



21, rue d'Artois, F-75008 PARIS
[http : //www.cigre.org](http://www.cigre.org)

CIGRE US National Committee 2023 Grid of the Future Symposium

Similarities and Differences to Horizontal Directional Drilling Design and Construction Considerations in Gas Pipeline and Cable System Projects

**Qilin HEATON*, Gabe GARCIA, Branako PRIMM
Burns and McDonnell
USA**

SUMMARY

Horizontal Directional Drilling (HDD) is one of the most common trenchless methods of installing underground infrastructure, such as gas pipelines, water lines, sewer lines, and cable systems, when the open-cut option is not feasible. While the fundamental HDD process remains the same for both gas line and cable system projects, there are several key differences in their implementation and design considerations. The focus of this paper is to explore the major similarities and differences in the HDD industry between gas pipeline and cable system projects.

KEYWORDS

Horizontal Directional Drilling, HDPE, Cable System, Thermal Grout , Gas Pipelines, Underground Electrical System

SIMILARITIES

HDD Process

The drilling process for electrical cable systems closely resembles that of gas pipeline installations. It generally commences with drilling an initial pilot hole, followed by one or numerous reaming passes as needed to properly enlarge the borehole, and concluding with the installation of the product pipe. Nonetheless, certain differences should be taken into account when working on smaller electrical distribution projects as opposed to larger pipeline installations in general.

For smaller distribution projects, the "pilot and pull" technique might be employed due to the limited size of the designated conduits. In this approach, a pilot hole is first drilled, and then the conduit is immediately pulled through the hole, eliminating the need for multiple reaming passes typically used in larger pipeline installations.

Environmental Impact

HDD is an innovative construction method for installing underground utilities with minimal surface disruption. By directionally drilling beneath the surface from one point to another, HDD allows for the installation of pipelines and cable systems in challenging terrain and urban areas without disrupting the surrounding environment. This environmentally friendly method can preserve natural habitats, minimize carbon emissions, and ensures efficient utility interconnection, making it a crucial aspect of modern infrastructure development. While HDD possess the potential to minimize environmental impacts, improper management can result in significant adverse effects on the environment. Some potential environmental concerns include:

- **Soil and Ground Water Contamination:** Drilling fluid used throughout the duration of the project may seep into the formation surrounding the borehole, potentially carrying contaminants into the ground.
- **Waterbody Contamination:** HDD could be the preferred installation method to cross waterbodies or environmentally sensitive areas, such as wetlands, to minimize surface disruption and protect natural habitats. However, insufficient measures to protect these sensitive habitats during the installation process could lead to habitat degradation or the disruption of aquatic ecosystem.
- **Drilling Cuttings:** The waste materials generated during the HDD process such as drill cuttings which need proper handling and disposal to prevent environmental harm.
- **Noise and Vibration;** HDD equipment can generate noise and vibration that may affect nearby communities, wildlife, and sensitive structures.

Regulatory and Permitting Requirements

Regulatory and permitting requirements for HDD projects can vary depending on the specific location and jurisdiction of the project location. The key areas of regulatory and permitting considerations for both gas pipeline and electrical cable system HDD are:

- **Environmental Regulations:** HDD projects usually involve working in environmentally sensitive areas and will need to comply with environmental regulations to protect natural resources, wetlands, water bodies, and protected habitats.

- **Land Use and Zoning:** Ensuring compliance with land use and zoning regulations is crucial. HDD projects may require approvals or variances to conduct drilling activities in specific areas or within certain land use zones. Compliance with local zoning ordinances and obtaining the necessary land use permits is essential.
- **Temporary Construction Permits:** The diverse range and scale of HDD project can potentially affect public infrastructure. In such cases, acquiring temporary permits from local or state authorities might be required.
- **State and Federal Regulations:** Depending on the scale and location of the HDD project, federal and state agencies may have specific requirements that need to be met. These requirements could involve obtaining permits from entities like the U.S. Army Corps of Engineers or the Environmental Protection Agency (EPA).
- **Similar to other non-HDD projects, HDD projects are subject to the following permitting and regulations requirements:**
 - Traffic control permits
 - Safety and Health Regulations
 - Noise and Vibration Restrictions
 - Utility and Right of Way Permits
 - Easements and Landowner Permissions

Hydraulic Fracture and Inadvertent Return Analysis

Annular pressure refers to the pressure that accumulates between the drill string and the external casing or borehole wall. For both pipeline and electrical HDD installations, annular pressure is a significant concern during the drilling process. Annular pressure must not exceed the geotechnical formation limiting pressure to minimize the risk of hydraulic fracturing, which leads to loss of drilling fluid. Annular pressure analysis calculates if the design drill path is deep enough or in a suitable formation that will prevent fluid from "fracking" the formation and flowing to the surface. Performing a hydraulic fracture and inadvertent return analysis to determine safe working pressures for HDD operations is essential for several reasons. Analysis plays a pivotal role in ensuring safety, environmental protection, cost-effectiveness, regulatory compliance, and wellbore integrity.

