DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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FROM: HQ AFCESA/CES
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SUBJECT: **Engineering Technical Letter (ETL) 04-4 (Change 1): Trenchless Technology (TT) for Crossing Air Force Pavements**

1. Purpose. This ETL provides general information and guidance on the use of TT in constructing, reconstructing, rehabilitating, renovating, cleaning, inspecting, locating, and detecting anomalies around underground pipelines, utilities, fuel hydrant lines, or communication lines crossing under Air Force pavements, including runways, taxiways, aprons, overruns, and roadways.

2. Application. All Air Force installations. Consideration of TT is encouraged in all instances where a project involves work on an underground pipeline, utility, fuel hydrant line, or communication line crossing under an Air Force runway, taxiway, apron, overrun, or roadway. When considering the use of TT, input/guidance should be sought from the major command pavement engineer and the appropriate functional engineer for the system involved.

2.1. Authority: Air Force Policy Directive (AFPD) 32-10, *Installations and Facilities*.

2.2. Effective Date: Immediately.

2.3. Intended Users:

- Air Force major command (MAJCOM) pavement engineers, utility system engineers, and fuel system engineers.
- Base civil engineers (BCE) and others responsible for constructing, reconstructing, rehabilitating, and renovating Air Force facilities (including, but not limited to, underground pipelines, utilities, fuel hydrant lines, and communication lines), or for cleaning, inspecting, locating, and detecting anomalies around Air Force underground pipelines, utilities, fuel hydrant lines, and communication lines.
- United States (U.S.) Army Corps of Engineers (USACE) and Navy offices responsible for constructing, reconstructing, rehabilitating, and renovating Air Force facilities, or for cleaning, inspecting, locating, and detecting anomalies around Air Force underground pipelines, utilities, fuel hydrant lines, or communication lines.

2.4. Coordination: MAJCOM pavement engineers, utility system engineers, and fuels engineers.

3. References:

3.1. Code of Federal Regulations (CFR):

- Title 29, CFR, Chapter XVII, Section 1910.146, *Permit-required confined spaces*

3.2. Environmental Protection Agency:

- *Operation and Maintenance of Wastewater Collection Systems*, Volume II, Section 10.320, "Pipeline Rehabilitation Methods," available online at http://www.epa.gov/OWM/

3.3. Air Force:

- ETL 04-6, *Inspection of Drainage Systems*, available online at http://www.afcesa.af.mil/Publications/ETLs/default.html
- AFPD 32-10, *Installations and Facilities*, available online at http://www.e-publishing.af.mil/pubfiles/af/32/afpd32-10/afpd32-10.pdf

3.4. American Society for Testing and Materials (ASTM):

- *F2207-02 Standard Specification for Cured-in-Place Pipe Lining System for Rehabilitation of Metallic Gas Pipe*, available online at http://www.astm.org/cgi-bin/SoftCart.exe/index.shtml?E+mystore
- *F1962-99 Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings*
- *F1871-02 Standard Specification for Folder/Formed Poly (Vinyl Chloride) Pipe Type A for Existing Sewer and Conduit Rehabilitation*
- *F1867-98 Standard Practice for Installation of Folded/Formed Poly (Vinyl Chloride) (PVC) Pipe Type A for Existing Sewer and Conduit Rehabilitation*
- Other ASTM standards related to trenchless technology

3.5. Private Industry:

- Transportation Research Board (TRB), National Cooperative Highway Research Program (NCHRP) Synthesis 242, *Trenchless Installation of Conduits Beneath Roadways*, 1997
- International Society of Trenchless Technology (ISTT) Web site, http://www.istt.com
- North American Society for Trenchless Technology (NASTT), *A Brief History of Trenchless Construction*, available online at http://www.nastt.org/
- Australasian Society for Trenchless Technology (ASTT), *State of the Industry Report on Trenchless Technologies in Australia*, prepared by Australian Water Technologies (AWT) Engineering Pipelines, September 2000, available online at http://www.astt.com.au/AWTReport.htm
- *Trenchless Technology: Rehabilitation of Potable Water Pipe*, Stuart Wilson, Rural Water, Volume 22, Number 4, Fourth Quarter 2001

- *What is Trenchless Technology Anyway?*, Glenn M. Boyce, Trenchless Technology, Volume 5, Number 6, June 1996
- Water Environment Federation (WEF) Manual of Practice (MOP) FD-6, *Existing Sewer Evaluation and Rehabilitation* (American Society of Civil Engineers [ASCE] Report on Engineering Practice No. 62), Chapter 7, "Pipeline Rehabilitation Methods," available online at http://www.wef.org/

4. Acronyms and Terms. A glossary of TT terminology is included as Attachment 1. Note that the lack of standardization of terminology in the TT industry is a significant problem. Identical TT terms vary in meaning with different manufacturers, contractors, researchers, and even with different individuals within the same organization.

AFPD	–	Air Force Policy Directive
AFPET	–	Air Force Petroleum Office
ASCE	–	American Society of Civil Engineers
ASS	–	advanced support structure
ASTM	–	American Society for Testing and Materials
ASTT	–	Australasian Society for Trenchless Technology
AWT	–	Australian Water Technologies
BCE	–	base civil engineer
CCTV	–	closed circuit television
CFR	–	Code of Federal Regulations
CIP	–	cast iron pipe
CIPP	–	cured-in-place pipe
DIP	–	ductile iron pipe
DOT	–	Department of Transportation
EHMWHD	–	extra-high molecular weight high density
EPB	–	earth pressure balance
ERW	–	electrical resistance welding
ETL	–	Engineering Technical Letter
GPR	–	ground penetrating radar
GRC	–	glass-fiber reinforced concrete
GRP	–	glass reinforced plastic
HDD	–	horizontal directional drilling
HDPE	–	high density polyethylene
HQ AFCESA	–	Headquarters, Air Force Civil Engineer Support Agency
IGN	–	Information Guidance Notes
IJS	–	intermediate jacking station
IRT	–	infrared thermography
ISTT	–	International Society for Trenchless Technology
MAJCOM	–	major command
MOP	–	Manual of Practice
MTBM	–	microtunnel boring machine
MWD	–	measurement while drilling
NACE	–	National Association of Corrosion Engineers

NASTT	–	North American Society for Trenchless Technology
NCHRP	–	National Cooperative Highway Research Program
O&M	–	operation and maintenance
OSHA	–	Occupational Safety and Health Administration
PE	–	polyethylene
POL	–	petroleum, oil, and lubricants
PP	–	polypropylene
PRC	–	polyester resin concrete
PVC	–	polyvinyl chloride
RPM	–	reinforced plastic mortar
RTR	–	reinforced thermosetting resin
SDR	–	standard dimension ratio
SRPC	–	sulfate resisting Portland cement
TBM	–	tunnel boring machine
TRB	–	Transportation Research Board
TT	–	trenchless technology
U.S.	–	United States
USACE	–	U.S. Army Corps of Engineers
VCP	–	vitrified clay pipe
VCT	–	vitrified clay tile
WEF	–	Water Environment Federation

5. History. The theory and recorded use of trenchless techniques dates back to early Roman times. Visit the North American Society for Trenchless Technology (NASTT) Web site at http://www.nasttglsl.on.ca/english/about.htm for a historical overview of TT.

6. Considerations. TT should be viewed as an alternative construction methodology. Consider system characteristics, constructability, site conditions, and cost when deciding whether to use TT. Each opportunity to utilize TT must be evaluated on a case-by-case basis.

6.1. System Characteristics. While TT is ideal for straight through runs of pipe, it is less well suited for projects involving characteristics such as numerous service connections, valves, and bends. Additionally, although very good control of grade is possible using TT, exercise caution when considering the use of TT for systems that require very tight grade tolerances, such as lines for petroleum, oil, and lubricant (POL) products.

6.2. Site Conditions. The *in situ* site conditions and the presence of underground interferences, whether natural (e.g., boulders) or man-made (e.g., underground structures and utilities), should be considered when deciding whether to use TT. Compared to soil deposits, the presence of natural rock or coral deposits can increase drilling costs, while underground interferences can cause alignment problems (i.e., deflections) during TT operations.

6.3. Constructability. The presence of qualified, experienced, certified contractors and equipment operators is essential to the success of a TT project, as is the availability of the proper equipment and materials for the job and site conditions. These factors are more likely to be a problem at overseas, remote, or hostile environment locations.

6.4. Cost. Since TT is an alternative construction methodology, compare its cost to that of conventional techniques such as cut-and-cover (i.e., trenching and backfilling) before deciding to use TT. In the cost analysis, include the indirect costs of conventional construction techniques, such as the need for a longer construction time or the disruption caused by having to close a pavement section.

7. Advantages. For the Air Force, the most important advantage of TT is that it minimizes disruption to both aboveground facilities (e.g., runways, hangars) and belowground facilities (e.g., existing utilities, bunkers). Other important collateral advantages of TT are:

7.1. Size Range. TT can be used to create almost any size range, from a tiny conduit for a fiber optic cable to a multilane vehicle tunnel.

7.2. Pipe Types. TT can use virtually any type of pipe, although some pipe types are better suited for particular TTs. Some pipe types commonly used in TT are:

- Steel pipe
- Polyvinyl chloride (PVC) pipe
- Polyethylene (PE) pipe
- Vitrified clay pipe
- Reinforced concrete pipe
- Polymer concrete pipe
- Fiberglass reinforced pipe

7.3. Pipe Shapes. TT can use a wide variety of pipe shapes. The most commonly used shape is circular, but TT can also use oval, elliptical, and semi-elliptical pipe shapes as well as a variety of box shapes. In addition, modular and other advanced construction techniques can be used to create unusual cross sections.

7.4. Site Preparation. TT can minimize the time needed for site preparation and/or the amount of disturbance. Common TT techniques require either no digging or digging of a drive pit and a receiving pit (adjacent to the ends of the pipe segment, on opposite sides). Even when pits are used, the amount of disturbance is significantly less than for a fully excavated trench. Not only is the disturbance reduced, but it can also be localized to areas that are not mission-critical (i.e., away from the main runways and taxiways).

7.5. Dewatering. While some systems, like POL lines, may need to be protected from contamination from water, mud, salt, and debris, many projects employing TT techniques will require little or no dewatering.

7.6. Safety. TT is safer than conventional trench excavation for several reasons:

7.6.1. Conventional excavating techniques usually require person-entry within the trench to lay the pipe. Even when a conventional trench is shallow, without proper support (e.g., shore jacks, trench “boxes”) there is still a danger of collapse. In addition, even when reinforcement or other safety equipment is required by contract, many workers do not take full advantage of the protection because of the sharp decrease in productivity associated with the use of in-trench safety equipment.

7.6.2. In sharp contrast to conventional construction techniques, most TTs do not require person-entry within the “trench” area. In addition, most TTs only require person-entry in insertion/receiving pits that are relatively easy to reinforce. Even in those TTs that require person-entry within the “trench” area (e.g., tunneling), the person is usually completely enclosed by a supporting pipe with sufficient strength to help guarantee the person’s safety in case of collapse.

7.7. Environmental Impact. Because TT methods minimize soil disturbance and dewatering, environmental damage is correspondingly minimized.

7.8. Replacement of Excavated Materials. Open trenches across an Air Force pavement almost always require replacement of a significant portion of the removed material to maintain pavement strength and stability. Since TTs minimize the disturbance of the *in situ* materials, the surrounding materials retain their existing strength and stability without material replacement.

7.9. Depth. There is a practical limit to conventional trenching (i.e., the depth a hoe or digger can reach), but virtually no limit to the depth for which TT can be used. In cases where existing underground structures, or even existing underground utilities, create an area of concern, TT can be used to go far beneath the problem.

7.10. Reduction in Operation and Maintenance (O&M) Costs. TT can reduce O&M costs by returning pipe systems to their design capacity (or sometimes even better than design capacity), often at a fraction of the cost of conventional reconstruction.

8. Applicability of Specific TT Methods. No single TT method is best for all cases, and applicability is contingent upon Air Force-specific conditions.

8.1. Local Geology. Local geology/subsurface conditions usually preclude the use of one single TT for all cases. This statement is supported by the Transportation Research Board (TRB), National Cooperative Highway Research Program (NCHRP) Synthesis 242, *Trenchless Installation of Conduits Beneath Roadways,* which addresses roadway utility crossings. The TRB compiled results of survey responses on TT from the departments of transportation (DOT) in 33 American states and 6 Canadian provinces. The TRB study had one major conclusion:

No one method is suitable for all types of utilities or all types of soil or site conditions. The selection of compatible methods is site specific and highly dependent on subsurface conditions. Therefore, an adequate soils investigation and an accurate underground utility location program are critical for minimizing subsequent construction problems and claims.

8.2. Time/Mission Disruption. Since mission capability is often the controlling factor in Air Force pavement crossings, there are several other factors related to time or mission disruption that preclude the use of one single TT for all Air Force cases.

8.2.1. Equipment Availability. Equipment availability is a key issue in the use of TT for Air Force pavement crossings. Unlike DOTs (with local jurisdiction), the Air Force has a worldwide jurisdiction, and with force projection comes the possibility of pavement crossing problems anywhere on the globe. Depending on the TT chosen, local equipment may not be available or adaptable to solve a particular problem.

8.2.2. Materials Availability. Local materials availability may affect the choice of TT for a particular problem or location. In this context, “materials” refers to items such as the pipe, pipe liner, grout, and drilling mud. The exact definition of “materials” will vary with the choice of TT method.

8.2.3. Adjacent Area Availability. The availability and usability of adjacent areas may determine the choice of TT. For a technology that requires an insertion pit or a receiving pit, there must be an adjacent area that can be excavated. Other TTs that do not require a pit (e.g., horizontal directional drilling [HDD]) still require a significant staging area, but the staging area does not always have to be adjacent to the pavement.

