United States
Environmental Protection
Agency

Water Technology Fact Sheet
Pipe Bursting

INTRODUCTION

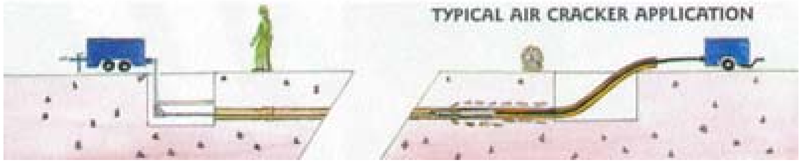
Under the traditional dig-and-replace method of sewer rehabilitation, a replacement or additional parallel sewer line is constructed by digging along the entire length of the existing pipeline, removing the existing pipe, and replacing it with new pipe. In contrast to the traditional method, which requires unearthing and replacing the deficient pipe, trenchless sewer rehabilitation techniques do not require excavation of the existing piping. Instead, these methods use the existing collection system piping as a conduit or host for replacing or rehabilitating the system. In general, trenchless technologies can be implemented through existing openings to the sewer system (such as the manholes) or through smaller insertion pits, rather than through excavation along the entire length of pipe. Because these types of sewer replacement methods do not require extensive excavation, they provide a method of correcting pipe deficiencies with less disturbance, economic impact, and environmental degradation, and they require less restoration than the traditional dig-and-replace method.

A number of trenchless sewer rehabilitation techniques are available, including pipe bursting, sliplining, cured-in-place pipe, and modified cross section lining. The focus of this fact sheet is pipe bursting, which, when referring to replacing existing pipe with new pipe of the same diameter, is also called in-line expansion. From a practical and value engineering standpoint, it is considered advisable to go to a larger pipe size, at least the next larger size, rather than maintain the existing size. This approach allows some additional pipe capacity in the case of increased loading conditions over time.

GENERAL DESCRIPTION

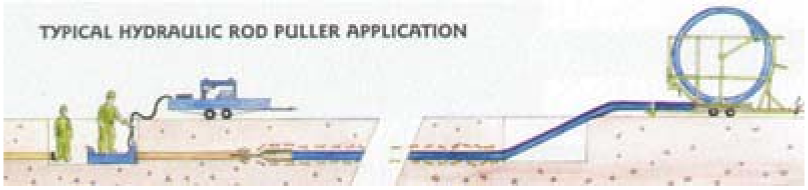
Pipe bursting is a method by which the existing pipe is opened and forced outward by a bursting tool. A hydraulic or pneumatic expansion head (part of the bursting tool) is pulled through the existing pipeline, typically by using a cable and winch. As the expansion head is pulled through the existing pipe, it pushes that pipe radially outward until it breaks apart, creating a space for the new pipe. The bursting device also pulls the new pipeline behind it, immediately filling the void created by the old, burst pipe with the new pipe. Pipe bursting can be used to replace existing pipe with similarly sized or larger pipe (see the discussion of size, shape, and orientation under the "Applicability" section below).

Various types of expansion heads can be used on the bursting tool to expand the existing pipeline. They can be categorized as static or dynamic. Static heads, which have no moving internal parts, expand the existing pipe through only the pulling action of the bursting tool. In contrast, dynamic heads provide additional pneumatic or hydraulic forces at the point of impact with the



Courtesy of U Mole Ltd.

Figure 1. Pneumatic Pipe Bursting



Courtesy of U Mole Ltd.

Figure 2. Hydraulic Pipe Bursting

existing pipe. Pneumatic heads pulse internal air pressure within the bursting tool, while hydraulic heads expand and contract.

Courtesy of Earth Tool Company, LLC

Figure 3. Pipe bursting to up-size pipe in Green Bay, Wisconsin.

Dynamic heads often are required to penetrate difficult pipe materials and soils. However, because dynamic heads can cause movement of the surrounding soils, resulting in ground heaving, static heads are preferred where pipe and soil conditions are not suitable for using dynamic heads.

