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An Overview of Safety Considerations for Large Diameter Direct Pipe® Installation

Brian Carpenter, Laney Directional Drilling, Spring, Texas
Maureen Carlin, Laney Directional Drilling, Spring, Texas
Alan Snider, Laney Directional Drilling, Spring, Texas

1. ABSTRACT

Safety is the most critical factor in delivering trenchless construction projects on time and on budget. The purpose of this paper is to present challenges associated with safety for large diameter Direct Pipe® construction, particularly with respect to *Confined Space Entry*. Direct Pipe® has the safety advantages of being a one-step process of pushing tunneling equipment and pipe simultaneously, as well as having no rotating equipment above ground. However, the Direct Pipe® Method requires Confined Space Entry at various stages of project execution. This presents a dangerous and challenging aspect of pipeline construction requiring extensive planning early in the project and throughout construction execution.

In response to this safety challenge, Laney Directional Drilling has worked extensively to develop an innovative and adaptive Direct Pipe® Confined Space Rescue Plan. This plan was designed to provide the Confined Space Rescue Team (CSRT) personnel with an understanding of customer operations and the site specific rescue methods to ensure a safe and effective rescue within a Confined Space during Direct Pipe® construction. Considerations of the Confined Space Rescue Plan that will be discussed include atmospheric monitoring and mitigation, internal pipe configuration, temperature, space access, space mobility, ventilation, and rescue team. Overall, this plan reinforces the core value that a successful health, safety, and environmental program requires the participation of all employees, to promote safety and environmental awareness and prevent all incidents, injuries, and illnesses to employees, customers, and the community.

Furthermore, this paper provides an understanding of customer operations and the site specific rescue methods to ensure a safe and effective rescue within a Confined Space. A recent record setting Direct Pipe® crossing project has been used as a case study reference and illustrates the most current practices that have been utilized for Confined Space Entries during Direct Pipe® execution.

2. CONFINED SPACE ENTRY FOR DIRECT PIPE® CONSTRUCTION

2.1 Overview

Many construction workplaces contain areas that are considered *Confined Spaces* because while they are not necessarily designed for people but they are large enough for workers to enter and perform certain jobs. This is particularly relevant to the pipeline construction industry, including trenchless applications. Confined Spaces include, but are not limited to, tanks, vessels, silos, storage bins, hoppers, vaults, pits, manholes, tunnels, equipment housings, ductwork, and pipelines. To be considered a *Confined Space*, the space must meet the following three (3) parameters:

1) The space (or pipeline) is large enough, and so configured, that an individual can bodily enter and perform assigned work.
2) The space (or pipeline) has limited or restricted means for entry or exit.
3) The space (or pipeline) is not designed for continuous human occupancy.

Confined Spaces are particularly dangerous as there are several hazards associated with entering the spaces. Six (6) major hazards facing those who enter pipelines include the following:

(1) *Toxic Atmosphere:* A toxic atmosphere may cause various acute effects, including impairment of judgment, unconsciousness, and death. A toxic atmosphere may occur due to the presence or ingress of hazardous substances. These substances may be present in the Confined Space for various reasons such as remaining from previous processing or storage, arising from the disturbance of sludge and other deposits, or the presence of a fire or flames within the space, among others.

(2) *Oxygen Deficiency*: Oxygen can be lacking a Confined Space due to displacement of air by another gas, various biological processes or chemical reactions, or absorption of air onto steel surfaces, especially where these are damp.

(3) Oxygen Enrichment: An excess of oxygen, in the presence of combustible materials, results in an increased risk of fire and explosion. Some materials, which do not burn in air, may burn vigorously or even spontaneously in an enriched oxygen atmosphere.

(4) Flammable or Explosive Atmospheres: A flammable atmosphere presents a risk of fire or explosion. Such an atmosphere can arise from the presence in the Confined Space of flammable liquids or gases or of a suspension of combustible dust in air. If a flammable atmosphere inside a Confined Space ignites, an explosion may occur, resulting in the expulsion of hot gases within the pipeline.

(5) *Flowing Liquid or Free Flowing Solids*: Liquids or solids can flow into the Confined Space causing drowning, suffocation, burns, and other injuries. Solids in powder form may also be disturbed in a Confined Space resulting in an asphyxiating atmosphere.

(6) *Excessive Heat*: The enclosed nature of a Confined Space can increase the risk of heat stroke or collapse from heat stress if conditions are excessively hot. The risk may be exacerbated by the wearing of personal protective equipment or by lack of ventilation.

