizing existing pressure or gravity pipelines economically and with minimal or no excavation. A wide range of techniques is available, based on pneumatic, hydraulic (expander, rod or cable based) or microtunnelling 'pipe eating' or HDD 'pipe reaming systems (see separate sections).
2. Correctly applied and with the right accessories, the various techniques can replace brittle and ductile materials including cast iron, clayware and un-reinforced concrete and steel.
3. In all cases, the success of the operation will depend on having accurate information about the original construction materials and the condition of the existing pipeline, including, for example, whether there have been any localised repairs, and whether sections of the pipeline have been surrounded in concrete.
4. Laterals and service pipes must be disconnected prior to the on-line replacement of the main, and then subsequently reconnected to the new pipeline. This is usually carried out from a small excavation. The number and frequency of connections may influence the economic viability of the technique.
5. On-line replacement is one of trenchless technology's major growth areas, and it is likely that new developments will continue to extend the capabilities of on-line replacement systems, whilst also adding to their economic benefits.

Return to Overview ▲

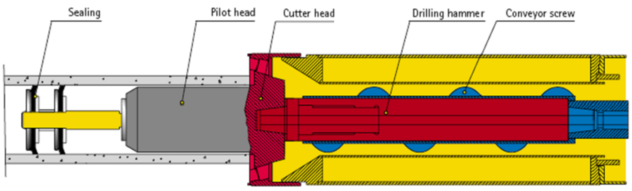
Disclaimer: This document is provided for historical reference only. This guideline has been replaced by the new Trenchless Technology Charts and Descriptions on the website. Be aware that some links may no longer work. Use this information at your own risk.

INTERNATIONAL SOCIETY FOR TRENCHLESS TECHNOLOGY	TRENCHLESS TECHNOLOGIES INFORMATION CENTRE	
	TRENCHLESS TECHNOLOGY GUIDELINES	THIRD EDITION
	PIPE EATING, REAMING AND EXTRACTION	LAST UPDATED MARCH 2009

1. PIPE EATING REPLACEMENT

Microtunnelling equipment, described in detail in Section 3, can be used for the trenchless replacement of undersized or damaged sewers, as well as for new installation. The 'pipe eating' process, as it is known, is suitable for the replacement of clayware, concrete, asbestos cement, GRP and even reinforced concrete pipes, with the new pipe being jacked in behind the microtunnelling machine.

Microtunnelling machines can excavate an existing pipe, whilst a new pipeline is simultaneously jacked in behind. The machine crushes the existing pipe material with its built-in crusher, and the process also permits realignment and upsizing of the sewer. Systems exist which allow on-line pipe replacement without flow diversion. During installation, the sewage flow is pumped through the shield separately from the pumped spoil slurry circuit, and no over-pumping is required.



Above: A schematic of the pipe eating microtunnelling operations showing the 'nose seal' position ahead of the cutting wheel. Right: The actual microtunnelling set up for pipe eating. *Pictures courtesy of Herrenknecht AG*

A further adaptation uses specially designed teeth within the cone crusher to cut the reinforcement in a concrete pipe, allowing the excavation of all conventional pipe materials in addition to concrete. Some machines have a pilot head fitted to the cutting wheel, which guides the machine within the existing sewer, together with pneumatic hammer action, which assists the cutting head to crush the old pipeline.

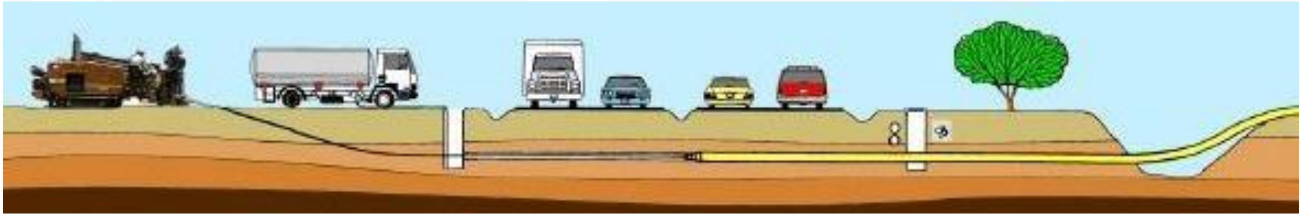
The machine are also often fitted with nose seal extensions ahead of the cutting wheel to ensure that the slurry system used to remove the cut spoil of ground and old pipe does not have to be of a volume that would need to fill the whole pipe length but only that needed in the area being cut.

