Pipe Jacking/Microtunnelling

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New Installations

- New Installations
  - **Non-Steering Methods**
    - **Moling/Piercing**
    - **Pipe Ramming**
    - **Auger Boring**
    - **Pipe Jacking**
  - **Steering Methods**
    - **Microtunnelling**
    - **Horizontal Directional Drilling**

Pipe Jacking

- Oldest method of trenchless technology
- Applications
    - Larger Diameter Pipe (1050 mm and up)
- Lengths can range from 3 to over 200m

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Pipe Jacking

- Person entry
    - Pipe diameters greater than 900 mm (36")
        - Difficult to work in excavations of this size
    - Practically limited to dia. greater than or equal to 1075 mm (42")
- Pipe installation process occurs from entrance and exit shaft
    - Access way locations

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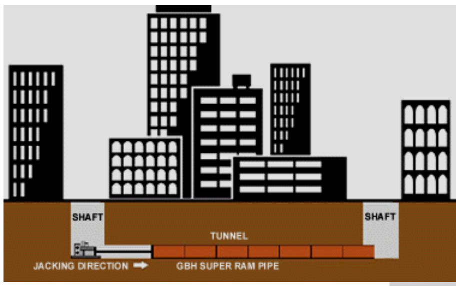
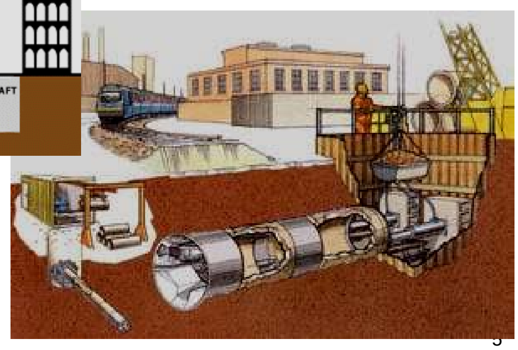
Pipe Jacking Process





Pipe Jacking

- Material excavation completed by persons within the excavation
  - Manual or machine face excavation
- Excavation takes place in front of an articulated shield
  - Designed for worker safety
  - Maintains open bore for pipe jacking or tunnel lining construction
  - Shield guided with individually controlled hydraulic jacks

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Pipe Jacking Excavation

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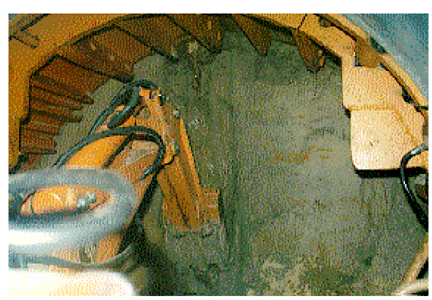
Pipe Jacking Excavation



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Pipe Jacking

- Types of Tunneling
  - Hand mining
  - Liner Plate
  - Jack Reinforced Concrete Pipe
  - Jack Steel Liner
  - Cap and Leg (Wood Lined Tunnel)

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Pipe Jacking Process

- Simple cyclic procedure
- Utilizes thrust from hydraulic jacks to force the pipe forward
  - Pipe placed on cradle in the entry or jacking pit
  - Thrust developed from thrust blocks
    - Concrete, steel, soil excavation

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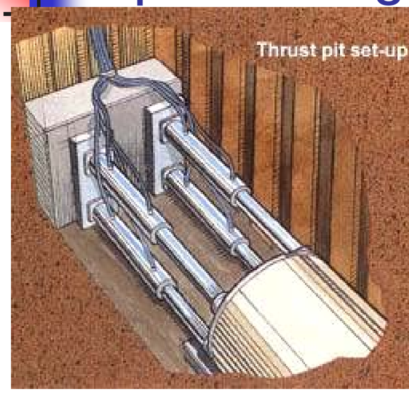
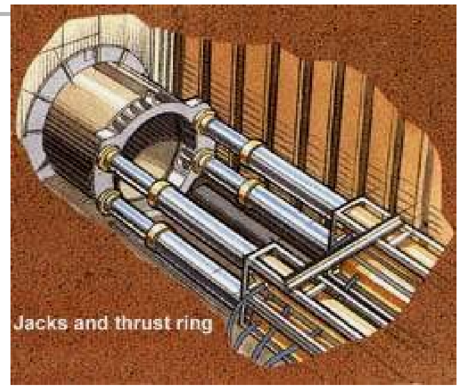
Pipe Jacking Pit





