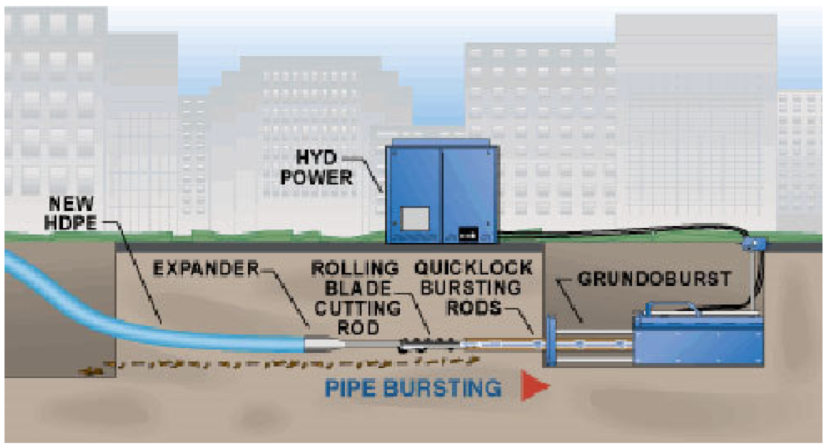
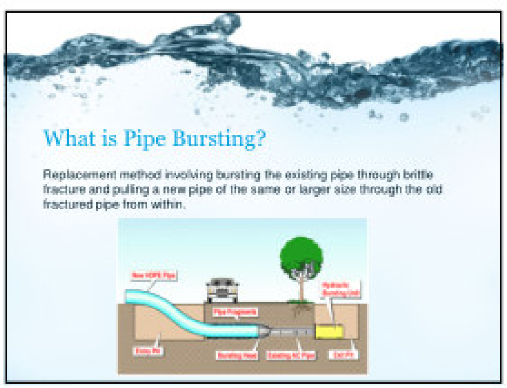
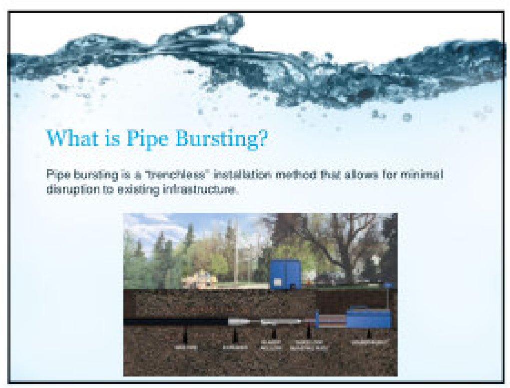
PIPE BURSTING – FINITE ELEMENT ANALYSIS FOR ESTIMATION

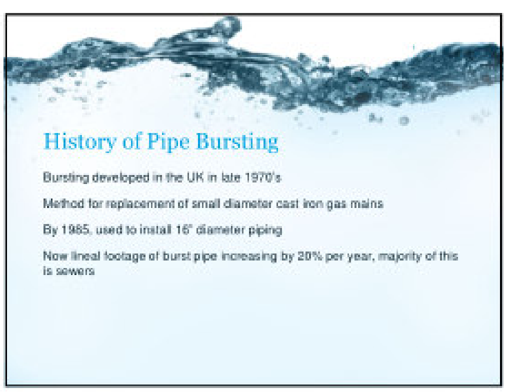
A. Chennakesava Reddy
Professor, Department of Mechanical Engineering
JNTUH College of Engineering, Hyderabad

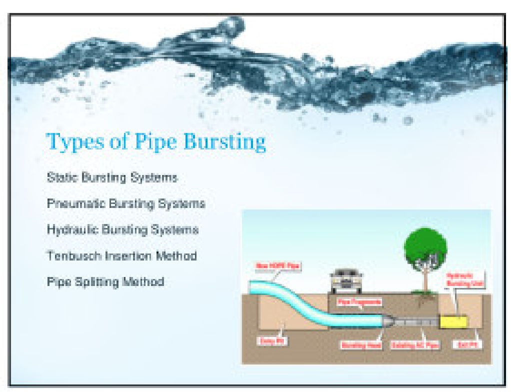
Pipe bursting is a trenchless method of replacing buried pipelines (such as sewer, water, or natural gas pipes) without the need for a traditional construction trench. "Launching and receiving pits" replace the trench needed by conventional pipe-laying. For years, ductile iron and steel pipe has been a major limitation of pipe bursting. See how the recently introduced hydraulically operated Grundoburst pipe bursting system makes bursting ductile iron and steel pipes a problem of the past.