2.2 Regulation

Two governing bodies regulate Confined Space Entry as well as overall safety with regard to pipeline construction. They are the Pipeline and Hazardous Materials Safety Administration (PHMSA), which is part of the United States Department of Transportation, and the Occupational Safety and Health Administration (OSHA), which is part of the United States Department of Labor. PHMSA ensures safety in the design, construction, operation, maintenance, and spill response planning of America's 2.6 million miles of natural gas and hazardous liquid transportation pipelines. PHMSA is responsible for regulating and ensuring the safe and secure movement of hazardous materials to industry and consumers by all modes of transportation, including pipeline construction and operation.

In close coordination with PHMSA, OSHA enacted the Occupational Safety and Health Act of 1970, which is designed to assure safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance. On Feb. 1, 1999, OSHA Standard on Permit-Required Confined Spaces, 29 CFR Part 1910.146, went into effect. In short, before anyone enters a Confined Space, an entry permit must be completed by supervisory personnel. Among other specifics, permits must clearly identify the Confined Space’s location, entry date, purpose, duration of occupancy, hazards and acceptable entry conditions, test results and rescue/emergency services. This regulation clearly defines workers’ rights when entering potentially life-threatening Confined Spaces. Among other requirements, employers must use a calibrated, direct-reading instrument to ensure safe Confined Space entry.

3. CASE STUDY

3.1 Project Overview

The project used for this case study is a recently executed record breaking Direct Pipe® shore approach crossing in Cameron County, Texas. The general site location is shown in *Figure 1: Project Vicinity Map*. This trenchless installation is part of the much larger project to construct approximately 155 miles of new 48-inch and 42-inch-diameter steel pipeline to transport natural gas in South Texas.

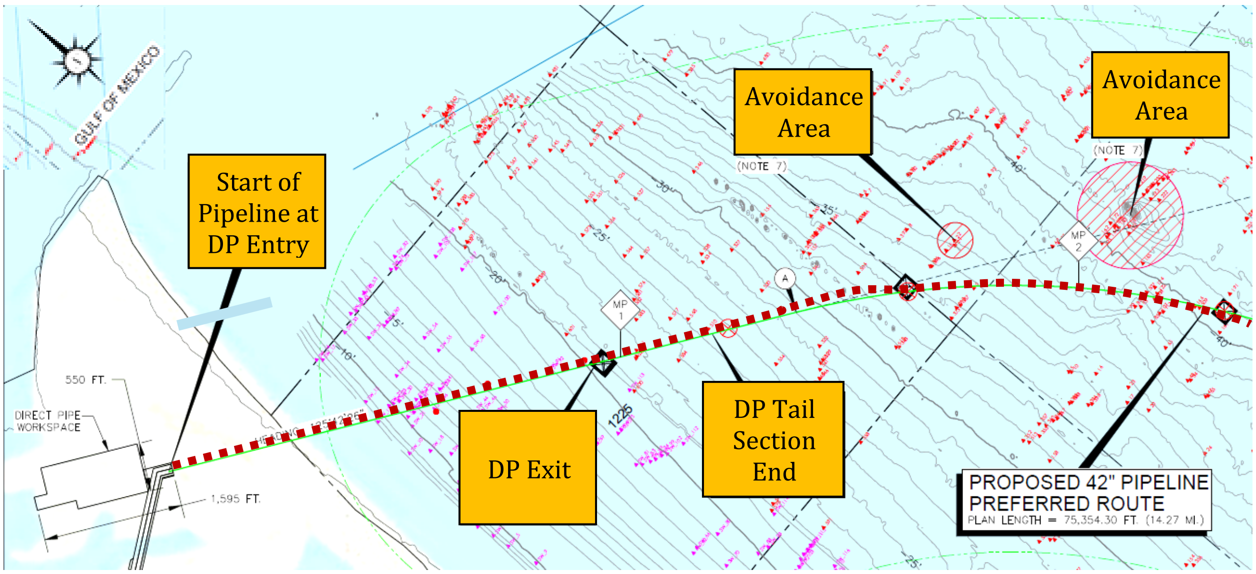

Figure 1: Project Vicinity Map.

The Pipeline Contractor (Prime) was a U.S. based pipeline construction firm who provide overall pipeline construction services in conjunction with Laney Directional Drilling Co. (Contractor) for the Direct Pipe® scope of work. Laney, a Houston, Texas based company licensed in engineering and construction in the state of Texas, was contracted to install the 42-inch diameter steel pipeline using a newer form of Microtunneling known as Direct Pipe®.

