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6 June 2019

TRI-SERVICE PAVEMENTS WORKING GROUP (TSPWG) MANUAL

TRENCHLESS TECHNOLOGY (TT) FOR CROSSING PAVEMENTS

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TRENCHLESS TECHNOLOGY (TT) FOR CROSSING PAVEMENTS

Indicate the preparing activity beside the Service responsible for preparing the document.

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This TSPWG M supersedes Air Force ETL 04-4, *Trenchless Technology (TT) for Crossing Air Force Pavements*, dated 31 March 2004.

FOREWORD

This Tri-Service Pavements Working Group Manual supplements guidance found in other Unified Facilities Criteria, Unified Facilities Guide Specifications, Defense Logistics Agency Specifications, and Service-specific publications. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and, in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the TSPWG Manual, the SOFA, the HNFA, and the BIA, as applicable. This manual 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. The information in this TSPWG Manual is referenced in technical publications found on the Whole Building Design Guide. It is not intended to take the place of Service-specific doctrine, technical orders (T.O.), field manuals, technical manuals, handbooks, Tactics, Techniques, and Procedures (TTP), or contract specifications, but should be used along with these to help ensure pavements meet mission requirements.

TSPWG Manuals are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction, maintenance, repair, or operations. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and the Air Force Civil Engineer Center (AFCEC) are responsible for administration of this document. Technical content of this TSPWG Manual is the responsibility of the Tri-Service Pavements Working Group (TSPWG). Defense agencies should contact the preparing activity for document interpretation. Send recommended changes with supporting rationale to the respective Service TSPWG member.

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- Whole Building Design Guide website: http://dod.wbdg.org/

TRI-SERVICE PAVEMENTS WORKING GROUP MANUAL (TSPWG M)
NEW SUMMARY SHEET

Document: TSPWG Manual 3-260-02.04-4, *Trenchless Technology (TT) for Crossing Pavements*

Superseding: Air Force ETL 04-4, *Trenchless Technology (TT) for Crossing Air Force Pavements*, dated 31 March 2004

Description: This TSPWG 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 pavements, including runways, taxiways, aprons, overruns, and roadways.

Reasons for Document: This TSPWG M provides designers and maintenance personnel with materials and methods for the use of TT.

Impact: There will be minimal cost impacts that are offset by the overall lifecycle cost.

Unification Issues: There are no unification issues.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This TSPWG M 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 pavements, including runways, taxiways, aprons, overruns, and roadways.

1-2 APPLICABILITY.

This TSPWG M is applicable to all DOD 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 a runway, taxiway, apron, overrun, or roadway. When considering the use of TT, seek input/guidance from the Pavements Discipline Working Group (DWG) or their designated representative and the appropriate functional engineer for the system involved.

Intended users include the following:

- All pavement engineers, utility system engineers, and fuel system engineers
- Design engineers and others responsible for constructing, reconstructing, rehabilitating, and renovating facilities (including, but not limited to, underground pipelines, utilities, fuel hydrant lines, and communication lines) or for cleaning, inspecting, locating, and detecting anomalies around underground pipelines, utilities, fuel hydrant lines, and communication lines
- Air Force, Army, and Navy offices responsible for constructing, reconstructing, rehabilitating, and renovating facilities or cleaning, inspecting, locating, and detecting anomalies around underground pipelines, utilities, fuel hydrant lines, or communication lines

1-3 GLOSSARY.

Appendix B contains acronyms, abbreviations, and terms.

A glossary of TT terminology from the North American Society for Trenchless Technology (NASTT) is included in Appendix B. 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.

1-4 REFERENCES.

Appendix C contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 TRENCHLESS TECHNOLOGY: MATERIALS AND METHODS

2-1 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.glsla.ca/about-us for a historical overview of TT.

2-2 CONSIDERATIONS.

TT is viewed as an alternative construction methodology. Consider system characteristics, constructability, site conditions, and cost when deciding whether to use TT. Evaluate each opportunity to utilize TT on a case-by-case basis.

2-2.1 System Characteristics.

While TT is ideal for straight-through runs of pipe, it is less well-suited for projects with such characteristics 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.

2-2.2 Site Conditions.

Consider 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) 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.

2-2.3 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.

2-2.4 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.