8.2.4. Specialized Training. The need for specialized training may restrict or eliminate the choice of some TTs for a particular need in a particular area (e.g., in a dangerous area). The engineer who considers the choice of a TT must also consider that the same personnel who can perform a wide range of other construction activities may not be capable of operating, for example, a computer-controlled directional drilling machine. The issue of training may not be as critical for peacetime construction performed by a qualified civilian contractor, but it could be a controlling issue in a force-projection environment. In any event, a TT contractor for an Air Force pavement crossing must have adequate training and experience to ensure a safe and satisfactory result, and any TT equipment operator must be properly and specifically trained on the TT equipment that will be used by that operator.

8.2.5. Use of Sleeves. For any pressurized utility or fuel line crossing under an active Air Force pavement (runway, taxiway, apron, overrun, or roadway), a TT which includes the use of a protective sleeve is highly recommended when extreme loadings may cause undue stresses on the pipeline. (**Note:** Such situations can usually be mitigated through the use of an increased pipe wall thickness and/or a greater depth of pipeline cover.) When a sleeve is used, the sleeve material should be of a type and strength that will minimize the risk of external leakage in the event of a breach in the main pipeline, since external leakage could cause environmental contamination, structural weakening of the pavement support system, or other danger (e.g., fire). In addition, the sleeve system should have adequate venting to maintain integrity and safety at all times, specifically to include the case of a breach in the main pipeline. Specific design and performance criteria (e.g., the need for protective coatings and cathodic protection) and venting requirements for the sleeves will depend on the TT chosen, the type of pressurized pipeline, and the material to be transported within the pressurized pipeline. When a sleeve is used for a cathodically protected pipeline: (1) the carrier pipe should be centered in the sleeve using non-metallic devices, and (2) the annular space should be filled with clean, non-corrosive fill material to allow cathodic protection current to reach the entire surface of the carrier pipe. A corrosion control specialist certified by the National Association of Corrosion Engineers (NACE) should be consulted when designing such work.

9. Performance Specifications. A growing number of DOTs are using performance specifications rather than product specifications for most, if not all, of their TT contracts for roadway crossings. With the growing number of methods and materials available, it is becoming harder and harder to write a good product specification that will allow contractors to use the best TT for a particular job (i.e., one that will maximize benefits and minimize cost), whereas performance specifications place the responsibility on the contractor to deliver a finished product with adequate performance characteristics to satisfy mission needs. For mission critical systems, like POL lines, the use of product specifications may still be preferable.

10. TT Types. Attachment 2 illustrates the major types of TT currently available. Hybrids of the major methods create a plethora of choices for a given TT application; however, the various methods can be separated into four major groups, three of which can be considered structural (new construction or reconstruction, renovation, and rehabilitation) and two non-structural (cleaning and inspection [to include pipeline location and anomaly detection]).

10.1. New Construction or Reconstruction. Construction methods may be categorized as either surface-launched or not surface-launched.

10.1.1. Surface-launched. In general, surface-launched TTs start by drilling a pilot hole that is then expanded by “backreaming” (i.e., pulling an enlarging cutting head back through the pilot hole) before pulling in the pipe. Backreaming can be done separately from, or in conjunction with, pipe pullback. An alternate method uses the pilot hole as a guide, with a cutting head and pipe being pushed along the guide path (similar to microtunneling). The main surface-launched TTs are HDD and guided boring; a hybrid type, the midi rig, is often referred to as a third type.

10.1.1.1. In the TT industry, the term “guided boring” is sometimes used generically to mean any horizontal boring with any degree of control over the drill head; however, the term is more commonly used to describe a type of small-scale, surface-launched boring rig that has a limited capability for guiding the auger-head. Guided borings are often used by utility companies for highway crossings and are particularly cost effective when several crossings need to be made in a single geographical area. The major advantage over traditional (horizontally oriented) rotary drilling methods is that no drive pit or receiving pit is needed. The major disadvantage is the mobilization cost of the specialized equipment and operators, which is why this method is often used only for multiple crossings.

10.1.1.2. HDD is, essentially, a larger-scale, higher-technology version of guided boring, usually with computerized remote control over the drilling head. (In fact, some vendors refer to a guided boring rig as a "mini HDD.") In sharp contrast to guided boring rigs, the largest HDDs are capable of traveling several miles underground with remotely controlled guidance (using radio-driven locator technology to track the drilling head). The major advantage of HDD is the relatively large depths and relatively long distances that can be traversed. HDD has been used for crossings under rivers, lakes, multi-lane highways, and airports. Mobilization costs remain the major disadvantage of this method, even more so than for guided boring.

10.1.1.3. Many vendors consider midi rig boring, a hybrid TT technique, a separate surface-launched method. The size of a midi rig varies, but it falls somewhere between a guided boring rig and an HDD rig. Similarly variable, the remote location and guidance capabilities of a midi rig would usually be thought of as better than a guided boring rig, but not as effective as an HDD rig; it is essentially a "supercharged" guided boring rig or "scaled-back" HDD rig. The advantages and disadvantages of a midi rig are similar to those of guided boring (paragraph 10.1.1.1) and HDD (paragraph 10.1.1.2).

10.1.2. Non-surface Launched. These methods may be divided into several types: boring/coring, push/pull (includes pipe jacking, pipe pullback, and pipe pulling), compaction, pipe ramming, water pressure, tunneling, and microtunneling. In TT terms, tunneling and microtunneling are considered "stand-alone" technologies; the other methods are used in conjunction with other TT methods to produce installed pipelines.

10.1.2.1. Boring/Coring. Boring/coring refers to traditional auger boring/coring rigs mounted horizontally. In TT terms, this is distinguished from guided boring or HDD by a lack of directional control at the cutting head. In traditional boring/coring, a receiving pit is used to "catch" the drilling apparatus so localized directional control is not required.

10.1.2.2. Push/Pull. Push/pull methods such as pipe jacking, pipe pullback, and pipe pulling use hydraulic, mechanical, or air jacks to push or pull a pipe through a horizontal stratum.

10.1.2.2.1. "Pipe jacking" is a term that has various meanings and usages within the TT industry and is sometimes even used to refer to any TT method. Though this ETL explains and categorizes pipe jacking methods, be aware that the term "pipe jacking" can have widely differing meanings depending on the source (see paragraphs 10.1.2.3 and 10.1.2.4). The most common use of the term "pipe jacking," however, is to describe any of several methods that use jacks to push or pull an open pipe through a horizontal stratum, with spoil removal either before or after inserting the pipe.

10.1.2.2.2. Pipe pullback is usually distinguished from pipe jacking by the location of the jack relative to the pipe insertion; that is, when the jack is located behind the pipe insertion so that the jack puts the pipe in compression, the method is usually referred to as pipe jacking. When the pipe is pulled back through a previously drilled borehole so that the pipe is put in tension, the method is usually referred to as pipe pullback. In the case of a pipe being pulled directly behind the cutting heads using a cable through a previously bored guide hole, there is no clear consensus on which term (i.e., pipe jacking or pipe pullback) should be used, even though the pipe is clearly being put in tension.

10.1.2.2.3. Usually pipe jacking is the method preferred in collapsible strata, whereas pipe pullback is preferred in self-supporting strata, although the preference may also depend on equipment availability. Either technique may be used in boreholes that are stabilized with fluid (e.g., driller's mud).

10.1.2.2.4. Pipe jacking is not limited to circular or elliptical cross sections. Box-shaped cross sections may be used in soft strata, or even in stiff strata, if oversize cutting heads are used ahead of the jacked pipe. Modular jacking has been used to build up support for structural components (such as bridge abutments) out of modular units jacked into soft soil. In addition, pipe jacking may be used to create an advanced support structure (ASS). The ASS is an enclosing support environment created by a series of closely spaced jacked pipes that form walls and/or ceilings, or often an archway, before excavation inside or underneath the ASS. In some cases, grout or glue is injected to fill the spaces between pipes; in other cases, the pipes are reinforced during or after excavation; and in some cases, particularly for temporary use, the ASS is used without interior reinforcement.

10.1.2.2.5. Though pipe pulling is a traditional utility industry TT technique, the term "pipe pulling" is frequently misused as a synonym for pipe pullback. In pipe pulling, an existing pipe is removed simultaneously with new pipe installation by a single pulling action. Because of side friction, this method is usually limited to very small diameter pipes with relatively short runs. While this technique is often overlooked in TT discussions (it is "low-tech" and has limited application), it is probably the best TT method in cases where its use is viable.

10.1.2.3. Compaction. Compaction methods are usually distinguished from jacking methods because they do not remove spoil (the term "pipe jacking" is sometimes used generically to describe these methods as well); that is, the soil around the pipe is compacted *in situ*, and remains around the installed pipe. When a closed pipe is driven, compaction is generically called "piercing." When a mechanical or hydraulic jacking system is used, piercing is often referred to as the push rod method; when a percussive system is used to drive the pipe, piercing is often referred to as impact moling; and when a horizontally mounted pile driver is used to drive the pipe, piercing is usually referred to as pipe ramming (paragraph 10.1.2.4). The use of auger-like cutting heads that both dislodge and compact the soil is often referred to as the rotary method or "cutting."

10.1.2.4. Pipe Ramming. The term “pipe ramming” is often generically used for any insertion of a pipe using a percussive device, particularly if the device is a horizontally mounted pile driver; therefore, the term “pipe ramming” is sometimes used in place of “pipe jacking” (i.e., spoil removed), but also sometimes used in place of “piercing” (i.e., spoil compacted in place).

10.1.2.5. Water Pressure.

10.1.2.5.1. Fluid-assisted Boring. Fluid-assisted boring uses a combination of mechanical drilling and pressurized fluid jets to provide the cutting action. This method is commonly used in rock coring or boring through extremely stiff soils.

10.1.2.5.2. Jet Cutting. Jet cutting (sometimes referred to as “jetting”) is a specialized piercing method, particularly useful in sandy soils, in which a water jet is used to “liquefy” the soil in advance of the inserted pipe (i.e., it makes the sand “quick”). As with pipe pulling, this method is limited to relatively small diameter pipes with relatively short runs because side friction acts on that part of the pipe that is not in the vicinity of the jet head. Use of the term “jetting” as a synonym for jet cutting can lead to confusion because the term “jetting” is also used to describe a pipe-cleaning method (paragraph 10.4.1.1.3).

10.1.2.5.3. Slurry Shield. The slurry shield method uses a mechanical tunneling shield with a closed face, and uses a liquid (usually water) to remove the excavated material and balance the ground water pressure. In another confusion of terminology, however, “slurry boring” is also used generically to describe any auger boring with driller’s mud; that is, “slurry boring” and “auger boring,” respectively, are sometimes used to distinguish “wet” drilling from “dry” drilling.

10.1.2.6. Tunneling. Tunneling methods include any technique that involves excavating soil or rock at the leading edge of a shield or boring machine and erecting a lining system from within the excavated space. Traditional tunneling methods range from removal by hand to sophisticated excavators. Hand-bolted segmental rings are frequently used in traditional tunneling, although shotcrete/gunite (i.e., blown concrete) is gaining in popularity for larger tunnels because of increased productivity (i.e., faster advance rates). The modern tunneling method uses a tunnel boring machine (TBM). TBMs are currently used worldwide to create large tunnels (e.g., for subways or highway tunnels). The distinguishing feature of all tunneling methods is that they allow person-entry during excavation and lining.

10.1.2.7. Microtunneling. Microtunneling installs pipe using a microtunnel boring machine (MTBM). The term “microtunneling” refers to the fact that person-entry is not required (in fact, it is usually not possible) during tunneling. The term “microtunneling” is frequently misunderstood and misused because it refers to the remote control aspect of the method (i.e., no person-entry needed), not the size of the tunnel. In fact, microtunnels can be quite large. MTBMs typically use pipe jacking to insert pipe just behind the cutting head (the jacked pipe continuously supports the tunneling operation), but in self-supporting strata (especially rock), pipe pullback is an alternative (paragraph 10.1.2.2.2).

10.2. Renovation. In this ETL, renovation is defined as a repair technique that depends, in part, on the original pipe for support after the upgrade is completed. That definition was adopted for this ETL for two reasons: (1) that definition is commonly used in the TT industry; and (2) that definition is convenient for grouping TT methods. Note, however, that it is also common within the TT industry to use the terms “renovation” and “rehabilitation” interchangeably. Renovation, as defined in this ETL, is most often used in pipes large enough for person-entry. The two main types of renovation are spot repairs and applied linings. For POL lines, repair and liner materials must be capable of withstanding exposure to both the product and any additives, and should be approved by the Air Force Petroleum Office (AFPET).

10.2.1. Spot Repairs. Spot repairs are usually either formed and cured *in situ* or prefabricated and inserted.

10.2.1.1. Traditionally, formed and cured *in situ* spot repairs were limited to manually formed repairs on large concrete storm sewers. More recently, however, the term “formed and cured *in situ* repairs” refers to a number of techniques that involve the use of a “packer” (sometimes called a “balloon”), which is cylindrical in shape, pulled into the area to be repaired and then inflated, sometimes bridging a damaged joint. The packer is then used as a form to hold a polymer concrete or other specialized grouting material that is injected through the packer and into the damaged pipe (and sometimes into the surrounding fill material).

10.2.1.2. In TT terms, “prefabricated and inserted repairs” refers to a number of methods in which pipe segments are grouted or glued in place. Although most prefabricated and inserted repairs are done by person-entry, there are two exceptions: cured-in-place repairs and sophisticated robotic repairs.