Microtunneling is a trenchless method of installing pipelines in areas where traditional open cut excavations are not feasible for environmental or logistical reasons. The microtunneling methodology being adopted for this project was developed by Herrenknecht AG (Herrenknecht), a corporation based out of Germany and has been trade marked as Direct Pipe® for a trenchless methodology. Refer to *Figure 2: Direct Pipe® Set-Up at Ground Entry* for general equipment set-up at entry location where man entry typically originates. Additional project parameters can be found in *Table 1: Installation Pipe Data*.

Figure 2: Direct Pipe® Set-Up at Ground Entry.

Table 1: Installation Pipe Data.

PROJECT PARAMETER	DESCRIPTION
Installation Length	5,000-Feet
Pipe O.D.	42.00-Inches
Wall Thickness	1.250-Inches
Pipe Grade	70,000 PSI
Pipe Coating	Fusion Bonded Epoxy (FBE) & Abrasion Resistant Overlay (ARO)

3.2 Project Schedule

The original project schedule included 129 working days, which included mobilization, site preparation, pipe fabrication, foundation and thruster set-up, welding, tunneling operations, and site restoration. The complete list of construction activities and scheduled durations is shown in *Table 2: Drill Plan Schedule of Activities.*

Table 2: Drill Plan Schedule of Activities.

ACTIVITY	**PLANNED SHIFTS**	**END DATE**	**PLANNED SHIFTS**
MOBILIZE TO SITE	17.00	VERIFY MTBM ON SEA FLOOR	1.00
FOUNDATION / THRUSTER SETUP	16.00	MID-WELD	2.00
DP EQUIPMENT SETUP	7.00	THRUST OUT TO BARGE	2.00
MTBM ASSEMBLY & PREP	6.00	LIFT MTBM	1.00
LAUNCH SEAL INSTALLATION	1.00	CUT-OFF MTBM	1.00
UMBILLICAL INSTALLATION	5.00	THRUST OUT ADD. STRING	4.00

ACTIVITY	PLANNED SHIFTS	ACTIVITY	PLANNED SHIFTS
TUNNEL PIPE STRING 1 & SURVEY	5.00	REMOVE UMBILLICALS	5.00
MID-WELD	2.00	UNLOAD UMBILLICAL & STORE	4.00
TUNNEL PIPE STRING 2	15.00	RIG DOWN / DEMOB	14.00
MID-WELD	2.00	STANDBY SHIFTS	0.00
TUNNEL PIPE STRING 3	15.00	WEATHER / CONTINGENCY	3.00
PUNCH OUT	1.00	OTHER	0.00
TOTAL SHIFTS:			**129.00**

3.3 Project Safety & Confined Space Entry

Overall, the work for this project was carried out according to the Contractor Safety Manual and the Site Specific Safety Plan as developed by the Prime and the Contractor. In all circumstances, work was performed in a manner to maximize safety and reduce exposure of its employees and equipment to hazardous and potentially hazardous conditions, in accordance with all applicable safety standards. Prior to mobilization, all stakeholder safety team leaders met to review all site specific safety requirements, which were added to the Site Specific Safety Plan for implementation. In addition, all regular and temporary employees participated in onsite Safety Program orientations to ensure workers were educated to the specific safety concerns presented by the project. Furthermore, before commencement of any operating shift, onsite crews completed a Job Safety Analysis (JSA) of the work planned for the shift. Each JSA included all the tasks that were scheduled to be performed during the shift, identifying the potential risks, and providing a discussion to mitigate the risks. Finally, all onsite crews held weekly tailgate meetings on the subject matter related to operations affecting the project.

With regard to Confined Space Entry, there were two types of scenarios for this project. The first was *planned scenarios*. Planned scenarios were anticipated during the initial connection of the MTBM and at the end during the MTBM's removal from the pipeline. For the first planned entry, a surveying team was scheduled to enter the pipe to survey and check alignment of the microtunneling boring machine (MTBM) to follow the pipeline as it progressed along the pre-planned alignment. The second planned entry was planned to occur during the installation of consecutive pipeline sections when connecting umbilical cords, slurry lines, and the electric cart track. After completing the installation of consecutive pipeline sections, entrants would enter to check alignment of equipment and rotation of booster pumps. In addition to the planned scenarios, the contractor anticipated several *unplanned scenerios*, which were likely for common repairs should mechanical, electrical, or HWL systems fail within the pipeline or the MTBM.

The Confined Space Designation for this project was determined to be a *Type 2 Designation*, which is used for *Horizontal Entry greater than 24 inch opening*. The internal configuration for this project was approximately 5,000-ft of 42-in horizontal pipeline with + or - 4° slope. All Confined Space Entries inside the pipeline were designed to be carried out in accordance to 29 CFR 1926.800 and 29 CFR 1910.146. The main features of the entry procedure were defined, submitted, and approved by the project safety team, and are described below. They include atmospheric monitoring and mitigation, internal pipe configuration, temperature, space access, space mobility, ventilation, and rescue team.