2-3 ADVANTAGES.

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:

2-3.1 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.

2-3.2 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

2-3.3 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.

2-3.4 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 (e.g., away from the main runways and taxiways).

2-3.5 Dewatering.

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

2-3.6 Safety.

TT is safer than conventional trench excavation for several reasons:

2-3.6.1 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.

2-3.6.2 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.

2-3.7 Environmental Impact.

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

2-3.8 Replacement of Excavated Materials.

Open trenches across a 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.

2-3.9 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.

2-3.10 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.

2-4 APPLICABILITY OF SPECIFIC TT METHODS.

No single TT method is best for all cases and applicability is contingent upon specific conditions.

2-4.1 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 six 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.*

2-4.2 Time/Mission Disruption.

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

2-4.2.1 Equipment Availability.

Equipment availability is a key issue in the use of TT for pavement crossings. Unlike DOTs (with local jurisdiction), DOD 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.

2-4.2.2 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.

2-4.2.3 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, ensure there is 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.

2-4.2.4 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, ensure a TT contractor for a pavement crossing has adequate training and experience to ensure a safe and satisfactory result and any TT equipment operator has been properly and specifically trained on the TT equipment that will be used by that operator.

2-4.2.5 Use of Sleeves.

For any pressurized utility or fuel line crossing under an active 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, ensure the sleeve system has adequate venting to maintain integrity and safety at all times, specifically in 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) center the carrier pipe in the sleeve using non-metallic devices and (2) fill the annular space with clean, non-corrosive fill material to allow cathodic protection current to reach the entire surface of the carrier pipe. Consult a corrosion control specialist certified by the National Association of Corrosion Engineers (NACE) when designing such work.

2-5 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.

2-6 TT TYPES.

Appendix A 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, including pipeline location and anomaly detection).

2-6.1 New Construction or Reconstruction.

Construction methods may be categorized as either surface-launched or non-surface-launched.

2-6.1.1 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.

2-6.1.1.1 Guided Boring.

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.

2-6.1.1.2 Horizontal Directional Drilling (HDD).

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.

2-6.1.1.3 Midi Rig.

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 2-6.1.1.1) and HDD (paragraph 2-6.1.1.2).

2-6.1.2 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.

2-6.1.2.1 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.

2-6.1.2.2 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.

2-6.1.2.2.1 “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 TSPWG M explains and categorizes pipe jacking methods, be aware that the term “pipe jacking” can have widely differing meanings depending on the source (see paragraphs 2-6.1.2.3 and 2-6.1.2.4). 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.

2-6.1.2.2.2 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 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 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.

2-6.1.2.2.3 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 stabilized with fluid (e.g., driller's mud).

2-6.1.2.2.4 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.

2-6.1.2.2.5 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.

2-6.1.2.3 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 2-6.1.2.4). The use of auger-like cutting heads that both dislodge and compact the soil is often referred to as the rotary method or “cutting.”

2-6.1.2.4 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).

2-6.1.2.5 Water Pressure.

2-6.1.2.5.1 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.

2-6.1.2.5.2 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 2-6.4.1.1.3).

2-6.1.2.5.3 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.

2-6.1.2.6 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.

2-6.1.2.7 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 2-6.1.2.2.2).

2-6.2 Renovation.

In this TSPWG M, 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 TSPWG M 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 TSPWG M, 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 service control point for all Defense Logistics Agency (DLA) fuel-related support issues, such as the Air Force Petroleum Office (AFPET).

2-6.2.1 Spot Repairs.

Spot repairs are usually both formed and cured *in situ* or prefabricated and inserted.

2-6.2.1.1 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).

2-6.2.1.2 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.

2-6.2.1.2.1 Cured-in-place Repairs.

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

2-6.2.1.2.2 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 has prohibitively high costs. The description of sophisticated robotic repairs is beyond the scope of this TSPWG M, 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.

2-6.2.2 Applied Linings.

Grouts, glues, polymers, or other exotic materials 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 2-6.4.1.2.1) 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.

2-6.3 Rehabilitation.

In this TSPWG, “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 is convenient for grouping TT methods. As noted in paragraph 2-6.2, however, it is also common within the TT industry to use the terms “renovation” and “rehabilitation” interchangeably. As defined in this TSPWG M, 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, ensure liner materials are capable of withstanding exposure to both the product and any additives, and should be approved by the service control point for all DLA fuel-related support issues, such as AFPET.