APPLICABILITY

Like other trenchless techniques, pipe bursting is particularly valuable in urban environments because it causes fewer construction impacts that are disruptive to businesses, homeowners, and automotive and pedestrian traffic.

Pipe bursting typically yields the largest increase in hydraulic capacity of any of the trenchless sewer rehabilitation methods because other methods, such as lining the inside of the pipe, decrease the existing pipe's inside diameter and capacity. Therefore, pipe bursting might be especially applicable to projects that require maintaining or increasing the size of the current pipe as well as replacing defective pipe.

Size, Shape, and Orientation of Pipe

Pipe bursting is most appropriate for pipes with an inside diameter range of 100 mm to 600 mm (4 in. to 24 in.), although pipes as small as 51 mm (2 in.) inside diameter or as large as 1,220 mm (48 in.) inside diameter have been replaced. Theoretically, there is no limit on the size of pipe that can be replaced, and successful installation of a larger pipe depends only on cost-effectiveness, local ground conditions (e.g., the potential for ground movement), and the ability to provide sufficient energy to break the old pipe and pull new pipe.

Pipe bursting has limitations. Difficulties can arise from expansive soils, close proximity of other service lines, a collapsed pipe along the pipeline, and other causes.

Pipe-bursting operations create outward ground displacements. These displacements tend to be localized and dissipate rapidly away from the bursting operation. The bursting operation also can cause ground heave or settlement above or at some distance from the pipe alignment. Critical conditions for ground displacement occur when the pipe to be burst is shallow and ground displacements are primarily directed upward, when much larger diameter pipes are used, and when deteriorated existing utilities are present within two to three diameters of the pipe being replaced. In addition, typical pneumatic pipe bursting can create quite noticeable ground vibrations on the surface above the bursting operation.

The most favorable ground conditions for pipe bursting are soils that can be moderately compacted. Less favorable ground conditions involve densely compacted soils and backfills and soils below the water table. Each of these soil conditions tends to increase both the force required for the bursting operation and the zone of influence of the ground movements.

Although the most common replacement scenario is a size-for-size replacement, replacement with a pipe of larger diameter can be accomplished using the appropriate pipe-bursting method. The amount of up-sizing possible depends on the compactness of the trench backfill and the native soil. Larger up-sizings also require more energy to power the bursting tool. Finally, larger up-sizings cause more ground movement because the bursting head must burst through not only the existing pipe but also the surrounding backfill and soil to allow the larger-diameter pipe to be inserted. Thus, these factors must also be considered when determining the feasibility of a large up-sizing of existing pipe.

Length of Pipe

Pipe bursting is most appropriate for a maximum installation length (for one run of pipe) of 230 m (750 ft). However, straight pulls of over 300 m (1,000 ft) have been performed. In 1997 a 475-m (1,550-ft) pull was used for replacing a 25-cm (10-in.) cast iron pipe with a 25-cm (10 in.) HDPE pipe in Stockbridge, Massachusetts. In Portland, Oregon, a 400-m (1,300-ft) pull was used to replace a 45-cm (18-in.)-inside-diameter sewer with a 50-cm (20-in.)-outside-diameter pipe (North American Society for Trenchless Technology 1999).

One factor that limits the installation length is friction. The higher the friction, the more difficult it is to pull the new pipe through the burst sections, so more power is required. Another limiting factor is the area available for laying out the new pipe in sections near the insertion point (a process referred to as "pipe lay-down"). The amount of space available determines the maximum length of the pipe sections and thus the length of the run of pipe that can be installed.

Although the traditional method of pipe bursting is well established and widely used, a number of innovative pipe-bursting techniques are also being employed to replace existing piping systems. Several of these new processes are discussed below.