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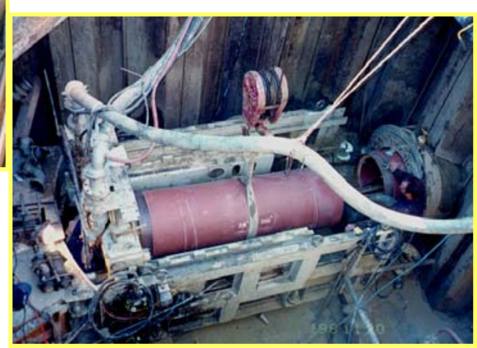
Pipe Jacking Pit



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Pipe Jacking Process

Unstable soil

- Face excavated simultaneously with the jacking operation
  - Minimize over excavation and the risk of face collapse
- After pipe jacked into place hydraulic rams are retracted and another pipe length is installed

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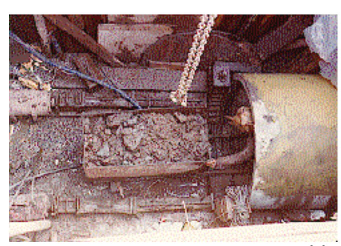
Pipe Jacking Process

Stable soil

- Face excavation may precede the jacking operation
- All spoils removed through the inside of the pipe to the jacking pit



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Hand Excavation

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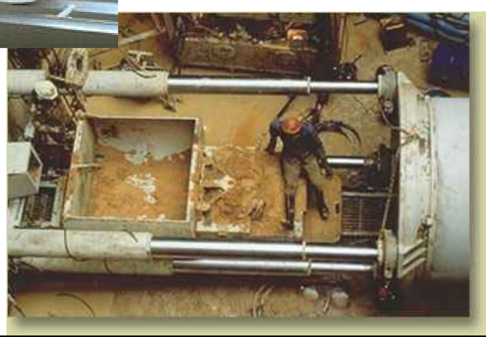
Pipe Jacking Process



Pipe Jacking Pit

- Jacking pit size is function of:
  - Length of pipe segments
  - Pipe diameter
  - Shield dimensions
  - Thrust wall design
  - Jack size
  - Pressure rings
  - Guide rail systems

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Pipe Jacking Pit

- Pit should be shored
  - Timber, steel piling or shaft liner plate, ground freezing
- For projects requiring large thrust
  - Design of launch pit is critical
- Pit should be dry
- Floor preparation key for controlling alignment

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Pipe Jacking Pit

- For a large job the placement of a concrete mud slab on the shaft floor is recommended
- For a smaller job the placement of a 300mm of crushed stone is recommended

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Pipe Jacking Force

- Force on jacked pipe includes:
  - Pipe dead weight
  - Penetration resistance
  - Soil-pipe friction
- Jacking force applied by two, four or six jacks

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Other Forces

- Soil dead load
- Railway or highway live loads
- Jacking force must not exceed allowable pipe compressive strength
  - Critical design location is the joints
    - Low surface area - high stress
    - Water tightness??

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Pipe Jacking Force

Soil-pipe frictional force minimized by the application of lubricant to the outer pipe surface

- Can reduce jacking force by 50%
- Manual application or pumping of bentonite slurry around pipe
- Polymers
  - Advantage only small amount required

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Pipe Jacking Force

To minimize pipe damage during jacking

- Packing material can be placed between the pipe joints
  - 12 to 19mm plywood
  - 12 to 25mm manila rope, jute, oakum
- Provides joint cushioning and flexibility

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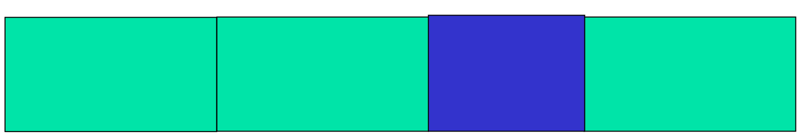
Pipe Jacking Force

For long pipe installations

- Intermediate jacking stations may be used
- Set of hydraulic jacks placed between pipe segments