Hydraulic fracture and inadvertent return analyses involve assessing both the design profile and geotechnical properties of the formation that the drill path passes through. The geotechnical characteristics are used to determine a maximum overburden pressure, which is then compared with the anticipated drilling fluid pressure present within the annulus of the borehole. The drilling fluid pressure accounts for factors such as the pumping rate, the depth of the design profile, and the volume of the annulus (i.e., the space between the borehole and the drill pipe). Essentially, as the depth of the borehole increases, the overburden pressure grows, providing a counteracting force against the drilling fluid pressure.

An analogy can be drawn to calculating the hoop stress of a buried pipe with pressurized liquid. Calculating the internal and external pressures imposed upon a buried pipe with pressurized liquid can help depict the significance of analyzing annular pressure during drilling operations. Both situations involve assessing the pressure and potential stresses within a confined space, emphasizing the importance of accurate analysis for ensuring structural integrity and preventing potential risk of failure.

Settlement Analysis

The settlement analysis determines if the depth of the drill path provides sufficient cover beneath the existing facility so that any potential collapse of the surrounding formation around the pipe will have minimal impact on the surface above. Settlement concerns can arise during HDD operations for various reasons, and they can affect both pipeline and electrical installations. Settlement issues may occur if the soil conditions are improperly assessed, the soil around the bore does not provide enough support, or if there is excessive ground movement during the drilling process. Settlement can lead to heaving or subsidence of the surface, posing a potential threat to existing utilities or above-ground infrastructure situated above the drill path.

The settlement analysis considers three key factors: the depth of the drill path below the crossing feature (such as a road, utility, or railroad), the volume of the annulus once the pipe is installed (final borehole size minus product pipe size), and the geotechnical formation. Its purpose is to identify any excessive void space within the hole that might lead to ground sinking and potentially cause movement in the road, utility, or railroad. When settlement values are found to be high, there are several potential remedies: adjusting the drill path's depth, increasing the size of the product pipe, or reducing the final borehole size. The stability and integrity of these assets may be compromised, highlighting the importance of careful settlement analysis to ensure the protection of existing infrastructure.

DIFFERENCES

Stress Analysis

The stress analysis calculates if the proposed product pipe properties are sufficient to be pulled through the design profile without compromising the integrity of the pipe. The stress analysis takes into consideration the design geometry and calculates if the stresses imposed upon the product pipe during installation are acceptable. The stress analysis for pipelines and cable systems in HDD projects differs due to the nature of the materials. While both gas pipeline and electrical HDD projects employ HDPE and Steel pipes as carrier or casing pipes, their usage varies. Steel pipes are more prevalent in the gas industry, while HDPE pipes are more commonly used in the cable industry. The following are some of the main distinctions in stress analysis between Steel and HDPE pipes.

- Steel pipe
 - Design Code: The Pipeline Research Council International (PRCI) design guideline (PR-277-144507-Z01) was developed by the Pipeline Research Council International (PRCI) of the American Gas Association specifically intended to be applied to the placement of steel pipe by maxi-HDD, including stress analysis guidance.
 - Corrosion: Steel pipes may require additional stress analysis to address corrosion effects, as it affects their long-term integrity.
 - Bending Radius: Steel pipes have higher tensile strength compared to HDPE pipes. Therefore, stress analysis for Steel pipes focuses on ensuring they can handle higher tensile loads during pulling and installation.
 - Temperature Effects: Steel pipes may experience temperature-induced stresses, especially in extreme environments. Proper analysis considers temperature variations to avoid issues like thermal expansion or contraction.