10.2.1.2.1. Cured-in-place Repairs. Cured-in-place repairs are patches that are inserted in a reduced or deformed (i.e., folded) shape and then expanded by one of several different methods to fit the inside of the pipe in the distressed area, and then held in place until cured.

10.2.1.2.2. Sophisticated Robotic Repairs. Although most cured-in-place repairs use some robotic components to complete the repairs, the term “sophisticated robotic repairs” refers to a highly specialized area of TT that is most commonly used in the nuclear industry and that has prohibitively high costs. The description of sophisticated robotic repairs is beyond the scope of this ETL, but it is important to note that the term “robotic repair” is sometimes used generically in the TT industry to describe any repair done by remote control, especially if a closed-circuit television (CCTV) camera is used.

10.2.2. Applied Linings. Grouts, glues, polymers, or other exotic materials that are applied by spray or flooding are considered “applied linings.” Due to the traditional need for surface preparation, most applied lining renovations are in large pipes with person-entry; however, recent advances in chemical (polymer) grouts have reduced the requirements for surface preparation, and recent equipment advances have improved the ability to deliver the lining material into smaller pipes. Chemical stabilization is a renovation method used to simultaneously repair a pipe defect and stabilize the surrounding soil; that is, the polymer flows out through the pipe defect into the surrounding soil, and when the polymer sets, it both stabilizes the soil and patches the pipe defect. Even with these advances, however, small pipe applied linings are usually not cost-competitive when compared with other TT methods, particularly in terms of the life-cycle cost. The exception may be in potable water lines, particularly metal pipes, where the combination of pigging (paragraph 10.4.1.2.1) and spray lining can be a cost-effective way to remove tuberculations (chemical deposits usually associated with “red water”) and return the pipe to a nearly new condition. Both cement mortar and polymer lining systems are currently available for renovating potable water lines.

10.3. Rehabilitation. In this ETL, “rehabilitation” is defined as a repair technique that does not depend on the original pipe for support after the upgrade is completed. This definition was adopted here because it is commonly used in the TT industry and because it is convenient for grouping TT methods. As noted in paragraph 10.2, however, it is also common within the TT industry to use the terms “renovation” and “rehabilitation” interchangeably. As defined in this ETL, rehabilitation methods can be further divided into three groups: applied lining methods, prefabricated lining methods, and upsizing. Both of the lining methods have the disadvantage of causing a reduction in pipe capacity (in addition to the disadvantage of usually needing person-entry). Upsizing, as its name implies, can return the pipe to its original capacity, or even increase its capacity, without person-entry. Still, there are many cases where a pipeline requires less than its original capacity (e.g., if a conventional communications cable was being replaced with a fiber optic cable), and in those cases, lining methods remain a useful rehabilitation alternative. For POL lines, liner materials must be capable of withstanding exposure to both the product and any additives, and should be approved by AFPET.

10.3.1. Applied Lining. Applied linings for rehabilitation are usually restricted to large pipes, with installation techniques similar to those for renovation linings (paragraph 10.2.2), but usually with thicker application and/or stronger material. Gunite/shotcrete (i.e., blown concrete) is gaining in popularity for large-pipe rehabilitation, particularly using advanced concrete mixes such as fiber-reinforced concrete.

10.3.2. Prefabricated Lining. There are four main rehabilitation methods using prefabricated linings: insert renewal, modified sliplining, spiral wound linings, and segmented linings. All four techniques are sometimes referred to generically as sliplining, but the term sliplining is properly applied only to insert renewal and modified sliplining.

10.3.2.1. Insert Renewal. Insert renewal is the simplest and most commonly used type of sliplining, particularly in pipes that have no internal tees. As its name implies, a finished pipe is inserted inside the original pipe. While the simplest of the sliplining methods both in concept and in execution, it is often not the ideal solution because it typically is also the method that most reduces pipe capacity.

10.3.2.2. Modified Sliplining. Modified sliplining involves slipping a lining with a reduced diameter inside the existing pipe and then expanding the lining. Modified sliplining is usually separated into cured-in-place pipe (CIPP), and fold and form pipe, although both of these methods involve curing the lining in place.

10.3.2.2.1. CIPP. CIPP is installed as a flexible insert (sometimes referred to as a "sock"), then expanded and cured. CIPP is typically resin-impregnated, but other exotic materials are also used. Many CIPP installation procedures require that the insert be subsequently pulled inside-out. CIPP has recently become a more popular rehabilitation technique, but price remains a concern because of the expense of the materials required to produce the blend of thinness, flexibility at insert, and strength after curing. Other benefits, however, such as less installation time or less disruption of mission capability, may offset the higher material costs of CIPP.

10.3.2.2.2. Fold and Form Pipe. Also known as deformed and reformed pipe, fold and form pipe is usually distinguished from CIPP although they are closely related. The most common type of fold and form pipe is folded at roughly the midline of the liner, so that the insert forms a "U" shape. (In some products, the "U" shape is folded again so that the liner is flat for insertion.) The folded pipe is either pushed or pulled through the original pipe and then inflated/expanded and cured in-place. Fold and form pipe is easier to insert and cure in specific sections of pipe than other modified sliplinings and therefore lends itself better for rehabilitation of pipes that have internal tee joints (that is, it can be used as a very long spot repair between the tees). Unfortunately, like other types of modified sliplining, fold and form inserts tend to be expensive. As with CIPP, however, other factors (e.g., less installation time or less disruption of mission capability) may offset the higher material costs.

10.3.2.3. Spiral-wound Lining. This technique uses a ribbed plastic strip that is spirally wound by a winding machine to form a liner. The liner is sometimes grouted, and sometimes expanded and cured in place. In large-diameter pipes, the strips are sometimes formed into panels and installed by hand (which would probably be more properly categorized as a segmented lining but usually is not).

10.3.2.4. Segmented Lining. The term "segmented lining" is used to describe either the use of short pieces of flexible (or folded) pipe insert (similar to spot repair liners) installed as overlapping panels that are either grouted or glued in place to form a continuous pipe liner, or the use of segments of pipe that are butted and either grouted or glued in place to form a continuous pipe liner. Typically these methods are used only in large-diameter pipes that allow person-entry. Segmented linings are becoming less favored because they have the disadvantages of spot repairs but none of the installation advantages of seamless lining systems.

10.3.3. Upsizing. Upsizing can be further subdivided into two types: pipe eating and pipe bursting. These two methods are conceptually similar in that both put a pipe of the same or larger size back in the position where the defective pipe was located and both cause minimal disturbance of surface assets, but the mechanics of the methods are dissimilar: Pipe eating is a tunneling technique (with spoil removal), and pipe bursting is a compaction technique.

10.3.3.1. Pipe Eating. Although MTBMs are used most often in new construction, they can also be used in a rehabilitation technique known as pipe eating, in which the MTBM is run along the axis of a defective pipe to remove the defective pipe with the near-surrounding soil (while the replacement pipe is inserted). While technically this method would qualify as a reconstruction technique, the TT industry typically refers to pipe eating as a rehabilitation technique (a logical designation for practical purposes [i.e., for bidding] even though it is technically incorrect). Before being “eaten,” the defective pipe is sometimes pre-filled with grout, which can improve the performance of the MTBM but increases the need for crushing capability during the “eating” process (this variation of pipe eating is sometimes referred to as pipe crushing). In addition, some pipe-eating systems employ a proboscis-like device to seal the pipe in front of the MTBM shield to collect and divert existing flow, thus allowing a sanitary sewer, for example, to remain "live" during the rehabilitation process.

10.3.3.2. Pipe Bursting. Pipe bursting is rapidly becoming the method of choice for pipe rehabilitation, particularly in spans of pipe that have no internal tee joints. In this technique, a splitting tool (typically called a “bullet”) is pulled by cable through the original pipe, along with a replacement pipe. The bullet may simply rely on its geometry to transfer the cable force to the pipe for splitting, but more sophisticated bullets are mechanized to actually expand outward to create splitting tensile forces (usually used only as needed). The principal advantage of pipe bursting over sliplining techniques is that pipes that are as large or larger than the original pipe can be inserted. This means that the pipe can be returned to its original capacity, or more, and that exotic replacement pipe materials are not required. An additional advantage of pipe bursting over most other rehabilitation techniques is that no surface preparation or even pipe cleaning is needed (although constrictions/blockages of sufficient size and strength to “stop the bullet” have to be addressed prior to beginning bursting). Pipe bursting usually has a minimal effect on surface assets since the amount of material being compacted is usually small compared to the original pipe’s cross section. Even so, pipe bursting is a compaction method, and the amount of surface disturbance depends to some extent on the quantity and quality of the original backfill material, the depth of burial, and the surrounding soil conditions, and depends to a great extent on the increase in size of the upsized pipe compared to the original pipe.

10.4. Non-structural Methods. Non-structural TT methods are overlooked often in technical discussions of TT methods even though they are the most common use of TT.

Non-structural TT methods can be divided into two groups: cleaning and inspection (to include pipeline location and anomaly detection).

10.4.1. Pipe Cleaning. Although there are many variations and combinations of the individual cleaning techniques, all commonly used pipe cleaning methods can be grouped as either hydraulic or mechanical.

10.4.1.1. Hydraulic Cleaning. There are two types of hydraulic cleaning: flushing and jetting; however, a variant of flushing called the "air hammer method" is often classified separately (paragraph 10.4.1.1.2). Hydraulic cleaning is not suitable for POL lines, where contamination of the fuel by residual water is a possibility and where lines must be vapor-free to prevent the possibility of fire or explosion before pressurized air is introduced.

10.4.1.1.1. Flushing. Flushing is using of a relatively large volume of water, flowing through the pipe, to induce cleaning. A fire hydrant is commonly used as the water source for this method since it provides an adequate volume of water with an adjustable flow rate. Ironically, flushing is the most common form of pipe cleaning but often the least effective. While loose debris is almost always flushed from the pipe (giving the appearance that the pipe has been cleaned), more firmly held debris, sediments, chemical deposits, and other materials that have become embedded or affixed to the pipe walls will usually not be removed by flushing. Still, the method is easy and requires no special equipment or training and provides a tangible benefit in most cases.

10.4.1.1.2. Air Hammer. The air hammer method is variant of flushing. The term "air hammer" is a misnomer, however, because the method uses an injected air bubble to create a "water hammer" that increases the cleansing ability of the flushing water. (Most people are familiar with the water hammer effect because of the loud noise and vibration in faucets and toilets after the water has been turned off and later turned back on and air is in the water lines.) The cleansing effect is increased because the water hammer (directly behind the air bubble) moves with great turbulence. This effect is similar to a massaging showerhead that sends out intermittent jets of water.

10.4.1.1.3. Jetting. The term "jetting," when associated with pipe cleaning, refers to any method that delivers pressurized water to a tip, or head, for thorough cleaning. Jetting requires more equipment than flushing since the jet head must be pulled through the pipe. Jetting can provide greatly improved cleaning compared to flushing, particularly when used in conjunction with CCTV inspection, but still cannot always break the mechanical bonds for complete removal of all deposits.

10.4.1.2. Mechanical Cleaning. There are two types of mechanical cleaning: pigging and manual cleaning.

10.4.1.2.1. Pigging. Pigging is the pulling of a slug, or "pig," through the pipe for cleaning. The advantage of pigging is that it can break the mechanical bonds of deposits in smaller pipes that other cleaning methods cannot. In addition, pigging can be used in conjunction with any of the other methods for improved cleansing. There are a wide variety of pigs, with varying sophistication. At the low-technology end, the pig may be a rubber, plastic, or metal slug. At the high-technology end, the pig may be a mechanical scrubbing machine. In between, there are many different pigs with various types of abrasive surfaces, studs, or brushes. For small pipes with severe clogging, pigging may be the only alternative to reconstruction.

10.4.1.2.2. Manual Cleaning. Large pipes may be cleaned manually. A wide range of techniques fall within this category, principally limited only by the available equipment and the diameter of the pipe. All variants on manual cleaning have the same two disadvantages, however: person-entry is required and small pipes cannot be cleaned by this method.

10.4.2. Inspection. Inspection methods can be divided into two groups: internal inspection and location/anomaly detection. See ETL 04-6, *Inspection of Drainage Systems*, for a more detailed study.

10.4.2.1. Internal. Internal pipe inspection is usually done by one of two methods. If the pipe is large, the inspection is done by person-entry; if the pipe is small, the inspection is done by CCTV.

10.4.2.1.1. Person-entry. The main advantage of a person-entry inspection is that it incorporates the oldest and most reliable method of inspection: the human eye. During a person-entry inspection, the inspector can get first-hand information about internal pipe conditions that are impossible to obtain by any other method. In addition, videotape records or photographs, guided directly by the inspector, can be used to supplement and document the inspector's findings. Measurements and samples can be taken directly. In every way, when practicable, person-entry is the best method of inspection; however, safety considerations require that a pipe be of an appropriate size and condition before person-entry is allowed. See Occupational Safety and Health Administration (OSHA) rules on confined space entry in Title 29, CFR, Chapter XVII, Section 1910.146, *Permit-required confined spaces*.

10.4.2.1.2. CCTV. CCTV is the **only** proven technology for internal inspection of small pipes. A key factor for the success of a CCTV inspection is establishing proper reference points so the video can be tied to exact locations in the pipe being inspected. The biggest disadvantage of CCTV is that the quality of the data is highly dependent on the operator's experience and skill. In addition, and particularly when videotape is used for analysis, the results are highly dependent on the quality of the equipment, its degree of maintenance, and the timeliness of hardware and software updates. There is a wide range of equipment for CCTV inspections, usually grouped by the size of pipe to be inspected. In addition to inspecting the internal condition of the pipe, CCTV can be used to estimate the infiltration/inflow of water due to leaks in the pipe.