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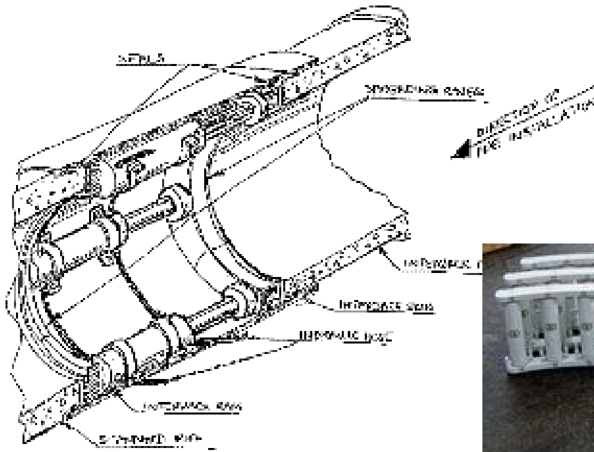
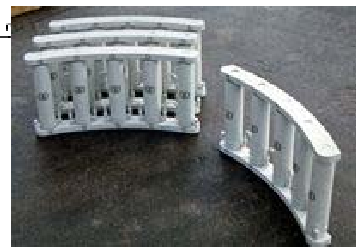
Intermediate Jacking Station (IJS)





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Intermediate Jacking Station (IJS)

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Intermediate Jacking Station (IJS)

- Total drive expected to exceed capacity of main jacks
- Capacity 100 to 1600 tons
- Diameter around 36” length 56”
- IJS assembled in four segments
- IJS must match pipe dia. for proper operation

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Intermediate Pipe Jacking

Three step pipe jacking process:

1. Intermediate jacks are used to jack the forward sections of pipe
   - Thrust is provide by the pipe section behind the intermediate jacks
2. Intermediate jacks are retracted
3. Back section of pipe is jacked using the launching pit cradle

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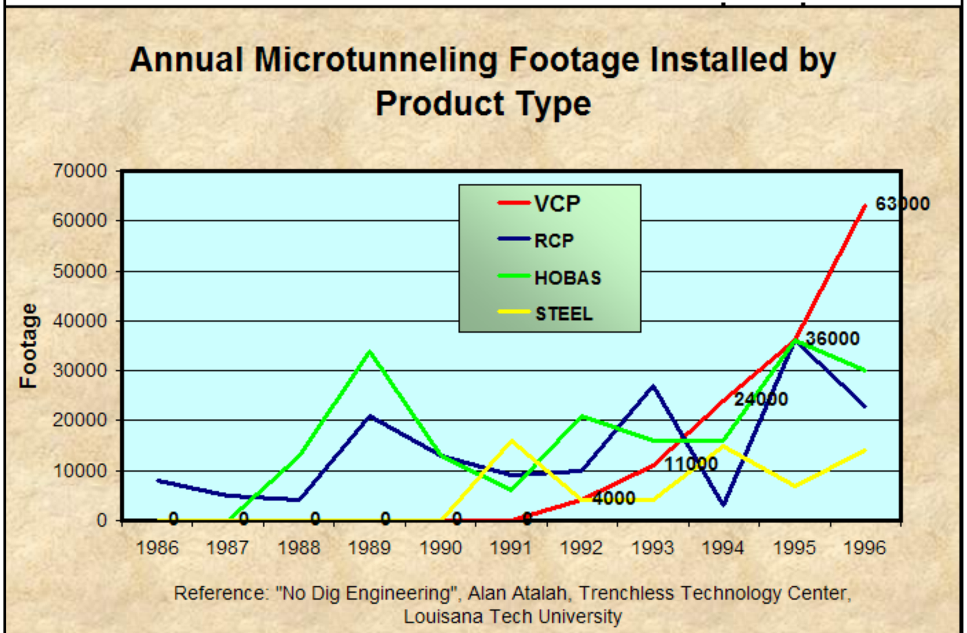
Jacking Pipe

REINFORCED CONCRETE PIPE

CLAY PIPE

Jacking Pipe Material

- Reinforced concrete (RCP)
- Polymer concrete
- Fibreglass (Hobas)
- Vitrified clay (VCP)
- Steel
- Ductile Iron
- Composites



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PIPE JOINTS

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Pipe Joints

- Must withstand high jacking forces
- Create water tight seals
- Flush joints to decrease jacking forces

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PJ Applications

- Sewers, and drainage construction
- Gas and watermains
- Oil pipelines
- Industrial pipelines
- Telecommunication
- Pedestrian subways (access tunnels)

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PJ Advantages

- Quick set-up
- When grade is critical
- Versatile in various ground conditions
- Cost efficient for large diameter pipe
- Small surface settlements
  - Settlement controlled by face excavation

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PJ Limitations

- Access to the face of the tunnel is needed at all times
- Speed of the mining operation is reliant on:
  - Speed of labour (workers)
  - Soil Matrix
    - Rock
    - Soft Soil
    - Water Table

- Dewatering of tunnel path is usually required

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New Installation

Steering Methods

- Microtunnelling
- Horizontal directional drilling (HDD)