Expandit Pipe Bursting

The Expandit system (Perco Engineering Services) is a pipe-bursting method that uses existing manholes or small excavations to insert the pipe-bursting tool and the new pipe. As such, it does not require the excavation of launch/insertion pits or recovery pits. It is a true "manhole-to-manhole" approach. First, the two manholes are prepared by removing the benching and the two pipe entry points. The Expandit head is then lowered into the launch manhole, while a winch is positioned above the reception manhole. The head is hydraulically expanded and contracted in place, bursting the existing pipe. The head is then jacked forward using segmental pipe (Perco's short "Snapit" pipe), which is machined to suit the size of the manholes. The winch is used to maintain the straight-line stability of the head and to ensure that it stays in the center of the existing pipe. Upon reaching the reception manhole, the head is disconnected and pulled out of the receiving manhole, and the benching in the two manholes is reinstalled. The Expandit process allows the diameter of the new pipe to be increased by up to 100 percent relative to the replaced pipe, and the new pipe can be clay, concrete, or high-density polyethylene (HDPE). Replacement pipe cannot be made from polyvinyl chloride (PVC) because PVC cannot support the jacking loads placed on the pipe.

Vermeer Air Impactor

The Air Impactor (Vermeer Manufacturing, Pella, Iowa) has been used in a number of innovative pipe-bursting projects. It combines an air-powered bursting tool with the pulling power of a horizontal directional drill, reducing setup time, excavation, and surface disruption compared to traditional pipe bursting. The surface launch capability of the horizontal directional drill reduces or eliminates the need for launch and exit pits because the bursting head is attached to the drill rod at the surface and is retrieved through a manhole. Thus, like the Expandit pipe-bursting system described above, it can be used from manhole to manhole.

Other advantages of the Air Impactor/horizontal direction drill combination compared to traditional pipe-bursting methods are reduced setup time and smaller crew size, which can significantly reduce costs relative to traditional pipe bursting. The stronger pulling power of the drill versus that of a winch is also an advantage, especially with the drill's ability to back out of the pipe if it gets stuck.

One limitation of the Air Impactor/horizontal directional drill method is that rods need to be removed from the drill string at periodic intervals, making it a start-and-stop process. In addition, the drill can be difficult to set up on paved surfaces.

Trenchless Lateral Replacement (TRIC Tools)

TRIC Tools, in Alameda, California, developed a pipe-bursting machine with the purpose of replacing private building/residential sewer connections, or laterals. The TRIC tool uses a steel cable to pull a static head and new HDPE pipe through the old pipe. The unique aspect of this method is that it can burst through small-diameter (10 cm to 15 cm [4 in. to 6 in.]) pipe and pull the new pipe through multiple bends. (The technology has been used on up to three 45-degree bends in one pull.) This can be achieved because of the small, 0.3-m (1-ft)-long static head, which can be maneuvered through bends in the old pipe, and because of the pulling action of the TRIC hydraulic puller, which can apply up to 60,000 pounds of force on the steel cable. Trenchless lateral replacement can be used to replace pipe of any material except ductile iron. The replacement pipe is always HDPE because of its flexibility and durability.

Dual-Process Rehabilitation

The DPR method (Renaissance Integrated Solutions of New York) combines pipe bursting with the simultaneous installation of a separate conduit system for carrying fiber-optic cable lines. An HDPE-fabricated pipe with up to eight conduits around its exterior is used to replace the existing pipe. The separation of the conduits from the interior of the pipe prevents exposure of the fiber conduit to wastewater or other corrosive elements, allows for easy access to the fiber for service and repair, and allows for routine cleaning of clogged sewer lines.

The major advantage of the DPR method is that two common infrastructure upgrade goals—replacement of damaged pipeline and installation of conduits for a local fiber-optic network that can connect every building within a densely populated downtown area—are accomplished simultaneously. Other advantages include:

- Long-term cost and short-term time savings from the simultaneous installation of sewer and communications infrastructure
- Potential income from telecommunication companies that lease the conduits
- The presence of a local fiber-optic network as an economic incentive for attracting businesses and other development to the area

DPR is best suited for nonresidential areas that are densely populated with business and for institutional, private, and government locations. Such environments are most likely to create a high demand for the fiber-optic system, which can help defray its extra costs. The initial cost investment is higher than that of sewer rehabilitation alone because two systems are being installed at one time (new sewer lines and new fiber conduit manholes, access boxes, etc.). Logistical concerns (such as who designs and builds, owns and operates, and services and repairs such a system) must be evaluated to ensure that the system functions efficiently once it is installed.