- HDPE pipe
 - Design Code: The ASTM F1962 provides an analytical method for selecting the polyethylene pipe strength requirements based upon the estimated installation loads on the PE pipe and helps determine the required capacity of the HDD equipment.
 - Handling and Installation: HDPE pipes' lighter weight and flexibility ease handling and installation compared to Steel pipes. Stress analysis for HDPE pipes may focus on ensuring they maintain structural integrity during the installation process.
 - Corrosion: HDPE pipes, being more resistant to corrosion, may require different considerations in stress analysis for their longevity.
 - Tensile Strength: HDPE pipes have lower tensile strength compared to Steel pipes.
 - Radial Stress: HDPE pipes are more sensitive to radial stress due to their flexible nature. The analysis considers the potential for compression or buckling of the pipe walls caused by radial forces during HDD installation.

Depth Constraints

Larger HDD contractors often prefer to drill deeper, when feasible, to mitigate the risks associated with inadvertent returns. Gas pipeline projects typically do not face significant depth constraints during HDD operations. Gas pipelines are designed to be installed at considerable depths to ensure safety, avoid interference, and ensure that industry standard HDD techniques can be employed at the desired depths with relatively fewer limitations.

On the other hand, electrical projects that involve the installation of underground power cables can face depth restraints due to ampacity considerations. Ampacity refers to the maximum current-carrying capacity of a cable or conductor without exceeding its temperature limits. When power cables are buried underground, the surrounding soil acts as thermal insulation, and it becomes essential to manage the heat generated during the transmission of electricity. Underground power cables experience derating when buried at greater depths because of thermal resistance and limited heat dissipation in the surrounding soil. The derating phenomenon refers to the reduction in the current-carrying capacity (ampacity) of the cable. Because it is the longest path to heat dissipation and limits operating temperatures, it becomes crucial to determine the maximum burial depth for the cable system during the HDD design phase.

Length Limitations

Compared to well-known steel pipeline HDD installations commonly seen in the oil and gas industry, the maximum electrical cable installation length falls behind. Typical oil and gas installations often span from 1,000 to 4,000 ft, with some reaching lengths of 10,000 to 15,000 ft. The length limitations for cable system HDD projects can govern several factors, including the tensile strength of cables, the maximum pulling loads of the carrier pipes, the cable reel length, owner requirements, and cable splicing length. Restrictions placed on cable system HDDs limit most cable installations to less than 4,000 ft, with many being installed less than 500 ft in length. Currently, the longest HDD installation for a cable system project is approximately 6,600 ft. The following is a brief discussion on some of the main governing factors on cable length limitations.

- **Tensile Strength of Cables:** The tensile strength of the cables being installed is a crucial factor in determining the maximum allowable pulling force during HDD. Exceeding the cables' tensile strength can lead to cable damage or failure, so the borehole length must be managed accordingly.
- **Reel Length:** Cables used in cable system HDD projects are typically supplied on reels. The length of these reels sets a practical limitation on the continuous length of cable that can be installed in one pull. Reels come in various sizes, and the length of the cable on the reel is predetermined by the manufacturer or supplier. HDD design engineers and contractors must consider the reel length when planning the installation, as they cannot pull a cable longer than what is available on the reel.
- **Cable Splicing Length:** In some cases, cable lengths may not be available in the required continuous length to span the entire distance of the HDD installation. To accommodate longer runs, cable splicing becomes necessary. Cable splicing involves joining multiple cable segments together to create a longer continuous length. It is crucial to emphasize that these splices typically take place within a vault and cannot be pulled through an HDD. Therefore, the length of the cable splicing must be taken into account when determining the maximum length of the cable installation.

In some cases, if longer cable runs are necessary, HDD projects may require specialized equipment and techniques to manage longer reels or minimize the number of splices. Additionally, using advanced cable handling methods and larger capacity reels can help extend the feasible length of the cable system installation in HDD projects. Careful attention to these length limitations is essential to ensure the successful completion of a cable system HDD project and the long-term integrity of the installed cable infrastructure.

Workspace

Considering workspace requirements is crucial during project planning. One significant aspect that impacts the workspace is the size of the rig, which is primarily influenced by the installation loads. Accurately calculating the installation loads is essential, especially when dealing with product pipes like steel or high-density polyethylene (HDPE) pipes at each crossing. This calculation plays a vital role in determining the minimum rig size and the necessary supporting equipment spread for the project.

It's worth noting that steel pipeline crossings generally weigh much more than HDPE crossings. Consequently, when comparing a steel pipeline crossing of similar length to a cable system crossing, one should anticipate the need for a larger rig and equipment spread. When planning the project workspace, the potential additional or reduced space required for the rig and equipment spread must be considered.