Types of Pipe Bursting

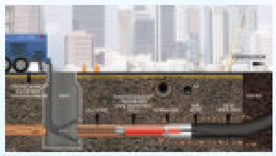
Static Bursting Systems

Pneumatic Bursting Systems

Hydraulic Bursting Systems

Tenbusch Insertion Method

Pipe Splitting Method



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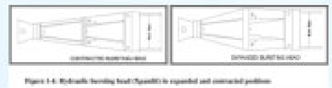

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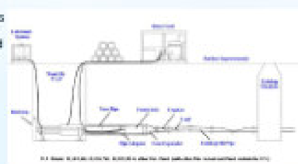

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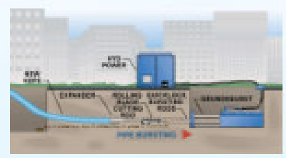


Types of Pipe Bursting Heads

Standard Cone Shaped Head

Types of Pipe Bursting Heads

Pneumatic Head

Types of Pipe Bursting Heads

Expanding Cone Head

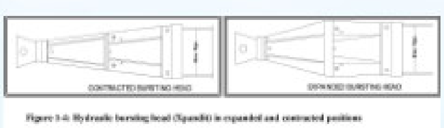


Figure 1-4: Hydraulic bursting head (Xpandit) in expanded and contracted positions

Types of Pipe Bursting Heads

Splitting Head

(cutting wheel or knives)

Selection of Method

Type of Existing Pipe

Type of Soils

Type of New Pipe

TABLE 2.1 from ASCE MOP 112

Discuss with Contractors

28 PIPE BURSTING PROJECTS

TABLE 2-1. Guidelines for Selection of Pneumatic or Static Pipe Bursting Methods

Existing Pipe	Pneumatic	Static
Metallic pipes including aluminum, copper, ductile iron,[a] wrought iron, steel, or stainless steel	No	Yes
Plastic pipe, including HDPE or MDPE,[a] PVC, CIPP, or fiberglass	Yes	Yes
Prestressed or bar-wrapped concrete cylinder pipe (PCCP or BWCCP), corrugated metal pipe (CMP), or corrugated plastic pipe	No	No
Fracturable pipes, including asbestos cement (AC), RCP or nonreinforced concrete pipe, CI, VCP, or Orangeburg	Yes	Yes
Valves, stainless steel clamps or repair bands, point repairs[b]	No	No
Pulling in prefabricated replacement pipe	No	Yes

[a]Limited distances, depending on option and existing conditions of surrounding soil.
[b]Limited success with static systems only; recommend open cut at these locations.

Types of Materials and Size

What types of pipe materials can be burst?

CI, DI, VCP, AC, RCP, PVC, HDPE, Copper, etc.

What types of pipe materials can be installed?

HDPE, PVC, DI, VCP, RCP

What are the minimum and maximum sizes that can be burst?

Pipe bursting has been successfully completed on 4"-36" piping.

How large can you make the new pipe?

New pipe can be upsized 2-3 sizes depending on soil conditions, new pipe material, and depth.

Advantages

No trenching involved means minimal disruption of existing infrastructure.

Pipe size can be increased along the same route.

Can be more cost effective given project conditions.

Faster installation than open cut, especially for deep pipe.

Minimal dewatering necessary in wet conditions.

Minimizes social costs such as traffic diversions, etc.

Disadvantages

Must dig up lateral locations

Cannot change slope of line

Bypass Pumping is usually necessary

Cannot burst through valves

Repair sleeves or encasements may be difficult or impossible to burst

If HDPE or welded PVC is pulled through, need room for long run of pipe

If heaving occurs, may need some surface restoration

Planning and Design Considerations

Soil Types and Conditions and Groundwater Depths

Existing Pipe Material and New Pipe Material

Surface Heaving

Utility Locations and Connection Points

Televise Existing Pipeline

Pit Locations and Pipe Layout Locations

Cost Considerations (including Social)

City of Zeeland Case Study

Background:

Business Growth Created Need for Increased Pipe Size, Larger Pump station

Project:

Increase 700 LFt of VC gravity sewer from 8" to 12" by pipe burst

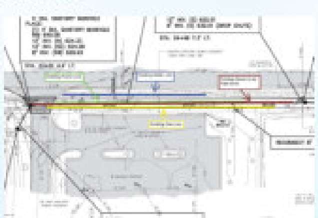
Increase pump station capacity

Increase forcemain size from 6" to 10" by open cut

Why Choose Pipe Bursting?

Utilities over the existing deep sewer pipe

- Water
- Electrical (4)
- Storm Sewer
- Gas
- Sidewalk
- Parking Lots
- Storm Pond
- Fiber Optic Cable



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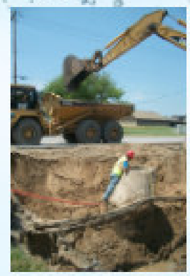
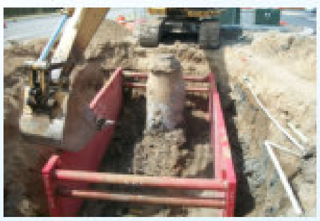
Why Choose Pipe Bursting?