2-6.3.1 Applied Lining.

Applied linings for rehabilitation are usually restricted to large pipes, with installation techniques similar to those for renovation linings (paragraph 2-6.2.2), 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.

2-6.3.2 Prefabricated Lining.

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

2-6.3.2.1 Insert Renewal.

Insert renewal is the simplest and most commonly used type of sliplining, particularly in pipes with 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.

2-6.3.2.2 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.

2-6.3.2.2.1 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.

2-6.3.2.2.2 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 the insert forms a “U” shape. (In some products, the “U” shape is folded again so 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 with 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.

2-6.3.2.3 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).

2-6.3.2.4 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.

2-6.3.3 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.

2-6.3.3.1 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.

2-6.3.3.2 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 as large as or larger than the original pipe can be inserted. This means the pipe can be returned to its original capacity or more and 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.

2-6.4 Non-structural Methods.

Non-structural TT methods are often overlooked 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 (including pipeline location and anomaly detection).

2-6.4.1 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.

2-6.4.1.1 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. 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.

2-6.4.1.1.1 Flushing.

Flushing uses 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 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 are typically not removed by flushing. Still, the method is easy, requires no special equipment or training, and provides a tangible benefit in most cases.

2-6.4.1.1.2 Air Hammer.

The air hammer method is a 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.

2-6.4.1.1.3 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 is 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.

2-6.4.1.2 Mechanical Cleaning.

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

2-6.4.1.2.1 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.

2-6.4.1.2.2 Manual Cleaning.

Large pipes may be manually cleaned. 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.

2-6.4.2 Inspection.

Inspection methods can be divided into two groups: internal inspection and location/anomaly detection. See TSPWG M, 3-260-03.04-6, *Inspection of Pavement Drainage Systems*, for a more detailed study.

2-6.4.2.1 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.

2-6.4.2.1.1 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*.

2-6.4.2.1.2 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 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.

2-6.4.2.2 Location/Anomaly Detection.

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

2-6.4.2.2.1 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 concern for TT use, the use of a manual probe will usually be impossible.

2-6.4.2.2.2 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.

2-6.4.2.2.3 Ground-penetrating Radar (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.

2-6.4.2.2.4 Infrared Thermography (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.

2-6.4.2.2.5 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.

2-7 INFORMATION SOURCES.

TT is rapidly being accepted worldwide and there are technical societies worldwide that are available as resources. See Appendix C for a listing of TT societies. There are also ASTM standards related to trenchless technology; see Appendix C.

2-8 USE OF TT.

There is no single TT method that will be useful in all situations. Still, the need for TT has subtle differences from that of most civilian agencies. First, many pavements have soil underneath the upper paving layers (i.e., rock coring is usually not needed). Second, many pipelines, utilities, and communication lines under 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, there are sometimes needs to combine utilities into a single pipe. Considering the specific factors, four TTs stand out as particularly interesting for future application: (1) guided boring; (2) HDD; (3) pipe eating; and (4) pipe bursting. Consider all the factors for each technology in this TSPWG M when searching for the “best” TTs but these four technologies have particular strengths worth emphasizing.

2-8.1 Guided Boring.

For the typical new construction/reconstruction situation, guided boring seems to be the best 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.

2-8.2 Horizontal Directional Drilling (HDD).

HDD is of special interest 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.

2-8.3 Pipe Eating.

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.

2-8.4 Pipe Bursting.

For the typical rehabilitation situation (e.g., broken water pipe), particularly when there are no internal tees, pipe bursting seems to be the perfect 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 2-6.1.2.3) 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 situations.

2-9 ADDITIONAL CONSIDERATIONS.

Decisions about the advantages and disadvantages of various TT methods may be moot for routine base maintenance if performance specifications are used to put the burden of decision-making about methodology onto the contractor. In addition, good decision-making about TT's use in non-routine situations (particularly in harm's way) requires thorough analysis. 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 in a hostile environment extremely difficult, if not impossible. Certain questions about differences in speed, mobility, and durability of the various TT equipment/methods can be answered only with field trials performed under controlled conditions.