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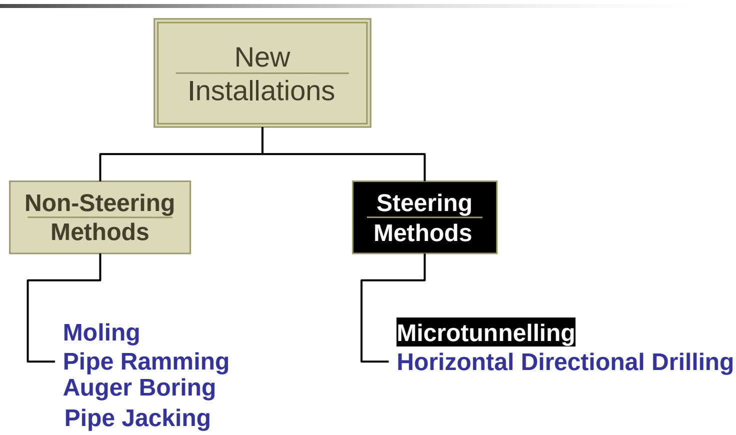
Microtunnelling



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Microtunnelling

- Remotely controlled and guided pipe jacking technique that provides support to the excavation face and does not require personnel entry into the tunnel
- Laser guided micro TBM used for soil excavation
- Drive from access way to access way (manhole locations)
- Mainly used for gravity sewers but can be used for large water mains

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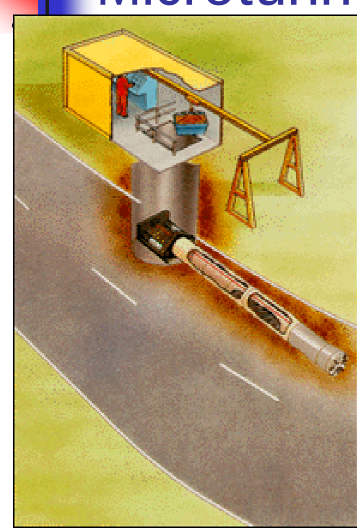
Microtunnelling



- Non-person entry
- Machine excavated (mini TBM)
- Remote controlled
- Similar to pipe jacking
- Pipe OD less than 1.0m

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Tunnel Boring (TBM)

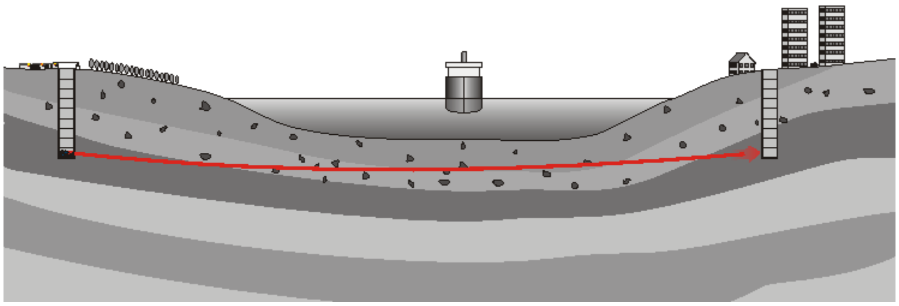
World largest tunneling machine (14.2 m in diameter)

people

Chunnel

Microtunnelling

Microtunnelling



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Microtunnelling

- Accuracy typically better than ± 25 mm per drive
- Laser controlled
- Variety of machines for different soil conditions
- Main applications: deep systems

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Microtunnelling

- Accurate monitoring and adjusting of the alignment and grade as work proceeds
  - Pipe can be installed on precise line and grade
- Generally used for pipe diameters less than 900mm (36 inches)
- Can be used for larger diameters

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Launching and Exit Pits

- Use same design procedure as for pipe jacking
- Length of tunneling machine can control launch and exit pit size

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Entrance and Exit Pit Shields

- Neopreme sheet stock held in steel ring

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Entrance and Exit Pit Shields

- Prevents slurry and ground water from entering into shafts

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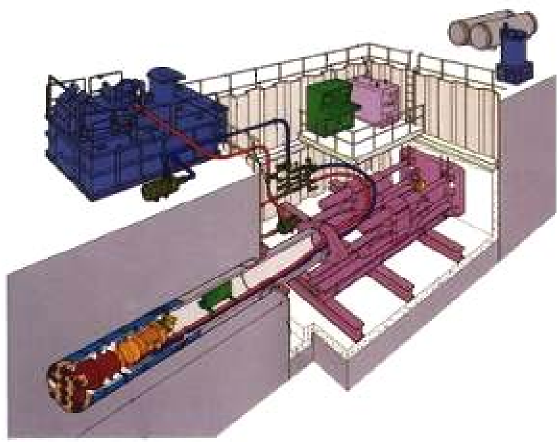
Jacking System