- Pipe type conditions were favorable
- Deep pipe would have had large dewatering costs
- Minimal laterals to connect
- Distance (700 ft) favorable for single pull
- Directly outside of business parking lot
- Prevent Dewatering of Decorative Stormwater Pond
- Surface heave not a problem in this case

Existing Utilities and High Groundwater Levels

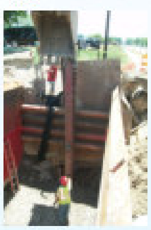


Excavating the Pulling Pit



Bypass Pumping & Gentex Temp Drive

Placing Whalers At Pulling Pit



Placing Thrust Blocks at Whalers

Placing Hydraulic Pulling Skid

Hydraulic Pulling Skid in Place

Capacity = 300 ton


Hydraulic Unit for Pulling Skid


Connecting Pulling Rods


Pushing the Pulling Rods Through the Existing Piping


Excavating Manhole at Insertion Pit


Layout of Long HDPE Pipe Run, DIPS, DR17


Pulling Head w/ Expander


MOORE & BRUGGINK, INC.
Layout of Long HDPE Pipe Run, DIPS, DR17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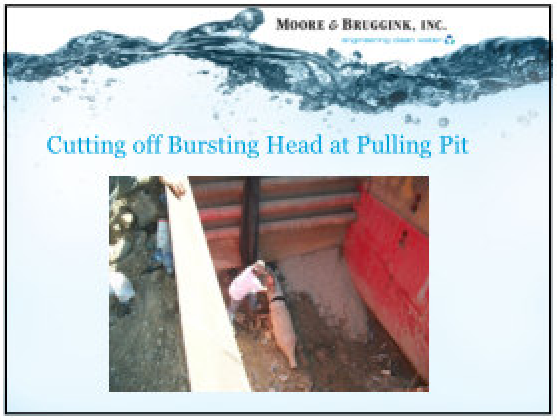
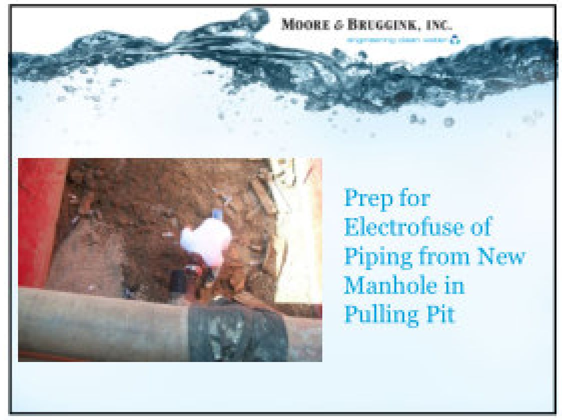




Underground service utilities in many American cities have been in place for over 100 years. While existing systems have functioned well beyond reasonably anticipated service life, underground systems are mostly deteriorated and need costly maintenance and repair. Common problems involve corrosion and deterioration of pipe materials, failure or leakage of pipe joints, and reduction of flow due to mineral deposits and debris build up inside the pipe. Damage to existing pipes can also occur by ground movements due to adjacent construction activity, uneven settlement or other ground instability. This leads to infiltration and inflow (I&I) increase in sewer systems. In water systems, it leads to flow and pressure reductions, persistent leakage (up to 30 percent of water provided in some systems), pipe bursts, and poor water quality. These problems tend to increase with the age of the network where maintaining this large network of underground sewer, water, and gas pipelines is difficult and costly. The above problems are compounded by the significant negative impacts (of open cut repair or replacement projects) on the daily life, traffic, and commerce of the area served by and along the pipeline in question.

The internal surface of the PE pipe is smoother than those of the concrete or clay pipes. For gravity applications, after some algebraic manipulation to the following Chezy-Manning equation, it is can be demonstrated that the flow capacity of the PE is 44% more than those of the concrete or clay pipes considering the internal diameter for the old clay or concrete pipe equals that of the replacement PE pipe.