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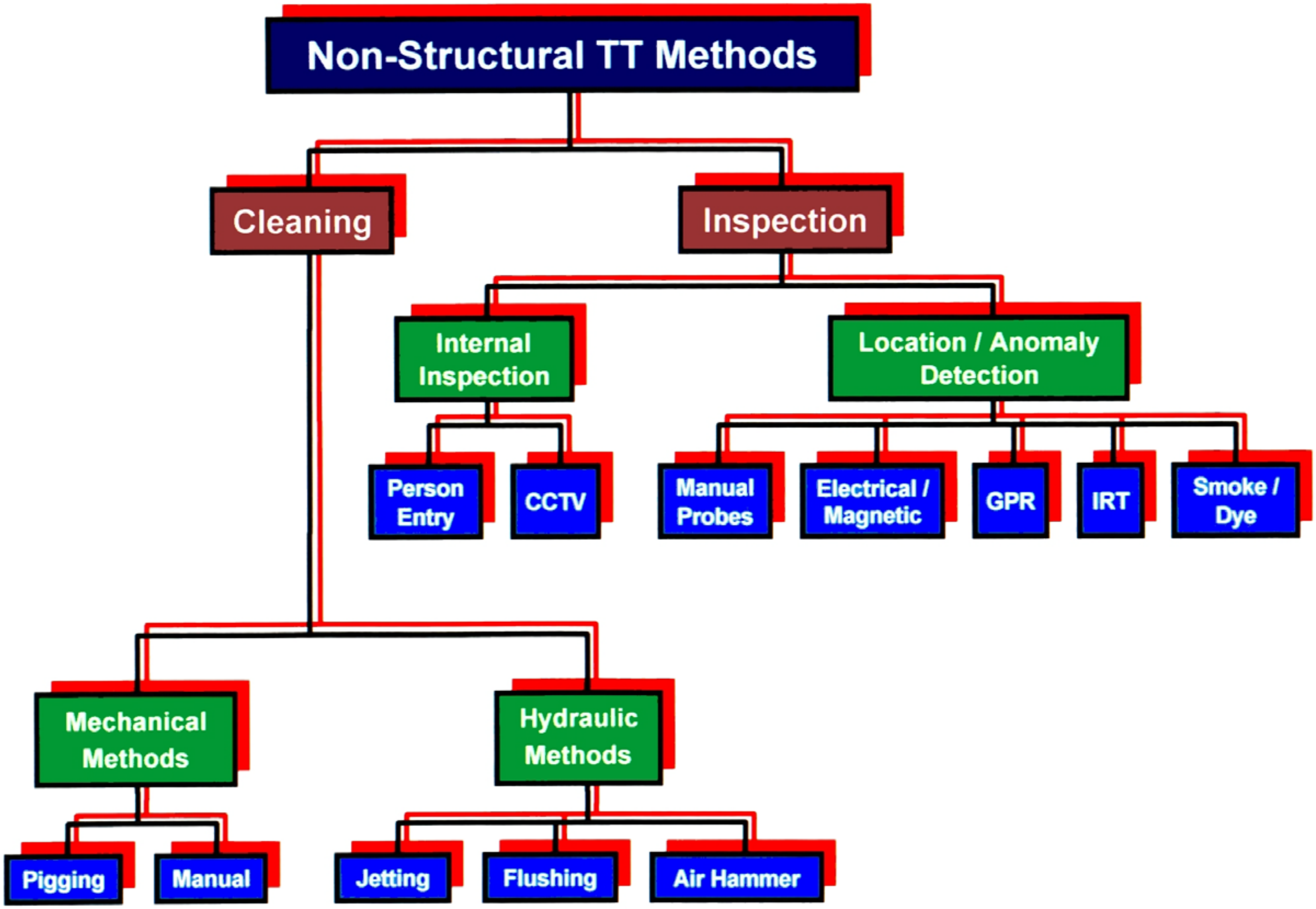
APPENDIX A TT METHODS