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History

- Originated in Japan and Germany in 1970's
- Development government sponsored
  - Need for pipe construction method with minimum surface disruption in over congested areas
  - Komatsu introduced first Microtunnelling machine in 1975 - IRONMOLE
  - ISEKI inc introduced there machine in 1976
    - Ability to counter balance earth pressure mechanically and hydraulically

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History

First Microtunnelling project in North America

- Fort Lauderdale Florida in 1984
  - 615 feet of 72 inch pipe under I-95
- Second project
  - Bridgeport CT in 1986
  - 3610 feet of 72 inch pipe

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History

As of October 1996

- Total MT North America footage 547,100 feet
- Total number of projects = 254

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MT Classification Methods

- Based on mode of operation
  - Slurry method
  - Auger method

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Slurry Method

- Tunnel face is supported mechanically or by a pressurized slurry
- Spoils (cuttings) removed hydraulically in the form of a slurry
- Conveying fluid is used to counteract hydrostatic forces caused by ground water pressure and soil removal

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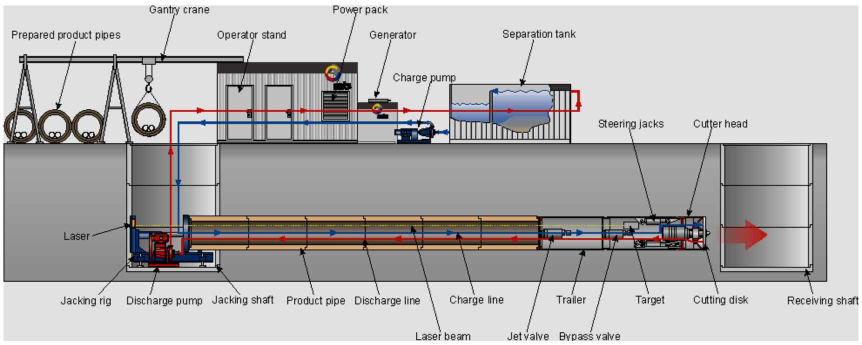
Slurry Method

LOVAT MTS 1000



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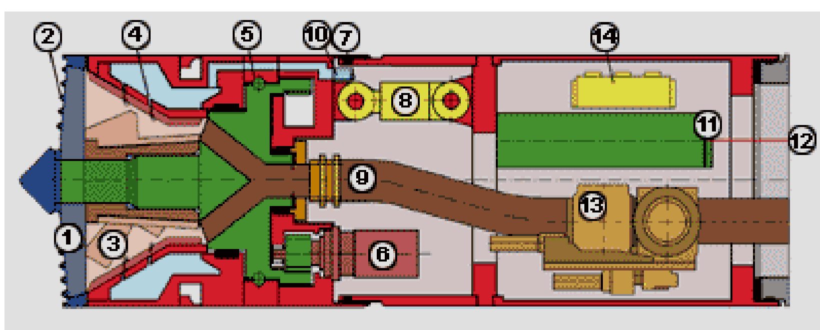
Slurry Method



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Slurry Method

- Soil cut mechanically
  - Cutting head designs depends of soil or rock type
- Cuttings removed by hydraulic action
- Cuttings enter bore head through inlet openings and placed in suspension in the slurry chamber - water and bentonite

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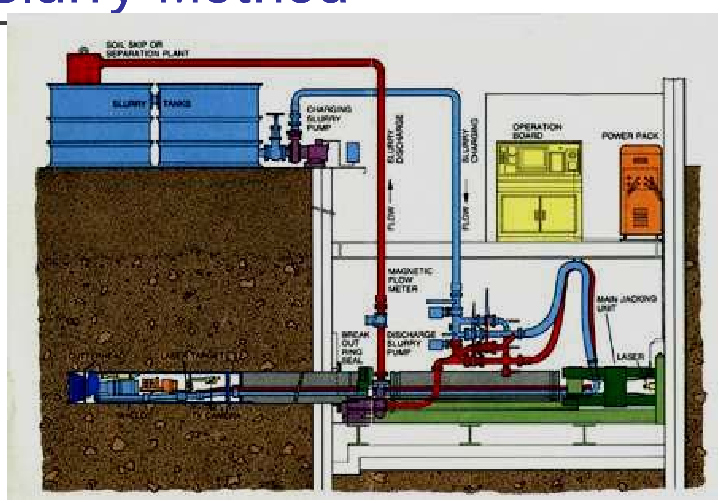
Slurry Method