10.4.2.2. Location/Anomaly Detection. While some aspects of location/anomaly detection can be satisfied during an inspection, this paragraph describes methods that can be used apart from an inspection to simply locate the pipe or locate specific anomalies in the general area of the pipe. These methods can be grouped as manual probes; electromagnetic; ground penetrating radar (GPR); infrared thermography (IRT); and smoke/dye.

10.4.2.2.1. Manual Probe. The simplest and most direct method of locating a pipe or large anomaly (such as a large void) is with a small diameter probe, though manual probes are usually useful only for pipes/anomalies close to the surface, and only for soil surfaces. Since pipes under pavements are the major Air Force concern for TT use, the use of a manual probe will usually be impossible.

10.4.2.2.2. Electromagnetic Locators. Several different types of locator systems use electrical or magnetic signatures to find a buried pipe. These methods are most effective when there is metal in the pipe system (i.e., metal pipe, pipe reinforced with metal rebar, metallic cables within pipe). With the increased use of plastic pipe and fiber-optic cables, electromagnetic location methods are becoming less reliable.

10.4.2.2.3. GPR. GPR is particularly well suited for finding large voids (for example, those caused by a washout in the vicinity of the pipe). GPR can also locate pipes, particularly large pipes. GPR can quickly provide information about underground structures that no other nondestructive test can. GPR is not used routinely in inspections because of cost, but since the biggest cost in most GPR surveys is mobilization, a large test area can usually be surveyed for not much more than the cost of a small test area. Another disadvantage of GPR is that an experienced operator is needed on site to interpret the data. The quality of the results of a GPR survey is highly dependent on the skill of the operator/data interpreter.

10.4.2.2.4. IRT. IRT has been used with varying degrees of success to locate pipes and voids around pipes. An IRT scanner measures temperature differences in the surface above the pipe, which may be significantly influenced by the pipe or by void areas. IRT scanners may be mounted on a permanent structure but are commonly used on portable overhead equipment (e.g., cherry picker), or even mounted on aircraft. The main advantage of IRT is the ability to survey relatively large areas in a short time; however, IRT is usually effective only for relatively shallow pipelines. Also, since the thermographs are two-dimensional, the depth of a pipe or void cannot be determined by IRT alone.

10.4.2.2.5. Smoke/Dye. Smoke and dye tests can be used in various configurations and combinations to locate leaks and sometimes estimate their extent. In addition, these tests are sometimes used to determine if a pipe is either completely clogged or broken and offset. Conversely, these tests are sometimes used to verify that a feature is, in fact, connected to a pipeline (for example, to see if a drop basin is connected to a storm sewer pipe), or to determine if there is a cross-connection between pipes from different systems. These tests are conceptually simple although sometimes cumbersome to perform. Smoke/dye is pumped/injected into the pipe and its appearance (or lack of appearance) is interpreted.

11. Information Sources. TT is rapidly being accepted worldwide, and there are technical societies worldwide that are available as resources. In addition, there are at least 5 regularly published magazines and 3 regularly published refereed journals devoted to TT, and there are also ASTM standards related to trenchless technology. See Attachment 3 for a listing of TT societies, along with contact information for each, and Attachment 4 for a listing of selected TT publications.

12. Air Force Use of TT. There is no single TT method that will be useful in all situations (paragraph 8). Still, the Air Force need for TT has subtle differences from that of most civilian agencies. First, many Air Force pavements have soil underneath the upper paving layers (i.e., rock coring is usually not needed). Second, many pipelines, utilities, and communication lines under Air Force pavements are run in a straight line, often without any internal tees. Third, in new construction or reconstruction, there is sometimes a need to bring a pipeline to the surface fairly accurately (e.g., for POL fill stands). Finally, the Air Force sometimes needs to combine utilities into a single pipe. Considering the Air Force-specific factors, four TTs stand out as particularly interesting for future Air Force application: (1) guided boring; (2) HDD; (3) pipe eating; and (4) pipe bursting. All the factors for each technology in this ETL should be considered when searching for the "best" TTs, but these four technologies have particular strengths worth emphasizing.

12.1. For the typical new construction/reconstruction situation, guided boring seems to be the best Air Force solution when equipment and trained personnel are available. Since a typical installation is often a "straight shot" at relatively shallow depths, the lack of cutting head control (compared to HDD) should not be a problem. The most obvious advantage is surface launching, with a smaller set-up area and less set-up time needed than for HDD.

12.2. HDD is of special interest for Air Force needs if there are underground structures or obstructions that require especially deep penetration during the pipe installation, or if heightened cutting head location and guidance ability are necessary (e.g., for a POL fill stand). In addition, a scaled-down HDD unit (i.e., the midi rig) would probably be adequate for most situations, provided the midi rig was equipped with the sophisticated locator and guidance technology usually associated only with the larger HDD rigs.

12.3. For combining utilities into a single pipeline, pipe eating is a solution worth considering because the MTBM can follow the existing pipe fairly precisely and can expand the pipe capacity to virtually any size, with no significant disturbance to surface assets. That is, since pipe eating is not a compaction method, the size of the new pipe is limited only by the cutting diameter of the MTBM, and large increases in pipe diameter still will not cause significant surface displacements because the displaced spoil is removed.

12.4. For the typical rehabilitation situation (e.g., a broken water pipe), particularly when there are no internal tees, pipe bursting seems to be the perfect Air Force solution. It is a relatively fast method, allows replacement pipes with capacities equal to or greater than the original, and it creates a relatively small effect on surface assets. Still, pipe bursting is a compaction method (paragraph 10.1.2.3) and caution is advised in dense soils and for extremely large increases in pipe diameter, particularly when the original pipe is close to the surface. Even with these caveats, pipe bursting would appear to be the rehabilitation technique of choice for many Air Force situations.

13. Future Research. Decisions about the advantages and disadvantages of the various TT methods may be moot for routine Air Force base maintenance if performance specifications are used to put the burden of decision-making about methodology onto the contractor (paragraph 9). In addition, good decision-making about TT's use in non-routine situations (particularly in harm's way) requires additional research. The claims of the various manufacturers/contractors and conflicting anecdotal evidence from published case studies make meaningful predictions about performance of the various TT methods for Air Force needs in a hostile environment extremely difficult, if not impossible. Certain questions about differences in speed, mobility, and durability of the various TT equipment/methods when used for Air Force purposes can be answered only with field trials performed under controlled conditions.

14. Point of Contact. Recommendations for improvements to this ETL are encouraged and should be furnished to Mr. James Greene, HQ AFCESA/CESC, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32408-5319, DSN 523-6334, commercial (850) 283-6334, FAX DSN 523-6219, Internet james.greene.@tyndall.af.mil.

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5 Atchs
1. TT Glossary
2. TT Methods
3. TT Societies
4. TT Publications
5. Distribution List

GLOSSARY OF TT TERMS

Adapter ring: A ring, typically made of steel, which serves to mate the **microtunneling** machine to the first **pipe** section. This ring is intended to create a waterproof seal between the machine and the spigot of the first **joint**.

Advance: The motion of the machine toward the **face** wall of the **entrance pit**.

Advance rate: Speed of advance of **pipe jacking** or other TT method, usually expressed as either millimeters per minute (inches per minute) or meters per day (feet per day).

Annular filler: Material for **grouting** the **annulus** between the existing pipeline and the **lining** system.

Annulus: Free space between the **pipe** and **lining**.

Auger: A **flight**-equipped drive tube having hex couplings at each end to transmit **torque** to the **cutting head** and transfer **spoil** back to the machine.

Auger boring: A technique for forming a **bore** from a **drive pit** to a **receiving pit** by means of a rotating **cutting head**. **Spoil** is removed back to the **drive shaft** by helically wound **auger flights** rotating in a steel **casing**. The equipment may have limited steering capability.

Auger machine: A machine used to drill earth horizontally by means of a **cutting head** and **auger** or other similar device; may be either a **track** or **cradle machine**.

Auger MTBM: A type of **MTBM** that uses **auger flights** to remove the **spoil** through a separate **casing** placed through the **product pipe**.

Auger TBM: **TBM** in which the excavated soil is removed to the **drive shaft** by **auger flights** passing through the **product pipe** pushed in behind the TBM.

Automated Spoil: An automated **transportation system** for **spoil** removal.

Backreamer (back reamer): A **cutting head** attached to the leading end of a **drill string** to enlarge the **pilot bore** during a **pullback** operation to enable a **carrier pipe, sleeve pipe**, or **casing** to be installed.

Backstop: Reinforced area of the **entrance pit** wall directly behind the **track**.

Bent sub: An offset section of drill stem close behind the drill head that allows steering corrections to be made by rotating the **drill string** to orient the **cutting head**.

Bit: A replaceable cutting tool on the **cutting head** or **drill string**.

Blind shield: Non-mechanical **shield** which has a controlled and partly sealed face.

Bore: A generally horizontal underground **void** created to receive a **pipe**, conduit, or cable.

Boring: (1) The dislodging or displacement of **spoil** by a rotating **auger** or **drill string** to produce a hole called a **bore**; (2) an earth-drilling process used for installing conduits or pipelines; or (3) obtaining soil samples for evaluation and testing.

Boring machine: A mechanism to drill earth.

Boring pit: An excavation in the earth of specified length and width for placing a **boring machine** on **line** and grade.

Box connector: A hexagonal shaped **socket**, also known as a **female hex connector**, which will accept a **shank**.

Bull plug: A steel plug that is pulled through a horizontal **bore** to remove the **spoil**.

Bullet: A device pulled through the existing **pipe** in a **pipe bursting** operation.

Buoyancy: The tendency of an empty **pipe** to float due to applied hydraulic pressure.

Burst strength: The internal pressure required to cause a **pipe** or fitting to fail within a specified time period.

Butt fusion: A method of joining **PE pipe** where two pipe ends are rapidly brought together under pressure to form a homogeneous bond.

Can: A principal module that is part of a **shield** machine in an **MTBM** or **TBM**. Two or more may be used, depending on the installation dimensions required and the presence of an articulated joint to facilitate steering. It is sometimes referred to as a trailing tube.

Carriage: The mechanical part of a **non-split boring machine** that includes: (1) the engine or drive motor; (2) the drive train; (3) the **thrust block**; and (4) the hydraulic cylinders.

Carrier pipe: (1) The tube that carries the product being transported and which may go through a **casing** at a highway or railroad **crossing**. It may be made of steel, concrete, clay, **plastic**, ductile iron, or other materials. It may sometimes be inserted without an exterior casing under highways and railroads. (2) A **pipe** to be rehabilitated by any TT **rehabilitation** method.

Cased bore: A **bore** in which a **pipe**, usually a steel **sleeve pipe**, is inserted simultaneously with the **boring** operation. Usually associated with a combination of **auger boring** and **pipe jacking**.

Casing: A **pipe** used to line bore a hole through which a **carrier pipe** can be installed; usually not a **product pipe**.

Casing adapter: A circular mechanism to provide axial and lateral support to a **casing** that has a diameter smaller than that of the **casing pusher**.

Casing pipe: A **pipe** installed as external protection for a **product pipe**.

Casing pipe method: Method in which a **casing**, usually steel, is placed (usually by **pipe jacking**), and within which a **product pipe** is later inserted.

Casing pusher: The front section of a **boring machine** that distributes the thrusting force of the hydraulic cylinders to the **casing** and forms the outside of the **spoil ejector** system.

Caulking: General term that refers to methods by which **joints** may be closed within a pipeline or between sections of **segmental lining**.

CCTV: See **closed circuit television inspection**.

Chemical grouting: Method for the treatment of the ground around a **shaft** or pipeline, using non-cementitious compounds, to facilitate the installation of an underground structure.

Chemical stabilization: **Renovation** method in which a length of pipeline between two access points is sealed by the introduction of one or more compounds in solution into the **pipe** and surrounding ground and, where appropriate, producing a chemical reaction. Such systems may perform a variety of functions such as the sealing of cracks and cavities, the provision of a new wall surface with improved hydraulic characteristics, or ground stabilization.

Chipper: A synonym for **bit**.

CIP: Acronym for cast iron **pipe**.

CIPP: See **cured-in-place pipe**.

Cleaning: (1) The action of a **boring machine** to remove **spoil** that occurs when the **auger** is rotating while axially stationary; (2) removing material within a **pipe** before **renovation** or **rehabilitation**.

Closed-circuit television (CCTV) inspection: Inspection method utilizing a CCTV camera system with appropriate transport and lighting mechanisms to view the interior surface of a **pipe** and other hydraulic structures.

Closed face: (1) The ability of a **TBM** to close or seal the facial opening of the machine to prevent or slow soil from entering the machine; (2) bulkheading of a hand-dug **tunnel** to slow or stop the inflow of material.

Close fit: Description of a **lining** system in which the new **pipe** makes close contact with the defective pipe at normal or minimum diameter. An **annulus** may occur in sections where the diameter of the defective pipe is in excess of this.

Cold bend: To force the **pipe** into a curvature without damage, using no special tools, equipment, or elevated temperatures.

Collaring: The initial entry of **casing** or a **cutting head** into the earth.

Come-out hole/pit: A synonym for **receiving pit**.

Compressed air method: General term that refers to the use of compressed air within a **tunnel** or **shaft** to balance ground water and prevent ingress into an open excavation.

Compression gasket: A device which can be made of several materials in a variety of cross-sections and serves to secure a tight seal between two **pipe** sections (e.g., "O" rings).

Compression ring: A ring fitted between the end bearing area of the bell and spigot to help distribute applied loads more uniformly. The compression ring is attached to the trailing end of each **pipe** and is compressed between the pipe sections during **jacking**. The compression rings compensate for slight misalignment, pipe ends that are not perfectly square, gradual steering corrections, and other pipe irregularities. Compression rings are also referred to as **spacers**.