A-1 NON-STRUCTURAL TT METHODS



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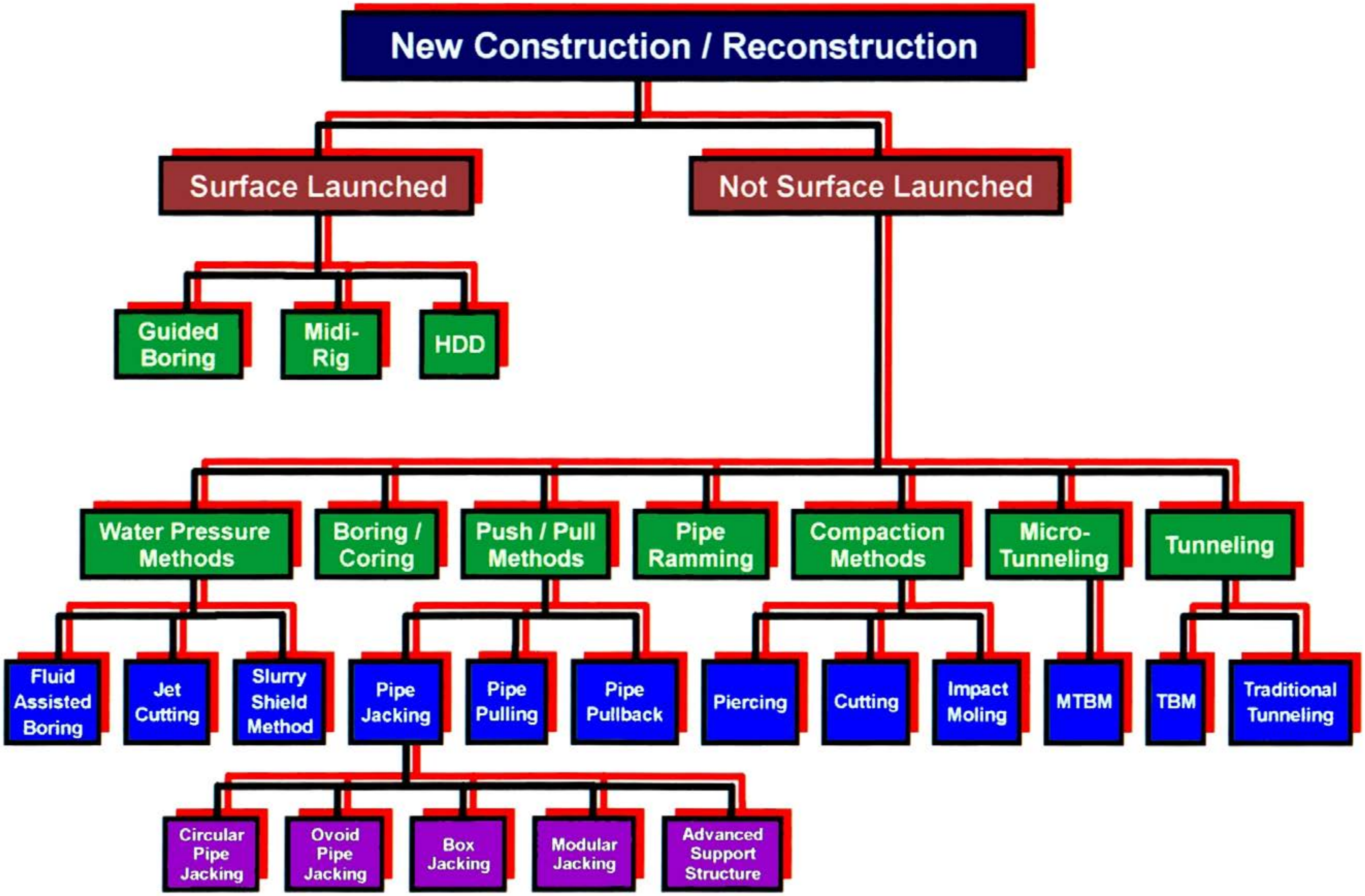