Thermal Grout

As mentioned earlier, the thermal properties of the materials surrounding the cables significantly influence the cable system's performance as well as the size and configuration of the Horizontal Directional Drilling (HDD). Among these properties, the native soils play a pivotal role. For precise cable ampacity calculations, it is crucial for the cable system designer to possess soil thermal resistivity (TR) data for in-situ or native soils. Thermal grout, also known as thermal backfill or thermal filler, plays a crucial role in HDD cable systems. In an HDD cable system, the thermal grout could serve the following purposes:

- **Thermal Conductivity:** One of the primary functions of thermal grout is to enhance the thermal conductivity between the cables and the surrounding soil. This is especially important for power cables, where efficient heat dissipation is essential to maintain optimal cable operating temperatures. Thermal grout ensures that the heat generated during cable operation can be efficiently dissipated into the surrounding soil.
- **Stability and Support:** Thermal grout helps stabilize the cables within the drilled borehole. It provides a stable and secure environment for the cables, preventing movement or shifting that could cause damage to the cables over time. The grout also acts as a supporting medium, ensuring the cables maintain their position and alignment throughout their service life.
- **Protection from External Elements:** Thermal grout acts as a protective barrier, shielding the cables from external elements such as moisture, soil, and other contaminants that could potentially damage the cables or degrade their performance.
- **Reduction of Mechanical Stresses:** Thermal grout helps reduce mechanical stresses on the cables by creating a uniform and stable environment around the cables, which can extend the lifespan of the cables and minimize the risk of failures.
- **Prevention of Groundwater Ingress:** Thermal grout can help prevent groundwater from infiltrating the cable system. This is particularly important for preventing water-related damage to the cables and maintaining their insulation integrity.

While annular grouting improves cable system performance, it also introduces higher risk and costs. Grouting in HDD projects may necessitate extra annular space and tremie tubes to ensure proper grout placement, flow, and consolidation within the bore. These additions can influence the bore size, conduit grade, and other design elements, necessitating collaboration between the specialty grout designer, design engineer, and drill contractor.

CONCLUSION

In conclusion, both gas pipeline and cable system projects share significant similarities in their HDD requirements, reflecting the advantages of this trenchless method for infrastructure development. Shared elements can also be found in the necessity for meticulous planning, the utilization of sophisticated drilling equipment, and strict compliance with safety protocols to guarantee a successful implementation.

The similarities between HDD for gas pipeline and cable system projects primarily revolve around the drilling process itself. Both projects demand comprehensive site surveys and thorough geotechnical investigations to assess soil conditions and potential obstacles. The use of cutting-edge drilling equipment and advanced technologies, including borehole guidance systems and mud recycling units, remains essential for achieving accurate, efficient, and safe drilling operations.

It is crucial to acknowledge the distinctive factors that can have a substantial impact on the success of each project. Gas pipeline projects often involve larger diameters and longer distances, necessitating more powerful drilling rigs and extensive logistical planning to transport materials and manage construction sites efficiently. Conversely, cable system projects demand specific consideration regarding cable depth constraints due to derating and

capacity factors as well as restrictions on cable length due to transportation, reel size, cable pulling tension, and splicing requirements.

Disregarding these subtle yet crucial differences can have severe consequences for the constructability and feasibility of either type of project. Failure to address unique requirements of gas pipelines may result in insufficient transportation capacity or increased risks of leaks and ruptures, leading to costly repairs and potential environmental hazards. Similarly, neglecting the specific demands of a cable system project can lead to cable damage, and service disruptions, significantly affecting users and businesses that depend on a reliable electricity supply for their daily operations. Through acknowledging and embracing the distinct aspects of each project, stakeholders can effectively navigate challenges effectively and ensure the seamless implementation of HDD in both gas pipeline and cable system projects, contributing to the growth and development of our infrastructure networks for years to come.

REFERENCES

- [1] The National Electrical Code (NEC), or NFPA
- [2] Plastic Pipe Institute, MAG Guidelines for Use of Mini-Horizontal Directional Drilling for Placement of HDPE (PE4710) Pipe in Municipal Applications, MAB-07 2020
- [3] The Plastics Pipe Institute, “The Plastics Pipe Institute Handbook of Polyethylene Pipe”, Second Edition, 2008, including errata.
- [4] North American Society for Trenchless Technology, Horizontal Directional Drilling (HDD) Good Practices Guidelines - 2017 (4th Edition).