IMPLEMENTATION

The general steps for pipe bursting are as follows:

- Obtain as much history as possible about the pipe's construction and repair. Use closed-circuit TV to view the pipe.
- Install the bypass.
- If necessary, construct access pits.
- Disconnect services.
- Cut or remove possible impediments (e.g., ductile iron repair couplings, steel repair couplings, valves, thick concrete encasement).
- Burst the old pipe (a typical rate is 30 m [100 ft] per hour) and pull the new pipe.
- Pressure-test the pipe.
- Tie the pipe into the existing system.
- Reconnect services and remove the bypass.

During the pipe-bursting process, the rehabilitated pipe segment must be taken out of service by blocking flows or rerouting them around the rehabilitation area. After the pipe bursting has been completed, the laterals are reconnected. Ground-penetrating radar might need to be used to locate any underground utilities that are not documented on existing maps or plans.

Unforeseen conditions, such as abandoned underground utilities that are not shown in utility records, can increase construction time as well as the risk to the client or contractor. To avoid these potential problems, pipe bursting or any trenchless rehabilitation projects should be coordinated with utility work by other agencies.

ADVANTAGES AND DISADVANTAGES

All trenchless rehabilitation methods, including pipe bursting, have many advantages relative to open-trench sewer replacement technologies. First and foremost, trenchless rehabilitation methods require substantially less construction work than do traditional dig-and-replace methods. Underground utility construction can cause disruptions to people living or working in areas near the construction zone. Because trenchless sewer rehabilitation has the potential to reduce surface disturbance relative to traditional dig-and-replace methods, it can reduce the number of traffic and pedestrian detours, minimize tree removal, decrease construction noise, and reduce air emissions from construction equipment. However, the benefits of trenchless sewer rehabilitation are not limited to urban areas. In wetland areas and areas with established vegetation, construction influences can be especially harmful to plants and aquatic habitat, and trenchless methods can reduce those potential impacts. In some instances, pipe bursting might be the only way to replace sewers in wetlands and trenchless technologies the only practical way to install sewer systems initially.

In addition to these benefits, reducing the amount of underground construction labor and the surface area of the construction zone confines work zones to a limited number of access points. This reduces the area where safety concerns must be identified and secured.

Pipe bursting also has a significant number of advantages relative to other trenchless sewer rehabilitation methods. These advantages include:

- Pipes of a wide range of diameters (5-cm to 120-cm [2-in. to 48-in.] inside diameter of existing pipe) can be burst.
- A pull length of more than 300 m (1,000 ft) can be used.
- Most types of existing pipe materials (other than HPDE) can be burst. (Some ductile iron and reinforced concrete can be very difficult to burst.)
- The condition of the existing pipe does not affect the ability to perform pipe bursting, as long as the pulling cable can be inserted into the existing pipe.
- Pipe bursting allows up-sizing of pipes.

Pipe bursting also has a number of disadvantages, including:

- Existing flows in the pipe must be bypassed or diverted.
- An insertion pit must be dug to insert the pipe-bursting apparatus into the pipe unless an innovative pipe-bursting method using manholes as access points is used.
- The method is not recommended for pipe in soils that are not compressible (e.g., rocky or sandy soils).
- The method might not be suitable for some pipe materials (e.g., HDPE, ductile iron pipe, reinforced concrete).
- Impediments inside the old pipe have to be removed.
- Replacement pipe can stretch as it is being pulled and then retract afterward, leaving gaps between the pipe and the manhole where it was inserted.
- Occasionally, the burst pipe fragments might be pushed into the manhole, filling it with debris, or the manhole itself might be pushed out of alignment while the replacement pipe is being pulled into the manhole.
- Ground heave can occur with shallow pipes.
- The percussive action from dynamic bursting heads can cause significant ground movement, which could damage nearby surface or underground structures.