Conduit: A broad term that can include **pipe**, **casing**, tunnels, ducts or channels. The term is so broad that it is often not helpful as a technical term in **boring** or **tunneling**.

Continuous sliplining: See **sliplining** or **lining with continuous pipe**.

Control console: An electronic unit inside a container located on the ground surface which controls the operation of the **microtunneling** machine. The machine operator drives the **tunnel** from the control console. Electronic information is transmitted to the control console from the heading of the machine. This information includes head position, steering angle, **jacking** force, progression rates, machine face **torque**, **slurry** and feed line pressures, and laser position. Some control consoles are equipped with a computer that tracks the data for a real-time analysis of the tunnel drive.

Control lever: A handle that activates or deactivates a **boring machine** function.

Conventional tunneling: Methods of **tunnel** construction ranging from manual excavation to the use of a self-propelled **TBM**. Where a **lining** is required, bolted segmental rings are frequently used, although **shotcrete** and **gunite** (i.e., blown concrete) is gaining in popularity because of increased productivity.

Cradle: A concrete or masonry structure that provides support to a **pipe**.

Cradle machine: A **boring machine** typically carried by another machine that uses winches to **advance** the **casing**.

Cross members: The lateral supports under the **track** of a **boring machine**.

Crossing: Pipeline installation in which the primary purpose is to provide one or more passages beneath a surface **obstruction**.

Crushing: See **pipe eating**.

Cured-in-place pipe (CIPP): A **lining** system in which a thin, flexible, **resin-impregnated** tube of polymer or glass-fiber **fabric** is expanded by means of fluid pressure into position on the inner wall of a defective pipeline before curing the resin to harden the material, typically assuming the shape of the existing pipe. The uncured material may be installed by winch or inverted by water or air pressure.

Cutting head: Any rotating tool or system of tools on a common support that excavates at the **face** of a **bore**. Usually applies to mechanical methods of excavation.

Cutting bit: The teeth and supporting structure attached to the front of the lead **auger**, drill stem, or front face of the **TBM**. It is used to reduce the material that is being drilled or bored to sand or loose dirt so that it can be conveyed out of the hole. It typically applies to mechanical methods of excavation, but may also include **fluid jet cutting**.

Dead man: A fixed anchor point used in advancing a **saddle** or **cradle machine**.

Deck assembly: Drive train assembly for a **split-design boring machine**.

Deformed and reformed liner: See **modified sliplining** and **fold-and-form lining/pipe**.

Dimple: A term used in tight-fitting pipeline reconstruction, where the new **plastic pipe** forms an external departure or a point of expansion slightly beyond the underlying pipe wall where unsupported at side connections. The dimples are used for location and reinstatement of lateral utility service.

DIP: Acronym for ductile iron **pipe**.

Directional drilling: A steerable system for the installation of **pipes**, conduits and cables in a shallow arc using a surface-launched drilling rig. Traditionally the term applies to a large scale **crossing** in which a fluid-filled **pilot bore** is drilled using a fluid-driven motor at the end of a **bent sub**, and is then enlarged by a **washover pipe** and **back reamer** to the size required for the **product pipe**. The required deviation during pilot boring is provided by the positioning of a bent sub. **Drill string** tracking is achieved by the use of a downhole **survey tool**.

Discrete sliplining: See **sliplining** or **lining with discrete pipes**.

Drill bit: A tool which cuts the ground at the head of a **drill string**, usually by mechanical means, but may include **fluid jet cutting**.

Drill string: (1) The total length of drill **rods**/**pipe**, **bit**, or swivel joint in a drill borehole; (2) system of rods used with a **cutting bit** or compaction bit attached to the **drive chuck**.

Drilling fluid/mud: A mixture of water and typically bentonite and/or polymer continuously pumped to the **cutting head** to facilitate cutting, reduce required **torque**, facilitate the removal of spoil, stabilize the borehole, cool the head and lubricate the installation of the **product pipe**. In suitable soil conditions water alone may be used.

Drive chuck: The **female hex connector** located within the **casing pusher**.

Drive shaft/pit: See **jacking shaft**.

Dry bore: Any drilling or **rod pushing** system not employing **drilling fluid** in the process. It is typically associated with guided **impact moling**, but also some rotary methods.

Duct: (1) A term often interchangeable with **pipe**; (2) in the **boring** industry, usually small **plastic** or steel pipes that enclose wires or cables for electrical or communication usage; (3) conduit inside which a utility service is installed.

Earth piercing: (1) Term commonly used generically as a synonym for **impact moling**; (2) the use of a tool that comprises a percussive hammer within a suitable **casing**, usually of torpedo shape. The hammer may be pneumatic or hydraulic. Piercing is usually associated with non-steered devices without a rigid attachment to the **launch pit**, and relying upon the resistance (friction) of the ground for forward movement. During operation the soil is displaced, not removed. An unsupported **bore** may be formed in suitable ground, or a **pipe** drawn (or pushed) in behind the tool. Cables may also be drawn in.

Earth pressure balance (EPB) machine: Type of **MTBM** or **TBM** in which mechanical pressure is applied to the material at the **face** and controlled to provide the correct counter-balance to earth pressures to prevent heave or subsidence. The term is usually not applied to machines where the pressure originates from the main **pipe jacking** rig in the **drive shaft/pit** or to systems in which the primary counter-balance of earth pressures is supplied by pressurized **drilling fluid**.

Earth pressure balance (EPB) shield: Mechanical **tunneling shield** which utilizes a full face to support the ground in front of the shield and usually employs an **auger flight** to extract the material in a controlled manner.

EHMWHD: See **extra-high molecular weight high density**.

Entrance/entry pit: (1) An opening in the earth of specified length and width for placing the machine on **line** and grade; (2) a synonym for **boring pit**.

Entry ring: A synonym for **launch seal**.

Entry/exit angle: Angle to the ground surface at which the **drill string** enters or exits in forming the **pilot bore** in a **directional drilling** or **guided boring** system.

EPB machine: See **earth pressure balance machine**.

EPB shield: See **earth pressure balance shield**.

ERW: Acronym for electrical resistance welding.

Exit pit: A synonym for **receiving pit**.

Expander: A tool that enlarges a **bore** during a **pullback** operation by compressing the surrounding ground rather than by excavation. Sometimes used during a **thrust boring** process as well as during **directional drilling** or **guided boring pullback**.

Extension track: An additional section of **track** used in front of the **master track**.

Extra-high molecular weight high density (EHMWHD): A high-density **polyethylene** material, used to make **pipe**, which has higher than normal molecular weight.

Fabric: Used to describe the physical material from which a **pipe** is made (e.g., **VCP**, brick, concrete).

Face: Wall of the **entrance pit** into which the **bore** is made.

Face stability: Stability of the excavated **face** of a **tunnel** or **pipe jack**.

Fairings: Molding features at the ends of **pipes**, usually of varying dimensions to the main pipe, to facilitate easy connection of **joints**.

Female hex connector: A synonym for **box connector**.

Ferro-cement: A **rehabilitation** technique that employs steel **fabric** mesh, usually in multiple layers but with the maximum mesh diameter not exceeding 2 millimeters (0.125 inch), which is fixed to the existing **pipe** and then covered in high-strength **grout**, either placed in situ by **person-entry** work to form a structural **lining** or pre-formed into segments for later installation.

Final drive: The final reduction unit in the drive line.

Flare/flaring: The bending out of the front end of the lead **joint** to give clearance. Depending on ground conditions, the flares may have all cracks or cuts fully welded, or a complete flare not welded, or a segmented flare where only portions of the joint are flared.

Flights: The spiral plates surrounding the tube of an **auger**.

Fluid jet cutting: A synonym for **jet cutting**.

Fluid-assisted boring/drilling: A type of **guided boring** technique using a combination of mechanical drilling and pressurized **fluid jets** to provide the soil-cutting action.

Fold-and-form lining/pipe: A **pipe rehabilitation** method where a liner/pipe, manufactured in a folded shape for reduced cross-sectional area, is pulled into an existing conduit and subsequently expanded with pressure and/or heat. The reformed pipe fits snugly and takes the shape of the inside diameter of the **host pipe**.

Forward rotation: The clockwise rotation of the **auger** as viewed from the machine end.

Free boring: To **bore** or drill without the use of **casing** installed at the same time as the hole is cut. This is not recommended for use with an **auger**.

Glass-fiber reinforced concrete (GRC): A **rehabilitation lining**.

Glass reinforced plastic (GRP): A **rehabilitation lining**; often generically known as **RPM** and **RTR**.

Glory hole: A synonym for **jacking pit**.

Grip: Used to apply force to the **rod** or **pipe**, which causes travel.

Ground mats: Metal mats rolled out on either side of a drill rack for operators and crew to stand on during operation to give grounding protection in case of electrical strike.

Ground mat cables: Cables connecting the drill rack to the **ground mats**.

Ground plane: The surface upon which the machine is placed.

Ground rod: This is a copper/brass **rod** which is hand-driven into the ground and is connected to the drill rack and mats to provide adequate grounding of the drilling unit and personnel.

Grout: (1) Material used to seal pipeline and manhole cracks; also used to seal connections within hydraulic structures; (2) a material, usually cement-based, used to fill the **annulus** between the existing **pipe** and the **lining**, and also to fill **voids** outside the existing pipeline; (3) a material such as a cement **slurry**, sand, or pea gravel that is pumped into voids.

Grouting: (1) Filling of the **annulus** between the **host pipe** and the **carrier Pipe**. Grouting is also used to fill the space around laterals and between the new **pipe** and manholes. Other uses of grouting are for **localized repairs** of defective pipes and ground improvement before excavation during new installations. (2) The process of filling **voids** or modifying/improving ground conditions. Grouting materials may be cementitious, chemical, or other mixtures. In **microtunneling**, grouting may be used for filling voids around the **pipe** or **shaft**, or for improving ground conditions. (3) A method of filling voids with cementitious **grout**.

GRC: See **glass-fiber reinforced concrete.**

GRP: See **glass reinforced plastic.**

Guard: A protective device fitted to the machine to minimize the possibility of inadvertent contact with hazards.

Guidance system: The guidance system continuously confirms the position of the MBTM.

Guide rail: Device used to support or guide the **shield**, and then the **pipe**, within the **drive shaft** during a **pipe jacking** operation.

Guided auger boring: A term applied to **auger boring** systems that are similar to **microtunneling**, but with the guidance mechanism actuator sited in the **drive shaft** (e.g., a hydraulic wrench which turns a steel **casing** with an asymmetric face at the **cutting head**). The term may also be applied to those auger boring systems with rudimentary articulation of the casing near the head activated by **rods** from the **drive pit**.

Guided boring/drilling: Method for the installation of **pipes**, conduits and cables using a surface-launched drilling rig. A **pilot bore** is drilled using a rotating **drill string** and is then enlarged by a **back reamer** to the size required for the **product pipe**. The necessary deviation during the pilot boring is provided by a slanted face to the drill head, an asymmetric drill head, eccentric **fluid jets**, or a combination of these, usually in conjunction with a **locator**.

Gunite: (1) Blown concrete, sometimes fiber-reinforced, used to stabilize a new **tunnel** opening; (2) a **rehabilitation** technique that employs steel reinforcement fixed to the existing **pipe** and covered by blown concrete.

HDD: See **horizontal directional drilling.**

HDPE: See **high density polyethylene**.

Heaving: Process in which the ground in front of a **pipe jack** may be displaced forward and upward causing a lifting of the ground surface.

Helicoid: A section of **auger flight**.

Hex drive: See **drive chuck**.

High density polyethylene (HDPE): A **plastic resin** made by the copolymerization of ethylene and a small amount of another hydrocarbon. The resulting base resin density, before additives or pigments, is greater than 0.941 gram per cubic centimeter.

Hold-down: A hinged or removable assembly that secures the **boring machine** to the **track**.

Holiday: Any discontinuity or bare spot in a coated surface.

Horizontal directional drilling (HDD): A synonym for **directional drilling**.

Horizontal earth boring: (1) Generically, the use of a **horizontal earth boring machine**; (2) use of an **auger boring** machine to prepare holes by the installation of a **casing** whereby the **spoil** is removed by the use of an **auger**.

Horizontal earth boring machine: A machine used to **bore** horizontally through the earth by means of a rotating tool, or nonrotating pushing, or by using a **piercing tool**.

Horizontal rotary drilling: The mechanical installation of **pipe** or **casing** by a rotating method that does not use an **auger** for removing **spoil**. This technique typically uses a fluid mixture of water and bentonite to remove spoil.

Host pipe: Tube that carries the product being transported, which may go through a **casing** at a highway or railroad **crossing**. It may be made of steel, concrete, clay, **plastic**, ductile iron, or other materials. It may occasionally be bored without a casing under highways and railroads.

IGN: See **Information Guidance Notes**.

IJS: See **intermediate jacking station**.

Impact: Stress in a structure caused by the force of a vibratory, dropping, or moving load. In design, this is usually calculated as a percentage of the live load.

Impact moling: Method of creating a **bore** using a pneumatic or hydraulic hammer within a **casing**, usually of torpedo shape. Impact moling is usually associated with non-steered or limited steering devices without rigid attachment to the **launch pit**, relying upon the resistance of the ground for forward movement. During the operation the soil is displaced, not removed. An unsupported bore may be formed in suitable ground, or a **pipe** drawn (or pushed) in behind the impact moling tool. Cables may also be drawn in.

Information Guidance Notes (IGN): An international reference source for **pipe lining** materials.

Insert renewal: **Rehabilitation** technique in which a smaller diameter finished **pipe** is pulled inside an existing pipe as a **replacement**. By definition, insert renewal reduces the capacity of the pipe.

Interjack pipe: **Pipe** specially designed for use with an **IJS**.