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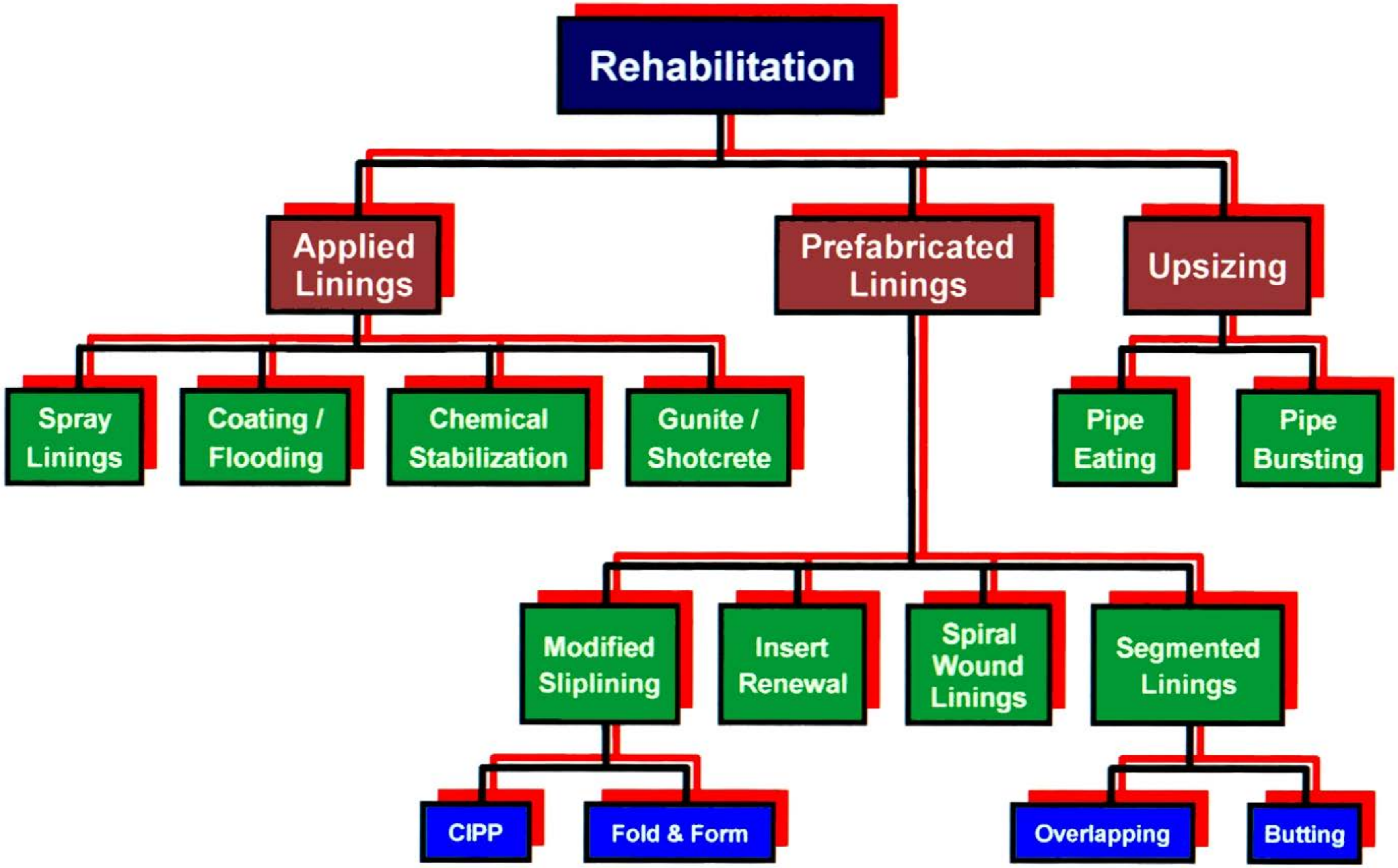
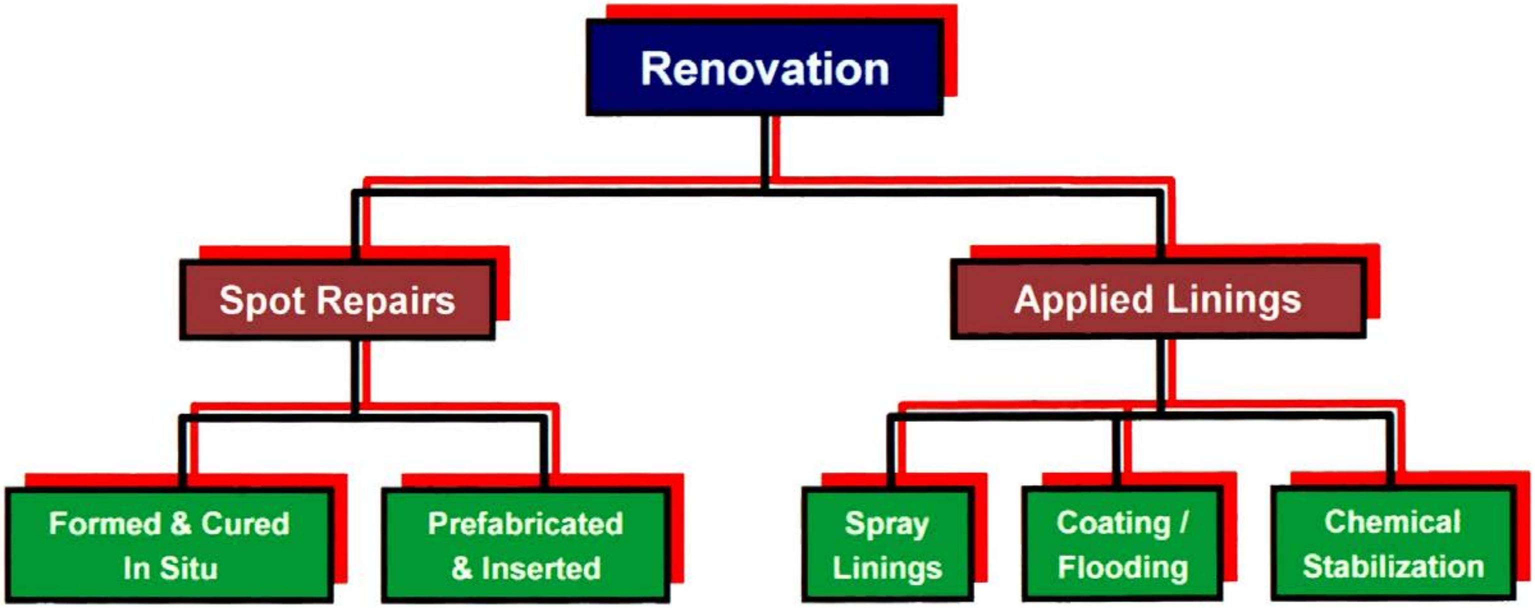