Access into the actual pipeline was the first critical factor in confined entry planning. For this typical Direct Pipe® alignment, entry points were selected at the end of the pipeline opposite of MTBM. In some cases, this end is suspended in the air by a crane, which would have required the use of a man lift. In this case, however, the pipe was located at ground level for this project. At the ground level, access was available at three (3) 2-ft x 2-ft square hatches on the MTBM section when the MTBM was not underground. For remaining sceneries access was made into the pipe prior to the welding of consecutive pipelines at the tail end. Finally, if required, a hatch would have been cut into the pipe for alternative exits.

Space Mobility was important for safely and efficiently traveling within the confined space of the pipeline. The main mode of transportation within the pipeline was an Electric Cart Rail System. The rail system runs from the opening of the pipe to the MTBM and stops and starts at each booster pump. In coordination with this rail system was a battery powered cart. This cart was the primary means of travel for the crew within the pipeline. In the event of an emergency, a secondary rescue sled/cart would have be utilized by the rescue team as the primary mode of travel to the patient. Once patient contact was made and the extraction was started, the cart/sled would be left behind, as the electric cart would then be utilized. Refer to *Figure 3 Front and Back View of Electric Cart* and F*igure 4: Interior Pipe Rail and Umbilical Configuration* for project layout within the pipeline.

Figure 3: Front and Back View of Electric Cart.

Communication was critical between each entry and the onsite crews at ground level. All members of the CSRT and the rescue equipment were located at the entry point of the pipe for the duration of all entries. There, a designated attendant kept constant verbal communication with the authorized entrants using a two-way radio. The constant blow of an air horn and/or whistle was also available in the event of radio failure. If there was an absence of communication within a predetermined amount of time, this would constitute a call for help. In that care, the CSRT lead was to notify the onsite Superintendent of an emergency, in which case the local Emergency Response Plan would have been activated for the dispatch of local emergency services.

Air Quality Monitoring inside the pipe was tested and evaluated before each entry and then monitored constantly throughout the duration of the entry. Monitoring data consisting of oxygen, LEL, and toxicity levels was recorded frequently. This monitoring was conducted at both ends of the pipe as well as on the intake of the air compressor so as to not contaminate the space with nearby gases. Testing was conducted continuously by a sensor located downhole near the MTBM and the readings were continuously displayed inside the drillers shack. Additionally, a personal monitor was worn by each entrant and CSRT member and levels were reported back during all communications. In addition, the temperatures inside the pipeline and the exterior temperatures were monitored and ranged between approximately 80°F - 120°F.

Figure 4: Interior Pipe Rail and Umbilical Configuration.

Ventilation inside the product pipe was provided by feeding compressed atmospheric air inside the Direct Pipe® machine. The type of ventilation used was determined by the phase of the operation in which the entry took place. During the initial connection of the MTBM to, and removal from, the pipeline, forced ventilation and exhaust techniques via multiple air movers/ blowers was used. Air flow movement was regulated to a minimum of 200CFM in accordance to 29 CFR 1926.800 and 29 CFR 1910.146. During all entry scenarios where the MTBM was located below the surface, Grade D breathable air was pumped down the pipe via a 2-inch hardline, and an air mover/ blower was placed at the entry of the pipe for exhaust ventilation. This technique provided continuous circulation of Grade D breathing air throughout the length of the pipeline.

Low profile self-contained breathing apparatus (SCBA's) were available to be used if any atmospheric hazards were identified. These SCBA's have the ability to connect to an alternative air source. This air source was a compressed cylinder filled with Grade D breathing air and was provided to the rescuers with an additional supply of Grade D breathing air, ultimately allowing more time for the CSRT to perform the rescue. Refer to *Figure 5: Breathing Air Cylinder and Manifold Securely Fastened to Electric Cart* and to *Figure 6: Ventilation and Man Entry* for photographs of active entry as detailed below.

Figure 5: Breathing Air Cylinder and Manifold Securely Fastened to Electric Cart.

Finally, though no emergencies were encountered during the duration of this project, a ***Contingency Plan*** was created in the event of an emergency. First, all able entrants needed to exit the space immediately. The CSRT Lead would take control of the entry and assume rescue command and give orders to Rescue Team member 1 and Rescue Team member 2 as deemed necessary. The pre-identified Rescue 1 Personnel and Rescue 2 Personnel were to stand by at the ready near the entrance of the Confined Space. Once hazards were mitigated and any available information was received the Rescue Team Lead will give the order to proceed with the rescue. Rescue 1 and Rescue 2 were to proceed into the pipe along with appropriate rescue gear via the custom sleds/ carts. Frequent status checks were to be made to the CSRT Lead or entrant attendant via the radio or hard lined phone system.