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Lubrication System

Typical system components:

- Variable speed discharge pump
- Charge pump
- Intermediate pumps
- Flow meter
- Flow controller
- Pit by pass to permit diversion of flows
- Piping, flexible hoses and cabling

Slurry Separation

Typical separation plant components:

- Vibrating screens
- Cyclones for small particle separation
- Clay ball separator
- Settlement tank

Slurry System

- Depth of ground water up to 30m can be managed
- Due to efficiency of shield small pipes can be used
- Full measurement and control of slurry flows

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Auger Method

- Soil cutting at the face by a bore head and soil removal by means of a continuous flight of augers
- Augers run in a separate guiding pipe
- Better suited for cohesive soils

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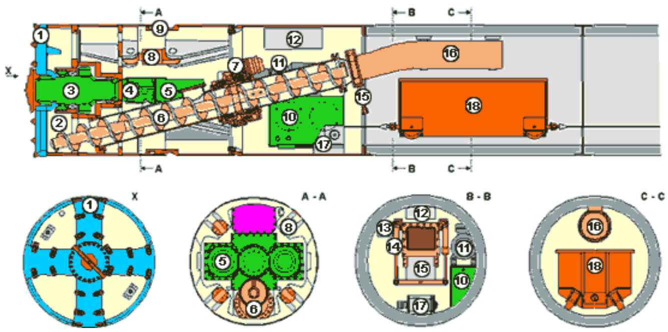
Auger Method



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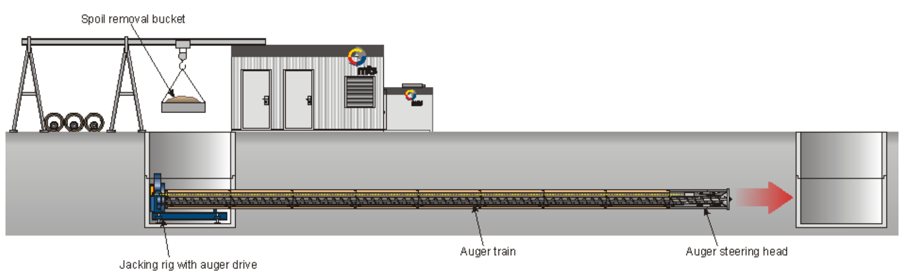
Auger Method

LOVAT MTS 1000



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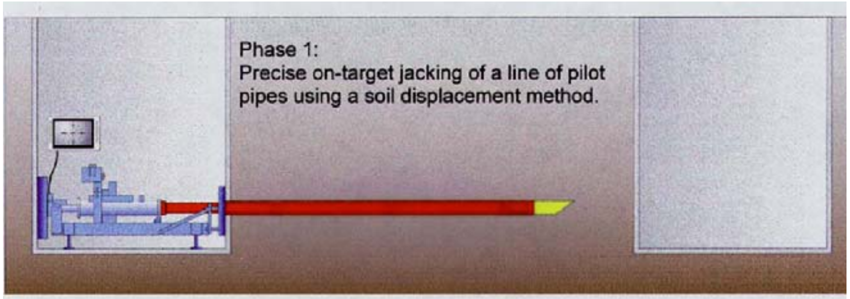
Auger Method (Drill)

Phase I

- **a steerable pilot tube is jacked into the ground displacing the soil.**



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Steerable pilot tube

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Phase I

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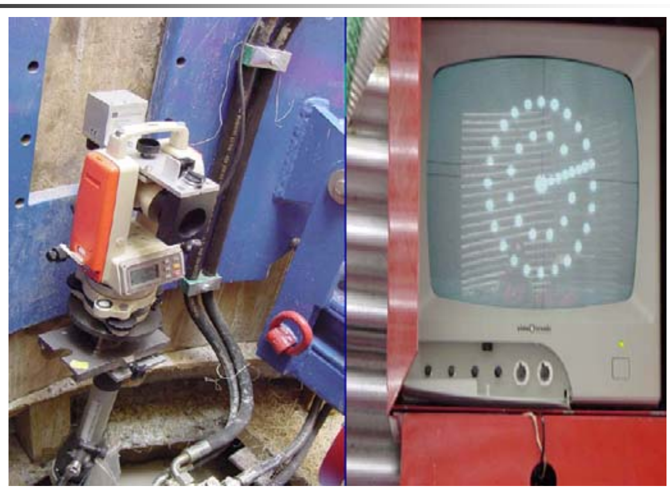
Guidance System