Interjack station: A contraction for **intermediate jacking station (IJS)**.

Intermediate jacking method: **Pipe jacking** method to redistribute the **jacking force** by the use of an **IJS**.

Intermediate jacking station (IJS): A steel cylinder, fitted with hydraulic jacks, that is incorporated into a pipeline between two **pipe** segments. Its function is to distribute the **jacking** load over the pipe string on long drives.

Inversion: The process of turning a **fabric** tube inside out with water or air pressure as is done during installation of many types of **CIPP**.

Jacking: A synonym for **pipe jacking**.

Jacking force: Force applied to **pipes** in a **pipe jacking** operation.

Jacking frame: A structural component that houses the hydraulic cylinders used to propel the **microtunneling** machine and pipeline. The jacking frame serves to distribute the thrust load to the pipeline and the reaction load to the **shaft** wall or thrust wall.

Jacking pipe: **Pipe** designed to be installed using **pipe jacking** techniques.

Jacking pit: The excavation that the machinery is set into to install a **casing** or **tunnel**, formerly known as a glory hole.

Jacking shaft: Excavation from which TT equipment is launched for the installation or **renovation** of a pipeline, conduit, or cable. It may incorporate a thrust wall to spread reaction loads to the ground.

Jacking shield: A steel cylinder from within which the excavation is carried out either by hand or machine. Incorporated within the **shield** are facilities to allow it to be adjusted to control **line** and grade.

Jacking station: A synonym for **IJS**.

Jet cutting (jetting): (1) A type of **directional drilling** or **guided boring** technique using pressurized **fluid jets** to provide the soil-cutting action; (2) a process using high-pressure water to wash out the **face** of a utility **crossing** without any mechanical or hand excavation of the soil in the face; (3) a process to remove material in open-pit mining.

Joint: The means of connecting sectional lengths of utility **pipe** into a continuous utility pipeline using various types of jointing materials. The number of joints depends on the lengths of the pipe sections used in the specific construction work.

Joint sealing: Method in which an inflatable **packer** is inserted into a pipeline to span a leaking **joint**, followed by the injection of **resin** or **grout**, until the joint is closed (and the packer removed).

Keeper: A synonym for **hold down**.

Launch pit: Sometimes referred to by the generic term **drive pit**, a launch pit is usually associated with "launching" an **impact moling** tool.

Launch seal: A mechanical seal, usually comprised of a rubber flange that is mounted to the wall of the **drive shaft**. The flange seal is distended by the **MTBM** as it passes through, creating a seal to prevent water or lubrication inflow into the **shaft** during **tunneling** operations.

Lead pipe: The leading **pipe** designed to fit the rear of a **jacking shield**, and over which the trailing end of the **shield** is fitted.

Line: (1) The specified direction of the proposed **bore** in a horizontal plane; (2) the shortest distance between two points for the installation of pipelines, usually as laid out by a survey crew.

Liner plate: A proprietary product that comes in formed steel segments and used as an alternative to **casing**. The segments are bolted together from inside the **tunnel** to form a structural tube that protects the tunnel from collapse.

Lining: (1) A process where a length of material is introduced to extend the life of the existing **pipe**. Lining may enhance the structural support of the existing pipe (**renovation**), or may independently provide complete structural support (**rehabilitation**). (2) An internal, non-structural coating applied to a pipe.

Lining with close-fit pipes: Method of **lining with continuous pipe** for which the cross-section is reduced to facilitate installation, and reverted after installation to provide a **close fit** to the existing **pipe**.

Lining with continuous pipe: Method of **lining** with a **pipe** made continuous for the length of the section to be renovated before insertion, and which has not been shaped to give a cross-sectional diameter smaller than its final diameter after installation.

Lining with cured-in-place pipes (CIPP): Method of **lining** with a flexible tube, usually impregnated with a thermosetting resin, which produces a structural **pipe** after curing by pressure and/or heat.

Lining with discrete pipes: Method of **lining** with **pipes**: (1) that are shorter than the section to be renovated; (2) which are not jointed before insertion to form a continuous pipe; and (3) which have not been shaped to give them a cross-sectional diameter smaller than their final diameter after installation.

Lining with inserted hose: Method of **lining** with a loose-fitting reinforced hose to provide a **pipe** lining such that fluids may be conveyed under pressure.

Lining with pipe segments: Method of **lining** with **pipe** sections made of at least two pieces with both longitudinal and circumferential **joints**.

Lining with spirally wound pipes: A synonym for **spiral lining**.

Lipping: A degree of overlap between adjacent units.

Live insertion: Installation of a liner while the **product pipe** remains in service.

Localized repair: A synonym for **spot repair**.

Locator: An electronic instrument, sometimes called a walkover system, used to determine the position and strength of electro-magnetic signals emitted from: (1) a radio transmitter in the pilot head of a **boring** system; (2) an **impact moling** tool; or (3) an existing underground service which has been energized.

Male hex connector: A synonym for **shank**.

Man-accessible: A synonym for **person-accessible**.

Man-entry: A synonym for **Person-entry**.

Manual mechanical shield: Open **shield** in which manpower is used to excavate the material but which has some steering capability.

Master track: The rear-most **track** section.

Measurement while drilling (MWD): Borehole survey instrumentation that provides continuous information simultaneously with drilling operations, usually transmitting to a display at or near the drilling rig.

Mechanical cleaning: Methods used to clean pipelines of debris with devices such as rodding machines, bucket machines, or **winch**-pulled brushes.

Mechanical props repair: See **rerounding**.

Microtunnel boring machine (MTBM): A machine that excavates by **microtunneling**.

Microtunneling: A TT method for installing pipelines. Microtunneling uses all of the following features during construction:

- Remote Controlled. The **MTBM** is operated from a control panel, normally located on the surface. The system simultaneously installs **pipe** as **spoil** is excavated and removed. Personnel entry is not required for routine operation.
- Guided. The **guidance system** usually references a laser beam projected onto a target in the MTBM, capable of installing gravity sewers or other types of pipelines to the required tolerance for **line** and grade.
- **Pipe Jacked**. The process of constructing a pipeline is completed by consecutively pushing pipes and MTBM through the ground using a **jacking** system for thrust.
- Continuously Supported. Continuous pressure is provided to the **face** of the excavation to balance groundwater and earth pressures.

Midi-rig: Steerable surface-launched equipment for the installation of **pipes**, conduits and cables. Applied to intermediate-sized drilling rigs used as either a small **directional drilling** machine or a large **guided boring** machine. Tracking of the **drill string** may be achieved by either a downhole **survey tool** or a **locator**.

Mini-horizontal directional drilling (mini-HDD): A synonym for **guided boring**.

Mixed face: A soil condition that presents two or more different types of material in the path of the **bore**.

Modified sliplining: A range of techniques in which the liner is reduced in cross-sectional diameter before insertion into the **carrier pipe**. It is subsequently restored to close to its original diameter, usually forming a close fit with the original **pipe**. Methods of cross-sectional area reduction include squeezing, folding into a U-shape, or stretching. See also **lining with close-fit pipes**.

Mole: A device used for **impact moling**.

Mole ploughing: (1) Burying a pipeline by pulling a plough through the ground while a continuous length of **pipe** is fed into the top of the plough and laid out underground from the tail of the plough; (2) using a plough blade with a **bullet** at the end to create a **tunnel** beneath the surface into which a pipe may be pulled.

Moling: A minimum excavation procedure for the construction of pipelines. See also **impact moling**.

MTBM: See **microtunnel boring machine.**

Muck: (1) As a noun, muck is a synonym for **spoil**; (2) as a verb, “muck” means “to dig,” as in "muck out the hole."

MWD: See **measurement while drilling.**

Nominal size: Size of **pipe** or **shaft** used to define the internal working diameter.

Non-man entry: A synonym for **non-person entry**.

Non-person entry: Size of **pipe**, **duct**, or **bore** less than suitable for **person-entry**.

Obstruction: Any object or feature that lies completely or partially within the cross-section of the **microtunnel** and prevents continued forward progress.

Open face shield: **Shield** in which manual excavation is carried out from within a steel tube at the front of a **pipe jack**.

Operator presence control: A control or mechanism designed so that operator presence is necessary to activate a specific function.

Ovality: (1) The difference between the maximum and mean diameter divided by the mean diameter. (2) The difference between the mean and minimum diameter divided by the mean. Ovality may be measured at any one cross-section of a **pipe** and is usually expressed as a percentage.

Overcut: The **annulus** between the excavated hole and the outside diameter of the **jacking pipe**.

Packer: A synonym for **compression ring**.

PE: See **polyethylene**.

Person-accessible: A **pipe** or excavation that can be physically entered by an operator.

Person-entry: Describes any TT process that requires a person to enter a **pipe**, **duct**, or **bore**. OSHA has no minimum size limit for person-entry; however, they address a much broader concept of "confined space" in 29 CFR Part 1910.146.

Piercing tool: A compacting device for creating a **tunnel** without removing **spoil**.

Pilot bore: The action of creating the first (usually steerable) pass of a **boring** process, which later requires a **back reamer** (or other enlargement). Pilot bores are used in **guided boring**, **directional drilling**, and two-pass **microtunneling** systems.

Pilot tube method: A multi-stage method of accurately installing a **product pipe** using a guided pilot tube, followed by **upsizing** to complete the installation.

Pins: Devices used to couple a **shank** with a **box connector**.

Pipe: A long tube of clay, concrete, steel, metal, or wood for conveying water, gas, oil, electrical wires, or communications.

Pipe bursting (pipebursting): A **rehabilitation** technique that breaks the existing **pipe** by brittle fracture, using mechanical force applied from within, and forces the remains of the pipe into the surrounding ground. At the same time, a new pipe, of the same or larger diameter, is drawn in behind the bursting tool. Pipe bursting may be done with an **impact moling** tool that exerts diverted forward thrust into the radial bursting effect, or it may be done with a hydraulic device that is inserted into the pipe and expanded to exert direct radial force.

Pipe cracking: A synonym for **pipe bursting**.

Pipe displacement: A synonym for **pipe bursting**.

Pipe eating: A **replacement** technique, usually using an **MTBM,** in which a defective **pipe** is excavated together with the surrounding soil as if for a new installation. The **microtunneling shield** machine usually needs some crushing capability to perform effectively. The defective pipe is sometimes filled with **grout** to improve steering performance. Alternatively, some systems employ a proboscis device to seal the pipe in front of the shield to collect and divert the existing flow (thus allowing a sewer, for example, to remain "live").

Pipe jacking: (1) A system of directly installing **pipes** behind a **shield** machine using hydraulic, mechanical, or air jacks to push the pipes so that they form a continuous string in the ground; (2) a generic term used either for pipe pushing, or for **pipe pullback**; (3) a term sometimes used (improperly) in a generic fashion to refer to any or all TT methods.

Pipe joint sealing: A synonym for **joint sealing**.

Pipe pullback: A **pipe jacking** method in which **pipe** is pulled by the jack into an open borehole, rather than being pushed by the jack.

Pipe pulling: (1) Traditionally, a method of replacing small diameter **pipes** in which a new **product pipe** is attached to the existing pipe that is then pulled out of the ground (as the new pipe is pulled into the ground); (2) pipe pulling is sometimes used as a synonym for **pipe pullback**.

Pipe pusher: A machine that pushes (or sometimes pulls) a **rod** or closed **pipe** to produce a **bore** by means of compaction without rotation or **impact**.

Pipe ramming: (1) A non-steerable system that forms a **bore** by driving an open-ended steel **casing** using a percussive hammer from a **drive pit**. The soil may be removed from the casing by auguring, **jetting**, or compressed air. (2) Any TT utilizing a horizontally mounted pile driver.

Pipe splitting: A synonym for **pipe bursting**.

Plastic: Any of a variety of thermoplastic and thermoset material used in pipeline construction (e.g., **HDPE**, **PP**, **PVC**, **GRP**, polyester felt reinforced **pipe**, epoxy and polyester mortars).

Point source repair: See **spot repair**.

Pointing: A method of repairing a brick sewer or manhole by the applying cement mortar where loss has occurred.

Polyethylene (PE): A form of thermoplastic **pipe**.

Polyolefin: A family of **plastic** material used to make **pipes**.

Polypropylene (PP): A type of **plastic pipe** from the **polyolefin** family.

Polyvinyl chloride (PVC): A form of thermoplastic **pipe**.

Potholing: Digging a hole to locate a utility.

Power package: (1) The engine and drive section of a **split-design boring machine**; (2) the remote engine and hydraulic pumps of a power unit.

PP: See **polypropylene.**

PRC: An acronym for polyester resin concrete.

Primary pipe: The basic or primary **pipe** that must meet the fit-for-use criteria. When a pipe section undergoes **rehabilitation** with a structural, monolithic liner, then the liner becomes the primary pipe and subsequent inspection and evaluation is performed with respect to the liner.

Product pipe: (1) Permanent pipeline for operational use; (2) **pipe** for conveyance of water, gas, sewage, and other products.

Pullback (Pull back): That part of a **guided boring** or **directional drilling** operation in which the **drill string** is pulled back through the **bore** to the **entrance pit** or surface rig, usually installing the **product pipe** at the same time.

Pullback force: The tensile load applied to a **drill string** during the **pullback** process. **Guided boring** and **directional drilling** rigs are usually rated by their maximum pullback force.

Pull-in piping: A synonym for **insert renewal**.

Push bar/block: A synonym for **thrust block**.

PVC: See **polyvinyl chloride**.

Ramming: A synonym for **pipe ramming**.

Receiving pit: (1) An opening in the earth located at the expected exit of a **cutting head** or **casing**; (2) the pit that is dug at the end of the **bore**, opposite the **jacking pit**.