A-4 RENOVATION TT METHODS



APPENDIX B GLOSSARY

B-1 ACRONYMS

AFPET	Air Force Petroleum Office
ASTM	American Society for Testing and Materials
CCTV	closed circuit television
CFR	Code of Federal Regulations
CIPP	cured-in-place pipe
DLA	Defense Logistics Agency
DOD	Department of Defense
DOT	Department of Transportation
ETL	Engineering Technical Letter
GPR	ground penetrating radar
HDD	horizontal directional drilling
IRT	infrared thermography
MTBM	microtunnel boring machine
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
PE	polyethylene
POL	petroleum, oil, and lubricants
PVC	polyvinyl chloride
TBM	tunnel boring machine

B-2 TERMS

A glossary of TT terminology from the North American Society for Trenchless Technology (NASTT) is located here: http://www.nastt.org/resources/glossary/. 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.

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APPENDIX C REFERENCES

CODE OF FEDERAL REGULATIONS (CFR)

Title 29, CFR, Chapter XVII, Section 1910.146, *Permit-required confined spaces*, https://www.ecfr.gov/cgi-bin/text-idx?SID=1f9d40e6783ea1386f6f920bbaac79a8&mc=true&node=se29.5.1910_1146&rgn=div8

AIR FORCE

TSPWG M 3-260-03.04-6, *Inspection of Pavement Drainage Systems*, http://www.wbdg.org/ffc/dod/supplemental-technical-criteria

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

https://www.astm.org/

F2207, *Standard Specification for Cured-in-Place Pipe Lining System for Rehabilitation of Metallic Gas Pipe*

F1962, *Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings*

F1871, *Standard Specification for Folder/Formed Poly (Vinyl Chloride) Pipe Type A for Existing Sewer and Conduit Rehabilitation*

F1867, *Standard Practice for Installation of Folded/Formed Poly (Vinyl Chloride) (PVC) Pipe Type A for Existing Sewer and Conduit Rehabilitation*

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