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Phase I

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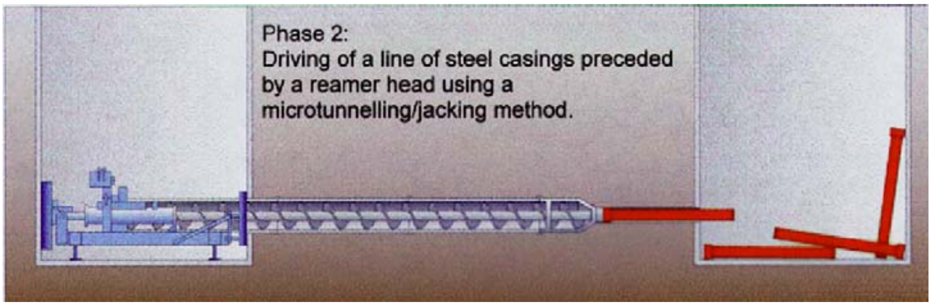
Auger Method (Drill)

Phase II

- **install a temporary steel casing**



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Standard Reaming Heads

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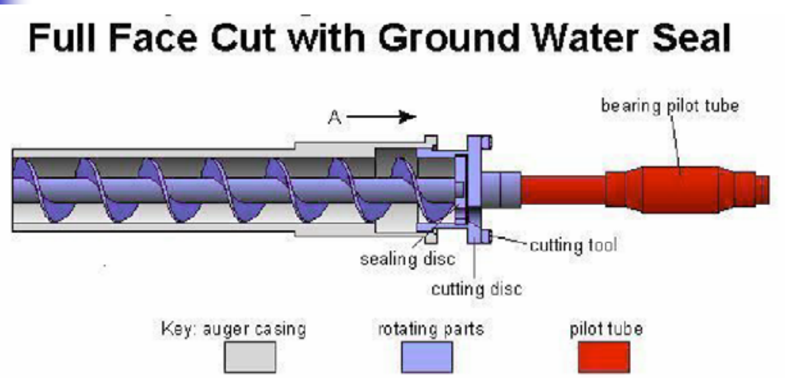
Phase II



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Standard Reaming Heads

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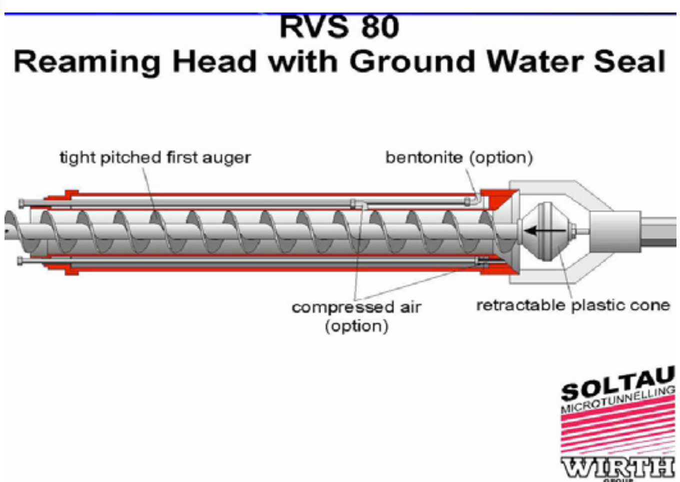
Phase II



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Full face with Ground water control

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Phase II – Casing with Augers

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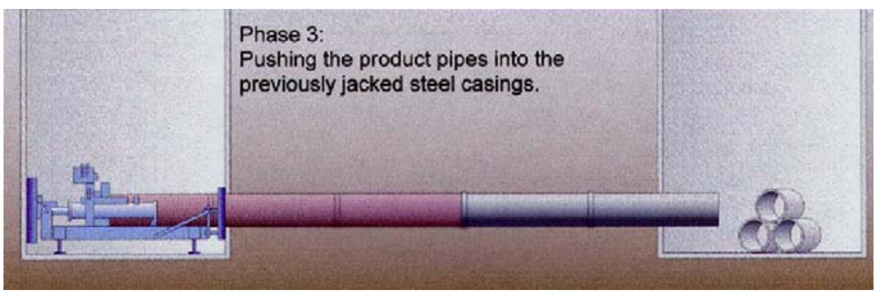
Phase II – Casing Installation

Auger Method (Drill)