Receiving shaft: Excavation into which TT equipment is driven and recovered following installation of the **product pipe**, conduit, or cable.

Rehabilitation: (1) Methods for restoring the performance of an existing pipeline system in which the existing pipeline is not counted on for structural support after the upgrade; (2) the term is also used generically to include **renovation**, and would then be defined as any *in situ* procedure that incorporates the original **pipe fabric** and improves the performance or extends the life of the pipe (excluding routine maintenance such as cleanout).

Reinforced plastic mortar (RPM): A form of thermoset **plastic pipe** within the **GRP** family.

Reinforced thermosetting resin (RTR): A form of thermoset **plastic pipe** within the **GRP** family.

Remote control system: A remote control system monitors and controls the MBTM, the automated transport system, and the **guidance system** from a location not inside the **MTBM**.

Renovation: (1) Methods of *in situ* **repair** which improve performance and/or extend the life of a **pipe** by incorporating the original **fabric** of the pipeline into the upgraded system; (2) renovation is sometimes used generically to include **rehabilitation**, in which case it is defined as any *in situ* repair that improves the performance or extends the life of a pipe.

Repair: Rectification of damage to the structural **fabric** of the **pipe**, or the reconstruction of short lengths but not the reconstruction of a whole pipeline.

Replacement: Construction of a new pipeline, on or off the **line** of an existing pipeline. The function of the new pipeline will incorporate that of the old, but may also include other improvements or development work.

Rerounding: A preparatory process that involves the insertion of an expansion device into a distorted **pipe** to return it to a circular cross-section. This is usually carried out before inserting the permanent liner or supporting band.

Resin: An organic solid or liquid polymer, typically thermoplastic or thermosetting.

Resin impregnation (wet-out): A process used in **CIPP** installation where a plastic-coated **fabric** tube is uniformly saturated with a liquid **thermosetting resin** while air is removed from the coated tube by means of vacuum suction.

Resin injection: The **localized repair** of **pipes**, usually sewers, by injection of a resin formulation into cracks or cavities that subsequently cures to prevent leakage and further deterioration. It may also increase the structural strength of the pipeline.

Retract: Move the machine away from the **face** of the **entrance pit**.

Robot: Remote control device with **CCTV** monitoring, used mainly in **localized repair** work, such as cutting away **obstructions**, re-opening lateral connections, grinding and re-filling defective areas, and injecting **resin** into cracks and cavities.

Rod: (1) Connection between the drilling machine and the **cutting head**, when a continuous **auger** is not being used; (2) flexible pole for removing blockages in pipelines, typically made of fiberglass or wood; (3) graduated measuring device for estimating internal **pipe** dimensions.

Rod pushing: A synonym for **thrust boring**.

Roller cone bit/reamer: A **bit** or reamer used for rock **boring**, in which the teeth rotate on separate internal shafts that are usually aligned perpendicular to the cutting line.

Rotary rod machine: A machine used to drill earth horizontally by means of a **cutting head** attached to a rotating **rod** (not an **auger**). Such drilling may include fluid injected to the cutting head through a hollow rod.

Rotation controls: Control the direction and/or the rotation of the tool.

RPM: See **reinforced plastic mortar**.

RTR: See **reinforced thermosetting resin**.

Saddle: A vertical support mechanism to hold the **casing** in position while starting (**collaring**) the **bore**.

SDR: See **standard dimension ratio**.

Segmental concrete tunnel liner: Used the same way as **liner plate** except that they are **tunnel** liners made of concrete.

Segmental lining: The use of prefabricated segments in **person-entry** work to form a new **lining** within a defective **pipe**. The segments are usually sealed at the **joints** and the **annulus** filled by **grouting**.

Segmental sliplining: Insertion of a string of discrete **pipes** by pulling segments into the existing pipe and **grouting** the **annulus**.

Shaft: A pit or wall sunk from the ground surface into a **tunnel** for the purpose of furnishing ventilation or access to the tunnel.

Shank: A hardened bar, sometimes called a **male hex connector**, containing one or more transverse holes, which fits into and couples with a **box connector**.

Shield: A steel cylinder at the **face** of a utility **tunnel** or **casing** which may sometimes employ the use of a mechanical excavator, may be steerable, and may provide hazard protection from the area covered.

Shield tunneling method: Method of excavation in the front of a **tunnel** or **pipe jack** using a **shield**.

Shotcrete: A synonym for **gunite**.

Skin friction: Resistance to thrust caused by soil pressure around the **casing**.

Sleeve pipe: A **pipe** installed as external protection for a **product pipe**.

Sliplining: (1) General term to describe the insertion of one **pipe** inside an existing pipe; (2) general term used to describe methods of **lining with continuous pipes** and/or **lining with discrete pipes**; (3) insertion of a continuous new pipe by pulling or pushing it into the existing pipe and **grouting** the **annulus**; (4) insertion of a string of discrete pipes by pulling segments into the existing pipe and grouting the annulus (also known as **segmental sliplining**).

Slurry: A fluid, normally water, used in a closed loop system for the removal of **spoil** and for the balance of groundwater pressure during **microtunneling**.

Slurry chamber: Located behind the **cutting head** of a slurry **microtunneling** machine. Excavated material is mixed with **slurry** in the chamber for transport to the surface.

Slurry line: A series of hoses or **pipes** that transport **tunnel muck** and **slurry** from the face of a slurry **microtunneling** machine to the ground surface for separation.

Slurry separation: A process where excavated material is separated from the circulation **slurry**.

Slurry shield method: Method using a mechanical **tunneling shield** with **closed face** that employs hydraulic means for removing the excavated material and balances the ground water pressure.

Socket: A synonym for **box connector**.

Sonde: A type of radio sending unit.

Sonde housing: This integral unit is the direction drill head that houses the radio sending unit.

Spacer: A synonym for **compression ring**.

Spacer block: A device used to extend the distance that a hydraulic ram can propel a pipeline.

Speed controls: Those controls that control the speed of the engine, rotation and travel of the tool, and forward or lateral movement of the machine.

Spiral lining: A technique in which a ribbed plastic strip is spirally wound by a winding machine to form a liner that is inserted into a defective pipeline. The **annulus** may be filled by **grouting** or the spiral liner expanded to reduce the annulus and form a **Close-**

Fit liner. In larger diameters, the strips are sometimes formed into panels and installed by hand. Grouting the annulus after installation is recommended.

Spiral weld pipe/casing: **Pipe** made from coils of steel plate by wrapping around a mandrill (i.e., steel shaft) in such a manner that the welds are a spiral helix.

Split-design boring machine: A **boring machine** having the capability of being broken down into two or more elements to reduce the lifting weight.

Spoil: (1) Earth, rock and other materials displaced by a **tunnel** or **casing**, and removed before or as the tunnel or casing is installed; (2) a generic term for material that has no further use.

Spoil ejector: A set of paddles, rotating in close proximity to the inside of the **casing pusher**, which facilitate the removal of **spoil**.

Spoil ejector door: A door that partially or completely closes the **spoil** removal opening when at rest.

Spot repair: **Repair** work on a **pipe**, to an extent less than the run between two access points.

Spray lining: A technique for applying a **lining** of cement mortar or **resin** by rotating a spray head that is pulled through the pipeline by a **winch**.

Spun lining: A bituminous **lining** in a **pipe**, made smooth or uniform by spinning the pipe around its axis.

SRPC: See **sulfate resisting portland cement**.

Stakedown plate: A plate staked to the ground to stabilize the forward end of the drill rack.

Standard dimension ratio (SDR): The ratio of outside **pipe** diameter to wall thickness.

Steerable moling: Method similar to **impact moling**, but with a limited steering capability.

Steering head: A moveable lead section of **casing** that can be adjusted to steer the **bore**.

Stringing: The process by which a line is floated through a **pipe** segment for later use to pull a cable for video inspection or cleaning equipment.

Sulfate resisting portland cement (SRPC): A cement customarily used for making concrete, mortar, and **grout** in aggressive conditions where sulfate concentrations may be high.

Sump: A depression in the pit to allow for the collection of water and the installation of a pump for water removal.

Survey tools: Downhole equipment and instruments used to determine the position of a **bore** in **directional drilling**.

Swab: A synonym for **bull plug**.

Swageing: The reduction in diameter of a **PE pipe** by passing it through one or more dies. The die may be heated if necessary.

Swagelining: A method of **sliplining** whereby the diameter of the **PE pipe** is temporarily reduced by **swageing** before inserting it into the defective pipe. After insertion, the pipe is expanded by means of steam or a **rerounding** device.

Swivel pulling: Used to attach service (to be pulled into drilled hole) to drill **pipe**.

Target shaft/pit: A synonym for **receiving pit**.

TBM: See **tunnel boring machine**.

Thermography: The recording of temperature variations to assist in the detection of **voids** around pipelines.

Threading: The process of installing a slightly smaller **pipe** or arch within a failing drainage structure.

Thrust: Force applied to a pipeline or **drill string** to propel it through the ground.

Thrust block: A manual or remote-operated locking mechanism that engages stations in the **track** to provide a thrusting base for the machine to **advance** and **retract**.

Thrust boring: (1) A compaction method for forming a **pilot bore** that drives a closed **pipe** or head from a thrust pit through the soil. Some small-diameter models have steering capability achieved by a slanted pilot-head face and electronic monitoring. **Back reaming** may be used to enlarge the pilot bore. (2) Used generically to describe various TT methods.

Thrust jacking: A synonym for **thrust boring**.

Thrust ring: A ring mounted on the face of the **jacking frame** and intended to transfer the **jacking** load from the jacking frame to the thrust-bearing area of the **pipe** section being jacked.

Thrust/travel controls: Those controls that control the **advance** and **retraction** of the tool.

Tile: A synonym for **VCT**.

Torque: The rotary force available at the **drive chuck**.

Torque limiter: A rotary slip clutch used to protect the **final drive**.

Track: A set of longitudinal rails mounted on **cross members** that support and guide a **boring machine**.

Track brake: A mechanical device to provide a limited resistance to movement between the machine and the **track**.

Track pins: Steel pins to be driven through holes in the **track** into the base of the pit.

Trailing tube: See **can.**

Transportation system: The mechanism for moving the excavated **spoil** from the **tunnel face** to the surface.

Trench box: A preconstructed set of side plates and adjustable **cross members** to prevent the walls of the pit from collapsing.

Trenchless technology (TT): Techniques for **pipe** (usually utility lines) installation, **replacement**, **rehabilitation**, **renovation**, inspection, location, and leak detection, with minimum excavation from the ground surface.

Tunnel: An underground conduit, often deep and expensive to construct, which provides conveyance and/or storage volume for water, gas, oil, electrical wires, or communications.

Tunnel boring machine (TBM): A full-face circular mechanized **shield** machine, usually of **person-entry** diameter, steerable and with a rotary **cutting head**. For **pipe** installation it usually leads a string of jacked pipes. It is usually controlled from within the shield, but some TBMs may be controlled remotely.

Tunneling: A construction method of excavating an opening beneath the ground without continually disturbing the ground surface, such that the opening diameter is large enough to allow **person-entry** and erection of a ground support system at the location of material excavation.

Tunneling head: A mechanical excavator used in a **tunnel** to excavate the front **face** of the tunnel.

Uncased bore: Any **bore** that has no **lining** or **pipe** inserted, whether temporary or permanent (i.e., a bore that is "self-supporting").

Upset: The inadvertent action of a **boring machine** that rotates the machine and **track** from its normal and upright position to another position.

Upsizing: Any method that increases the cross-sectional area of an existing pipeline by replacing with a larger diameter **pipe**.

Utility corridor (utilidor): **Duct** in which two or more different utility services are installed with access for maintenance.

Vitrified clay pipe (VCP): A term used to describe **pipe** manufactured from fired hydrous alumina silicate clay.

Vitrified clay tile (VCT): A term used to describe products (both **pipe** and block) manufactured from fired hydrous alumina silicate clay.

Voids: (1) Holes on the outside of the **pipe** in the surrounding soil or material; (2) a term usually applied to paint to describe **holidays**, holes, and skips in the film; (3) shrinkage in castings or welds.

Volume: The amount of **drilling fluid** flow.

Walkover system: A synonym for **locator**.

Washover pipe: (1) A rotating drill **pipe** of larger diameter than the pilot drill pipe and placed around it, with its leading edge less far advanced; (2) in **directional drilling**, its purpose is to provide stiffness to the drilling pipe to maintain steering control over long bores, to reduce friction between the **drill string** and the soil, and to facilitate mud circulation.

Waste ejector: A synonym for **spoil ejector**.

Water jetting: (1) Method for the internal **cleaning** of pipelines using high-pressure water jets; (2) method for installing **pipe** using a spray head to open the horizontal installation hole (mainly used in sandy soils).

Wet-out: See **resin impregnation.**

Winch: A mechanical device used to pull **CCTV** cameras or **cleaning** tools through a **pipe**.

Wing cutters: Appendages on a **cutting head** that will open to increase the cutting diameter of the head when turned in a forward direction, and close when turned in a reverse direction. They are used to cut clearance for the **casing pipe**.

Wrapped casing: A coating on **pipe** for protection from corrosion, usually composed of asphalt and asphalt-coated paper. Some coatings may contain **plastic**, fiberglass, coal tar, or other materials.