Pipe bursting is not favorable under the following conditions:

- Obstructions along the pipe. Obstructions increase friction or might block the path of the expansion head and replacement pipe.
- Metallic point repairs that reinforce pipe with ductile material. Ductile material is difficult to burst.
- Existence of adjacent pipes or utility lines. The existence of other underground utilities might require that the pipe-bursting operation not deviate in any direction from the existing pipe so as not to damage the other utility lines.
- Soil below the groundwater table. Bursting in saturated soil can cause the water pressure to rise around the bursting head, and groundwater can have a buoyant effect on the bursting operation by flowing toward open insertion/reception pits.

PERFORMANCE

Traditional Pipe Bursting

King County, Washington, used pipe bursting in several pilot projects as part of its Regional Infiltration and Inflow (I/I) Control Program. This program, initiated in 1999, includes a 6-year, $41 million I/I control study that was kicked off in 2000. The study includes efforts to identify sources of I/I, test the effectiveness of various I/I control technologies, examine the costs and benefits of various I/I control technologies, and prepare a regional plan for reducing I/I in local agencies' collection systems. Technologies tested under the pilot program have included rehabilitating pipes with cured-in-place materials and replacing pipes with open-trench and pipe-bursting methods. Most of the existing system consisted of concrete, although several newer sections of PVC pipe that were defective or improperly installed have also been rehabilitated.

Pipe bursting was tested in 5 of the 12 programs (Auburn, Kirkland, Redmond, Ronald, and Skyway). Different pilot projects used pipe bursting on mains, laterals, and side sewers (see Table 1).

The pilot projects used HDPE replacement pipe and typically replaced 15-cm (6-in.) pipe with 15- or 20-cm (6- or 8-in.) pipe for mains; laterals and side sewers typically consisted of 10- and 15-cm (4- and 6-in.) pipes that were replaced with pipes of similar size.

Pulls were typically 60–100 m (200–300 ft) for mains, 100 m (300 ft) for laterals, and 12 m (40 ft) for side sewers.

The Kirkland basin, which consisted of 4,900 m (16,400 ft) of sewer main, experienced defects in most of the collection system infrastructure, as well as several inflow sources. Twenty-five percent of the mains were rehabilitated using pipe bursting, and the system experienced a 25 percent reduction in I/I. In the Ronald basin, which consisted of 3,990 m (13,100 ft) of sewer main, few defects were found in the mains, so the pilot project focused on the laterals and side sewers. Approximately 72 percent of the laterals and side sewers were replaced, and the system experienced a 74 percent reduction in I/I.

Table 1.
Summary of King County, Washington, Pipe Bursting Pilot Projects

Project	System Component Rehabilitated				System Improved	I/I Reduction (%)
	Main	Manhole	Lateral	Side Sewer		
Auburn	✓	✓	✓	✓	11% of mains	Negligible
Kirkland	✓	✓	✓		25% of mains	28
Ronald			✓	✓	72% of laterals and side sewers	74
Skyway	✓	✓	✓	✓	100% of system	86

Source: Adapted from King County, Washington, 2004.

In the Skyway pilot, 100 percent of the system was rehabilitated (3,060 m [10,040 ft] of mains, laterals, side sewers, and manholes), and the system achieved an 86 percent reduction in I/I. Although pipe bursting was conducted in the Auburn and Redmond areas, it was not a significant part of the sewer rehabilitation in those areas.

The Fairfax County (Virginia) Department of Public Works performed a pipe-bursting project in 2002 in a wealthy, established subdivision. Approximately 1,220 m (4,000 ft) of clay pipe, which had been installed in the 1940s, was replaced. Closed-circuit TV inspection of the pipe revealed that much of it had been completely shattered and that raw sewage was leaking out of the pipe into the soil. Dig-and-replace methods were not feasible because of the residents' concerns regarding the disturbances that would be caused during construction. Pipe bursting was chosen as a preferred alternative because no other trenchless rehabilitation method was suitable for the shattered pipe. The pipe needed to be upsized from a 15-cm (6-in.) diameter to the County's minimum-requirement 20-cm (8-in.) diameter. The project, which included significant input from residents, took several years to plan and complete and cost approximately $1 million.