Figure 6: Ventilation and Man Entry.

Upon contacting the patient(s) an initial triage assessment would have been made and appropriate first aid measures administered to stabilize the patient(s). A status of the progress of the rescue and patient(s) condition would be given to the CSRT Lead for analysis and possible further communication with EMS services. Once patient(s) were stable, patient packaging or evacuation were to commence. Depending on the rescue needs of the patient, a full rescue stretcher may have been used to extract any incapacitated patients. The packaged patient would have been carefully transferred to the electric cart and over any booster pumps where upon the electric cart would transport the patient out of the pipe. Appropriate First Aid/ CPR, EMR care would have continued to be given to patient(s) if needed or until handover to the local EMS. If multiple entries were to be made by the rescue team, an assessment of the team members, by the Team Lead would have been made to identify lack of strength, heat exhaustion or any signs or symptoms that would potentially hinder a consecutive rescue or harm one or more rescuers. If needed the Team Lead would have exchanged rolls with one of the Rescue members and continue the rescue as outlined above.

Potential rescue scenarios included those medical in nature such as a heart attack, dehydration, heat exhaustion, shortness of breath, stroke, impact injuries, and/or atmosphere contamination including Oxygen deficient/enriched atmosphere. In the case of this project, none of these scenarios were encountered.

3.4 Schedule & Results

Mobilization began 09/19/2017. Foundation and Thruster construction and Direct Pipe® Equipment Set-Up took 34 shifts starting on 09/22/2017 and completing on 11/02/2017. MTMB Assembly & Prep, Launch Seal Installation & Umbilical Installation was completed began on 10/06/2017 and lasted until 11/07/2017 and took 23 shifts. Tunneling operations started on 11/09/2017 and were completed 36 shifts later with punch out occurring on 12/02/2017. Three (3) mid-welds were performed. An additional 7 shifts were used to thrust out the remaining pipe string to the barge completing on 12/14/2017. Finally, umbilical removal and equipment de-mobilization took 16 shifts with all project operations completing on 01/13/2018. A total of 135 shifts were performed for this crossing project. With regards to Confined Space Entries, Refer to Table 3: Breakdown of Confined Entries.

Table 3: Breakdown of Confined Entries.

ENTRY	PLANNED / UNPLANNED	REASON FOR ENTRY	DATE OF ENTRY
Entry 1	Unplanned	Repair Leak	11/23/17
Entry 2	Unplanned	Repair Internals	11/24/17
Entry 3	Planned	Disconnect Internals	11/25/17
Entry 4	Planned	Connect Sections	11/26/17
Entry 5	Planned	Connect Sections	11/26/17
Entry 6	Planned	Verify Connections / Inspect Equipment (2nd Shift)	11/26/17
Entry 7	Unplanned	Equipment Repair	11/29/17
Entry 8	Unplanned	Equipment Repair	12/01/17
Entry 9	Planned	Disconnect Equipment	12/02/17

In total, Laney performed nine (9) confined entries including both planned and unplanned scenarios. The first series of planned entries consisted of four (4) separate entries over four (4) shifts to disconnect internals, make connections and verify those connections. The second planned scenario was completed in one (1) shift to disconnect equipment on 12/02/2017. Four (4) additional unplanned entries were completed to repair leaks, repair internals and repair equipment. In the end, all entries were made safely with no negative results or safety breakdowns.

4. CONCLUSION

In conclusion, the importance of safety is immeasurable for trenchless pipeline construction, particularly for large-diameter Direct Pipe® installations. The Direct Pipe® Method requires Confined Space entry at various stages of project execution which is a dangerous and challenging aspect of pipeline construction requiring extensive planning during early project planning throughout construction execution. In response to this safety challenge, Laney Directional Drilling has worked extensively to develop a State-of-the Art Direct Pipe® Confined Space Rescue Plan. This plan was designed to provide the Confined Space Rescue Team (CSRT) personnel with an understanding of customer operations and the site specific rescue methods to ensure a safe and effective rescue within a Confined Space (CS).

In conclusion, Confined Spaces represent major health and safety risks for construction workers. Recognition and planning for Confined Space work can mean the difference between a job well done and disaster. It is necessary measures to protect workers functioning within them. Buy-in of all construction stakeholders including project owners, engineers, pipeline contractors and trenchless professionals is key to executing projects safely.

5. REFERENCES

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