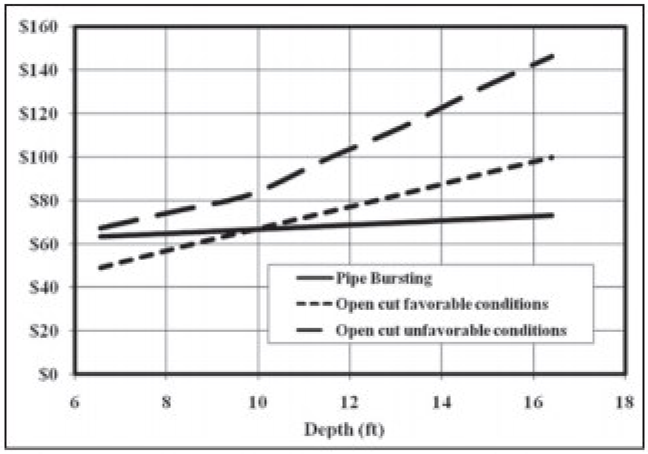
$$Q = \frac{1.49}{n} A (r_H)^{2/3} \sqrt{S}$$

WHERE

Q = the flow quantity
n = Manning roughness coefficient
A = the area of the pipe
r_H = hydraulic radius
S = the slope of the energy line, which is parallel to the water surface and pipe invert if the flow is uniform.

The n value ranges for clay or concrete pipes between 0.012 and 0.015 (on average about 0.013), and it is about 0.009 for PE (Lindeburg 1992).

The increased depth has a minimal effect on the cost per foot for pipe bursting as shown in Figure (Poole et al 1985). Specific studies carried out in the US have shown that pipe bursting cost savings are as high as 44% with an average savings of 25% compared to open cut (Fraser et al 1992). This cost saving could be much more if the soil is hard rock because rock excavation is extremely expensive compared to pipe bursting. Additionally, open cut can cause significant damage to nearby buildings and structures (Atalah 2004).



Cost Comparison Between Pipe Bursting and Open Cut Replacements (Poole et al 1985)

Summary of NASSCO Pipe Bursting Classification

Criteria	A – Routine (all of the criteria below apply)	B - Moderately Difficult to Challenging	C – Challenging to Extremely Challenging
Depth	Less than 12 feet	12 ft to 18 ft	More than 18 ft
Existing Pipe	4"-12"	12" to 20"	20"-36"
New Pipe Diameter	Size for size or one diameter upsize	Two diameter upsize	Three or more diameter upsize
Burst Length	Less than 350 feet	350 feet to 450 feet	More than 450 feet
Trench Width	Relatively wide trench compared to upsized diameter	Trench width less than 4" wider than upsize diameter	Incompressible soils (very dense sand, hard clay or rock) outside trench
Soil	Compressible soils outside trench (soft clay, loose sand)	Moderately compressible soils outside trench (medium dense to dense sand, medium to stiff clay)	Constricted trench geometry (width less than or equal to upsize diameter)

The PE pipes are available with iron pipe sized (IPS) or ductile iron pipe sized (DIPS) outside diameters. PE pipes are extruded with fixed outside diameter with variance in the inside diameter controlled by the Standard Dimensional Ratio (SDR) as shown in following equation:

$$\mathrm{SDR} = \frac{\text{Pipe O.D.}}{\text{Wall Thickness of Pipe}}$$

The PE pipe should withstand the internal pressure requirements of the water or the force main line, overburden dead and live loads, and pulling forces during the bursting phase. The SDR of the PE pipe is a major factor in the ability of the pipe to withstand the installation forces and service pressures. Experience has shown that SDR 17 is sufficient for gravity sewer applications, and thinner wall pipes with SDR of 19 or 21 can be used in shorter and smaller diameter applications. Thinner wall pipes tend to stretch excessively during bursting. For pressure applications, if the maximum allowable design pressure is less than 100 psi, SDR of 17 is sufficient. If the maximum allowable design pressure is more than 100 psi, the allowable pressure governs the needed SDR. If the allowable pressure is 150 psi, PE pipe with SDR 11 meets needed pressure requirements. In most trenchless applications, but not always, the pipe that withstands the pulling stresses during installation can withstand the vertical overburden and traffic pressures. The pipe stresses caused by construction are higher than those caused by vertical pressures. However, each application is different; it is possible that a specific application can require a different SDR. An engineering analysis is suggested for very deep or very shallow installations. Deep installations may be subject high overburden pressures, and shallow installations may be subject to high concentrated traffic loads that the pipe has to withstand.

Corrosion has become one of the main threats towards maintaining pipeline's integrity. At the point of corrosion, the wall of the pipe becomes thinner and starts to lose its mechanical resistance. Methods for assessing metal loss defects have been available for many decades, as for instance the NG-18 equation and ANSI/ASME B31G code. Throughout the years many modifications to the original equations have been made and newer methods like Modified B31G and RSTRENG were adopted. These days, several in-house methods and commercial codes are available but they are known to be conservative. Therefore, pipeline operators need reliable defect assessment methodology not only to assure safe operation but also to implement optimum operation cost. Based on these motivations, in the recent years various alternative methods have been developed mostly based on **finite element** studies and burst tests. This study presents the application of nonlinear **finite element** analyses for burst strength analysis of corroded pipe.

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