Expandit Pipe Bursting

Perco Engineering Services used its patented Expandit pipe-bursting method for a major sewer replacement project at the Royal Botanic Gardens in Kew, England, where 160 m (525 ft) of 225-mm (9-in.)-diameter pipe was installed as part of a project to expand public facilities in the gardens. For this project, it was essential that tree and other plant root systems not be damaged, and the only way to access the sewer lines was through existing 1.2-m by 1.0-m (4-ft by 3-ft) brick manholes. Furthermore, the gardens are open to the public 363 days of the year, and the disruption to visitors and local residents had to be minimal.

Air Impactor

Pipe bursting with a Vermeer Air Impactor, in conjunction with a horizontal directional drill rig, has been used at a number of locations. One such location was Dalton, Georgia, where $1.2 million was budgeted for replacement of 3,350 m (11,000 ft) of clay sanitary sewer line. Over a period of 6 months in 2001, approximately 1,000 m (3,300 ft) of sewer line was replaced using the Vermeer Air Impactor method with HDPE pipe. The drill rod was able to push through root intrusion in the pipes, and the contractor was able to burst an average of 1 m (3 ft) per minute.

COSTS

Factors influencing the cost of a pipe-bursting project include:

- Diameter and material of both the pipe to be replaced and the replacement pipe
- Length of pipe to be rehabilitated
- Removal of the burst pipe fragments
- Specific defects in the pipe (such as joint offsets, root intrusions, and severe cracking)
- Depth of the pipe to be replaced and changes in grade over the pipe's length
- Locations of access manholes
- Number of additional access points that need to be excavated
- Location of other utilities that have to be avoided during construction
- Provisions for flow bypass
- Number of service connections that need to be reinstated
- Number of directional changes at access manholes
- Ground conditions

Tables 2 and 3 list the costs from the case studies described above.

Table 2.
Example Costs from Case Studies

Year	Method	Location	Length and Material of Pipe	Estimated Cost	Pipe Cost per ft
2001	Vermeer Air Impactor	Georgia	3,300-ft clay pipe	$1,200,000 (cost also includes 7,700 ft of trench-and-replace work)	NA*
2002	Traditional Pipe Bursting	Virginia	4,000-ft clay pipe	$1,000,000	$250
2003	Traditional Pipe Bursting	Washington (pilot project)	30,769 ft	$749,400	NA*
2003	Traditional Pipe Bursting	Washington (pilot project)	16,406 ft	$1,190,400	$73
2003	Traditional Pipe Bursting	Washington (pilot project)	23,143 ft	$1,273,400	NA*
2003	Traditional Pipe Bursting	Washington (pilot project)	13,097 ft	$1,531,400	$117
2003	Traditional Pipe Bursting	Washington (pilot project)	10,038 ft	$1,883,900	$188
2005	DPR	Louisiana	31,000-ft clay pipe	$5,300,000	$171

*Included significant amounts on non-pipe-bursting work.

Table 3.
Summary of Costs from Traditional Pipe Bursting: Washington State I/I Pilot Projects

Project	Design Cost ($)	Construction Cost ($)	Construction Management Cost (Including Inspection) ($)	Total Cost ($)
Auburn*	$96,100	$384,700	$72,200	$749,400
Kirkland	$154,700	$838,200	$57,600	$1,190,400
Redmond*	$193,800	$840,100	$82,600	$1,273,400
Ronald	$145,000	$1,077,300	$176,300	$1,531,400
Skyway	$238,400	$1,395,200	$157,700	$1,883,900

*Project included significant non-pipe-bursting component.

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Other EPA fact sheets can be found at http://www.epa.gov/owm/mtb/mtbfact.htm

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