TT METHODS

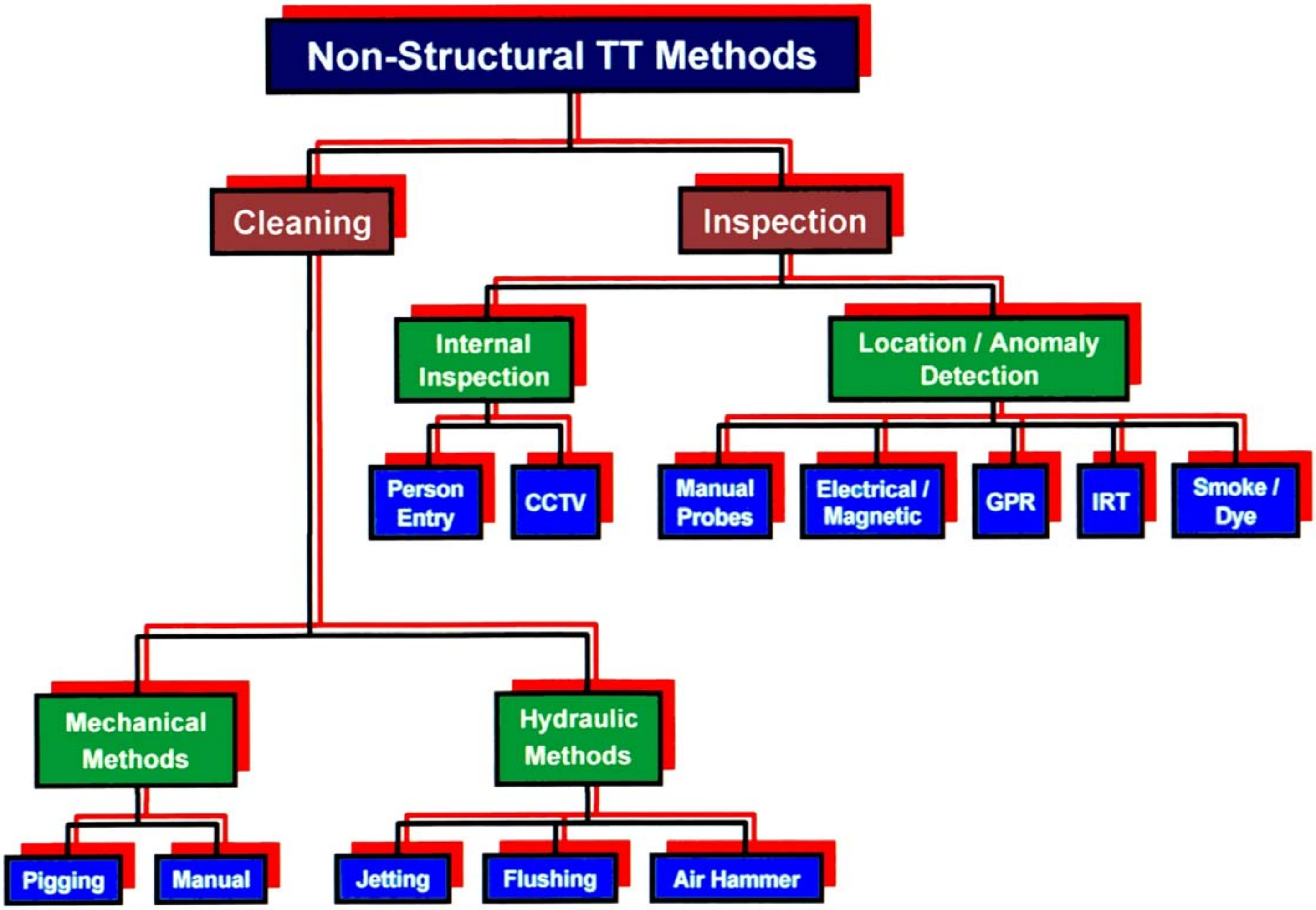

Figure A2.1. Non-structural TT Methods

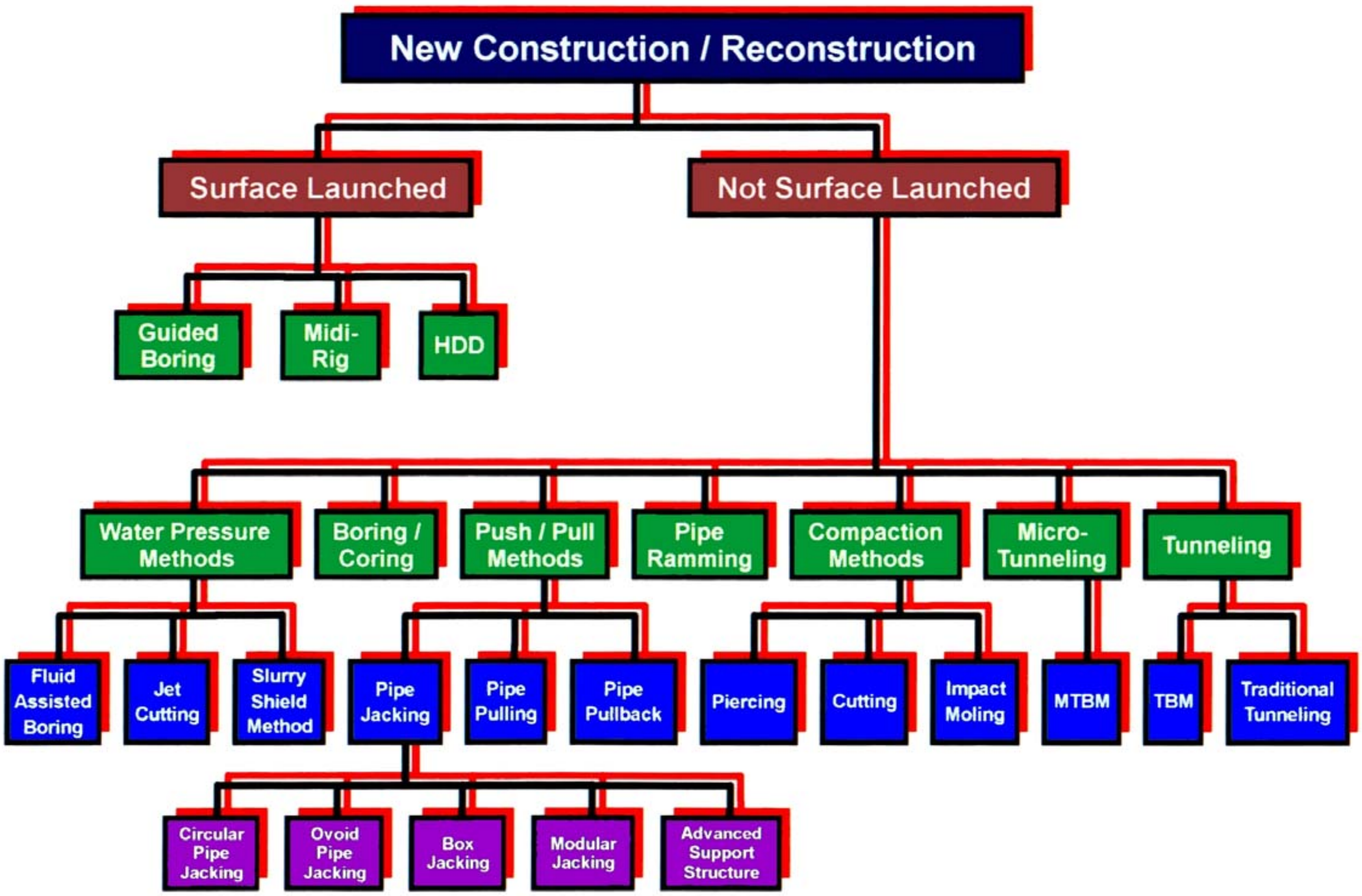

Figure A2.2. New Construction/Reconstruction Methods

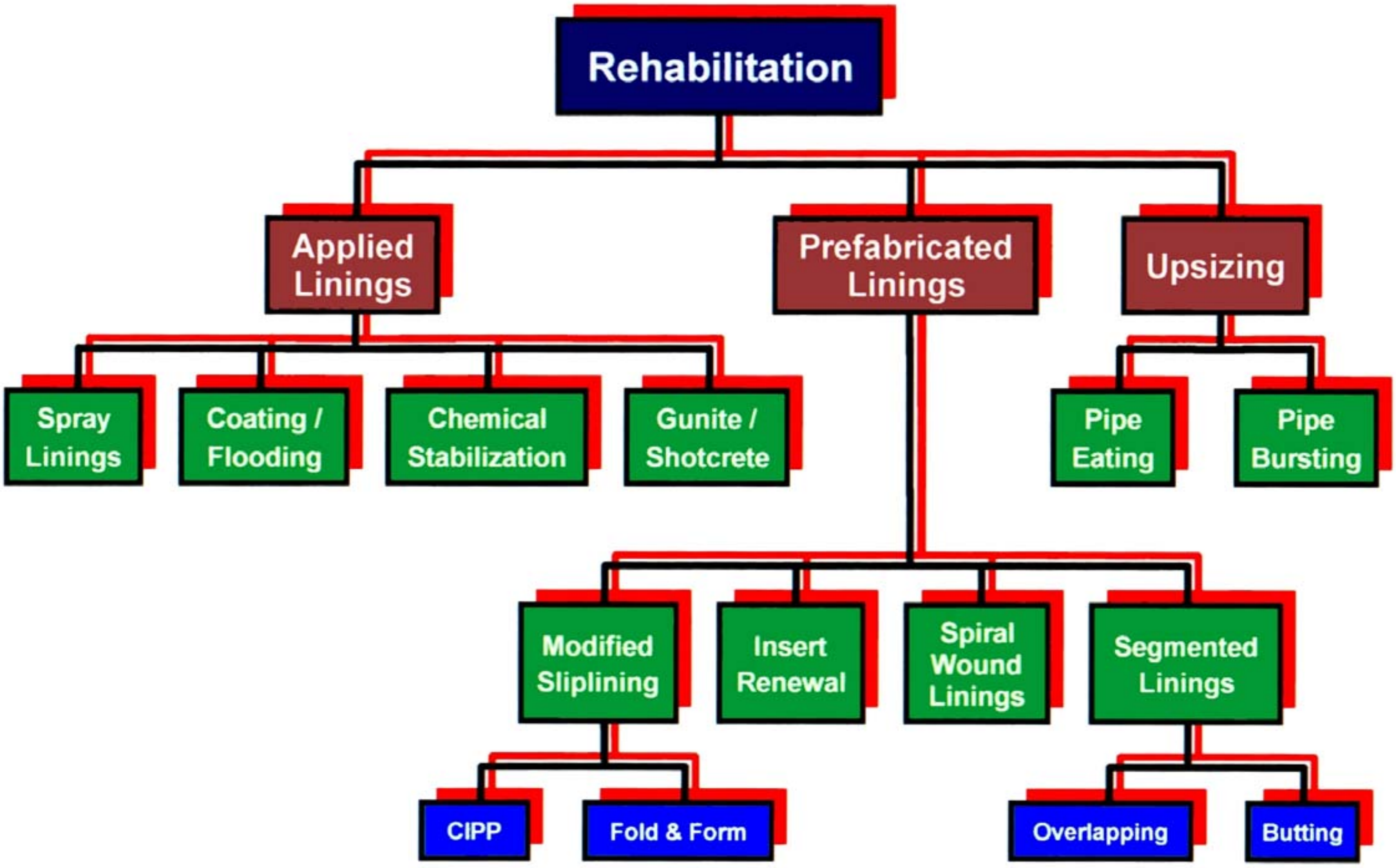

Figure A2.3. Rehabilitation Methods

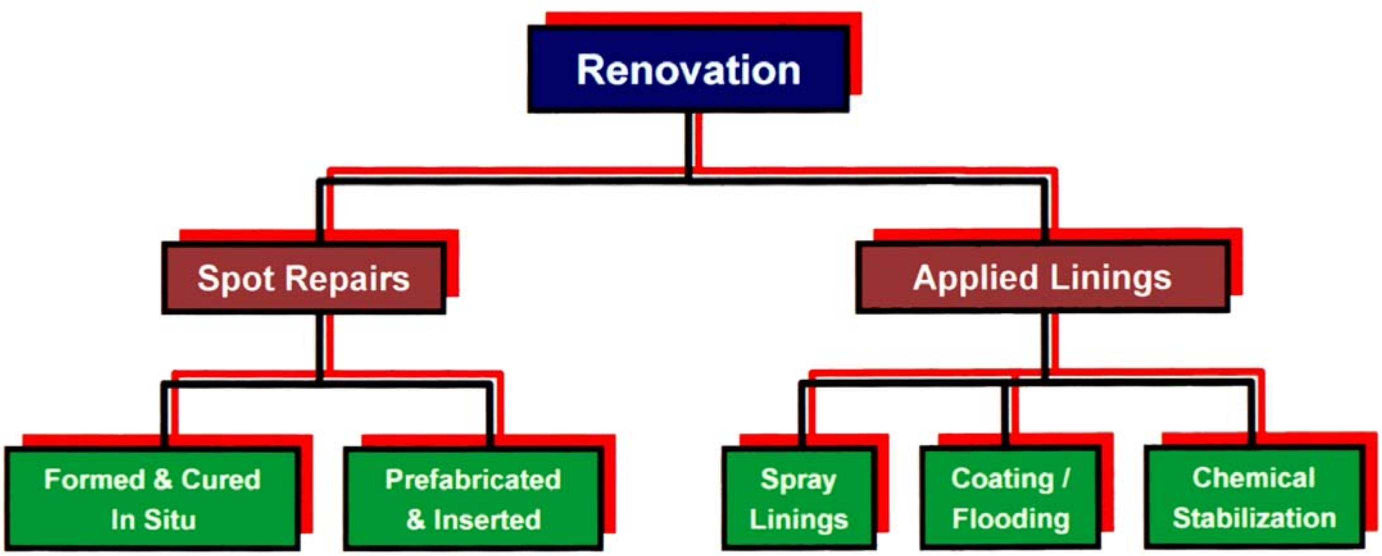

Figure A2.4. Renovation Methods

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