Phase III

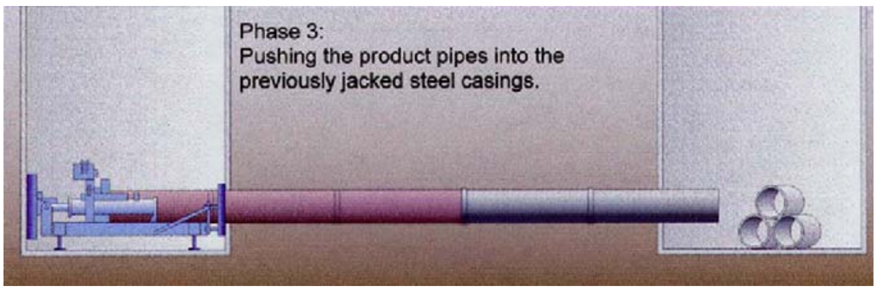
- **the product pipe is installed**



Auger Method (Drill)

Phase III

- **the product pipe is installed**



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Phase III

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Auger Method (Drill)

- Steered pilot tube
- Combined Phase II & III (<150mm OD)
- Phase III (150 to 225mm)
- Shafts 2m dia
- Drive lengths 60m plus

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MT Equipment Selection

- Variety of machine types
- Choice depends on ground condition
  - Type of soil/rock
    - Sand, gravel, clay, boulders, etc
    - Ground water table
- Project success depends on have a proper soil investigation

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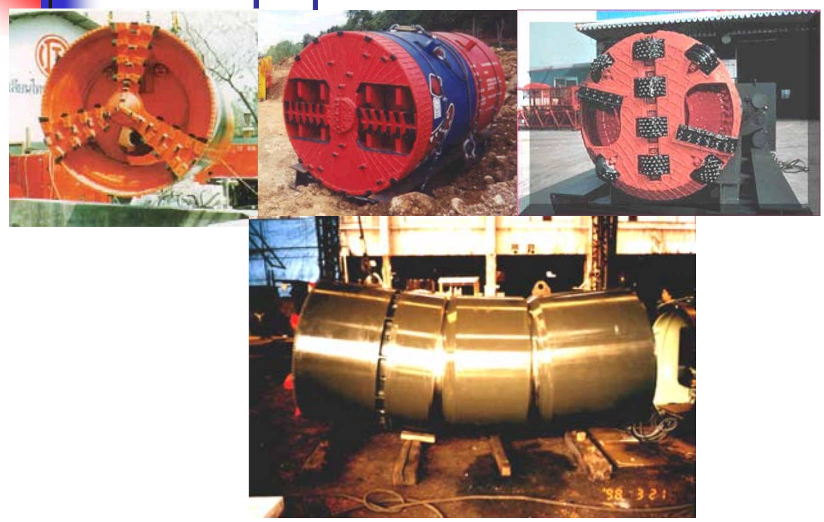
MT Equipment



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MT Advantages

- Grade and alignment accuracy (± 25 mm)
- Works well in a wide variety of soil conditions
  - Some problems with boulders
- Works well below groundwater table
  - No expensive dewatering systems required
  - Up to approx 30m below GWT
- Increasing line depths does not significantly increase cost

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MT Advantages

- Worker safety
- No ground surface settlement

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MT Disadvantages

- High equipment capital cost
- Lateral connections?
- Difficulty with boulders
- Changing ground conditions
- Wood and debris

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Microtunnelling Pipe

- Same as for pipe jacking

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Other Recommendations

- Ensure sufficient room adjacent to the launch pit for:
  - Pipe and machine storage
  - Drill fluid mixing and recycling
  - Spoil/cutting removal

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Safety Precautions

- Safe pit design
- Overhead clearance for equipment
  - Lower pipe and machine into the access launch pits
  - Retrieve machine from exit pits
- Underground utility clearance

MT Risks

- Pipe diameter
  - Risk decreases as diameter increases
- Length
  - Risks increases as length increases

Cost

- 36” (900 mm) = $650 to 850/ft
- 48” (1200 mm) = $800 to 1200/ft
- Shafts
  - 50 to 100k
  - Depends on groundwater, depth & soil conditions
- Need over 1million dollar project to start to look at Microtunnelling

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Microtunnelling in KL

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Microtunnelling in KL

- Approx. 70km 1800mm OD sewer
- LOVAT MTS (Toronto Canada)
- 3 to 4 pipe sections 2950mm long per day
- Drive length 64 sections (~190m long)
- ~RM90,000,000 Project

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Microtunnelling in KL

EXIT SHAFT

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Microtunnelling in KL

- MT machine currently stuck under the river
- Will sink rescue shaft to recover

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