Return to Overview ▲

2. PIPE-REAMING WITH DIRECTIONAL DRILLING MACHINE

Disclaimer: This document is provided for historical reference only. This guideline has been replaced by the new Trenchless Technology Charts and Descriptions on the website. Be aware that some links may no longer work. Use this information at your own risk.

This technique allows on-line replacement using a directional drilling machine, as described in Section 3, with a pullback capacity of at least 10 tonne. The system employs specialised reaming tools to grind up the old pipe, whilst the new pipe string is drawn in behind. The fragments are suspended in the drilling fluid and pass through the existing pipe to a manhole or recovery pit.

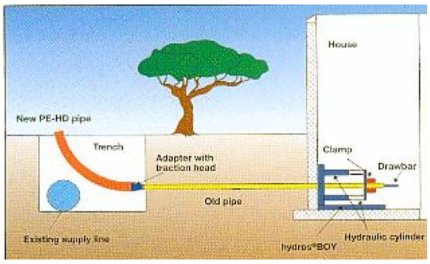


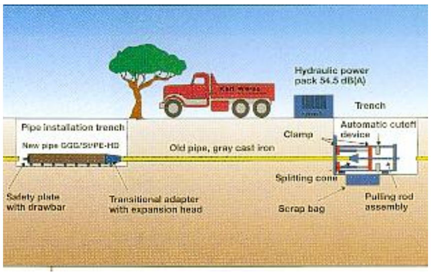
Above: A schematic of the pipe reaming method using an HDD rig as the pulling system. Right: A typical pipe reaming head. *Pictures courtesy of Nowak Pipe Reaming.*

3. PIPE EXTRACTION

Lead water pipes can represent a significant health risk through the absorption of lead into drinking water. Lead water mains can be lined or replaced by techniques discussed elsewhere in these Guidelines. However, the major problem of lead contamination arises in small-bore service pipes (typically 12 to 25 mm diameter) for the replacement of which most systems, aimed at larger pipes, are inappropriate. The lining of lead service pipes with a thin-wall, folded PE liner is covered in Section E. Plastic pipe can also be replaced using Pipe Extraction.

A method of extraction and replacement has been developed in which the existing pipe is pulled out of the ground and replaced by a new PE service. The key element of the technique is a steel cable fitted with cones that expand to grip the internal wall of the existing pipe. A winching force is applied to the cable, and a pushing device is used on the rear of the pipe. As the old pipe is extracted and wound onto a drum, a new PE pipe is pulled in simultaneously by the same cable.





Typical pipe extraction site set-ups. *Pictures courtesy of Karl Weiss.*

4. SUMMARY

1. Pipe eating like other 'On-line' replacement systems offers a means of replacing or upsizing existing pressure or gravity pipelines economically and with minimal or no excavation.
2. Correctly applied and with the right accessories the technique can replace a variety of existing pipe materials.
3. In all cases, the success of the operation will depend on having accurate information about the original construction materials and the condition of the existing pipeline, including, for

example, whether there have been any localised repairs, and whether sections of the pipeline have been surrounded in concrete.

4. Laterals and service pipes must be disconnected prior to the replacement of the main, and then subsequently reconnected to the new pipeline. This is usually carried out from a small excavation. The number and frequency of connections may influence the economic viability of the technique.
5. Techniques have been developed for the extraction and replacement of lead service pipes for potable water.
6. On-line replacement is one of trenchless technology's major growth areas, and it is likely that new developments will continue to extend the capabilities of on-line replacement systems, whilst also adding to their economic benefits.

Return to Overview ▲

Conference Papers & Bibliography: A list of relevant Conference papers and reading list (Bibliography) may be accessed via the TRC Home page.

If there is any information that you consider to be missing from this Guideline or have seen any information that you feel is incorrect please contact ISTT directly stating the omission or incorrect item. ISTT will endeavour to correct any such omission or error subject to further investigation to validate any such claim. Email: info@istt.com

Bibliography additions:

Handbook of Pipe-Bursting Practice Book by Meinolf Rameil ISBN: 3802727509 Published: 10 January, 2007

Pipe Bursting Projects Prepared by Mohammad Najafi, P.E. for the Pipe Bursting Task Force of the ASCE Committee on Trenchless Installation of Pipelines (TIPS)) (Manual and Report No. 112) ASCE, 978-0-7844-0882-7, 2007

Code of Practice for Pipe Bursting suiting Indian Condition by Prof. Niranjan Swarup, Executive Director, Indian Society for Trenchless Technology