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APPLICATIONS

## Horizontal Directional Drilling

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Since its first use in the early 1960s, Horizontal Directional Drilling (“HDD”) has become a fast-growing trenchless technology that provides certain benefits over traditional open-cut installations for pipelines transporting water, wastewater, and other liquids. HDD minimizes disruption to vehicular and maritime activities, can require less time and working space, and reduces surface disruptions and restoration requirements without interfering with existing infrastructure.

The use of Ductile iron pipe in HDD applications continues to grow as engineers and utility owners recognize the benefits Ductile iron pipe provides compared to substitute pipe materials.

Ductile iron pipe restrained joint systems provide a better distribution of thrust forces around the bell and barrel of the pipe. Acting like a chain during the pullback process, the axial tension normally experienced in pipelines with joints that are welded or fused is minimized.

The high material strength of ductile iron allows greater pullback forces during HDD installation, while its relative buoyancy in drilling fluids can reduce the required pullback forces compared to other pipe materials.

Ductile iron pipe has the capability of accommodating a radius of curvature due to the available angular deflection of the joints. Because of its flexibility and ease of assembly, Ductile iron pipe can be installed using either the cartridge method, where pipe lengths are added as the pull is made (Figure 1) or the assembled-line method more typical of HDD installations (Figure 2). The cartridge method provides an exceptional advantage for efficiently installing pipes in limited easements and right-of-way locations.

Additionally, polyethylene encasement of Ductile iron pipe is compatible with HDD installations. Normal, IL has used HDD to install several Ductile iron pipelines. According to Steve Gerdes, Water Director for Normal IL, “...the polyethylene encasement used in the HDD installations was intact at every excavation point and we had 30

excavations of pulled pipe for installation of taps, fire hydrants, and valves. So, there’s no question of the ‘polywrap’ making it through the pull.” (Ingram, 2006)



Figure 1: HDD cartridge method with Ductile iron pipe



Figure 2: HDD assembled-line method with Ductile iron pipe

## Procedure

Referring to Figures 3 and 4, HDD is a trenchless construction method that involves drilling a pilot hole using technology that allows the drill to be steered and tracked from the surface. After completing the pilot hole, a back reamer is attached to the pilot hole rods and pulled through the pilot hole to enlarge it. This is repeated until the bore path is sufficiently large to pull the pipe through. At that point, the pipe is attached to the drill stem and pulled back through the enlarged hole to the entrance pit.

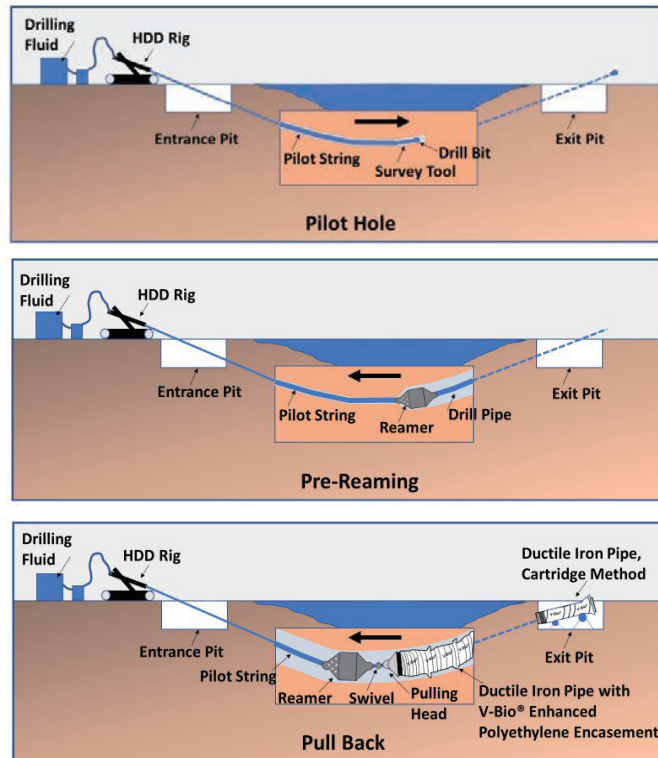


Figure 3: HDD Stages



Figure 4: HDD boring machine - courtesy of Trenchless Technology Magazine

## Pilot Hole

The pilot bore is launched from the surface at an angle between 8 and 20 degrees to the horizontal, then transitions to horizontal as the required depth is reached. A bore path of gradual curvature or near-straight alignment is normally followed to minimize friction and to stay within the allowable joint deflection and curve radius for the pipe. This minimizes the chance of getting the pipeline “hung up” in the soil or damaging the pipe.

## Reaming

To achieve the appropriate bore path size, it may be necessary to perform several reaming operations. Generally, all reaming procedures prior to the actual product installation are referred to as pre-reams. The final ream to which the Ductile iron pipe is attached is referred to as the back ream. Back reamers are available in various sizes and types, based on the size of the pipe and ground conditions.

For distribution sizes, the final bore path size should be approximately 1.5 times the largest outside diameter of the new pipe, which is typically the outside diameter of the bell. For larger sized pipe, add approximately 12 inches to the largest OD.



Figure 5: Attaching back reamer and swivel connection to Ductile iron pipe



## Pullback

After the pre-reams, the pulling head and connected Ductile iron pipe are attached to the reamer using a swivel, a device that isolates the pipe from the rotation of the HDD drill pipe (Figure 5). This prevents transmission of torsional loads to the pipe. The Ductile iron pipe is then pulled behind the final reamer back through the bore path to the desired final pipe depth and location, exiting at the pit on the rig side. The pulling head is then removed and the directionally drilled pipe may then be connected to the rest of the pipeline to continue the job (Figure 6).



*Figure 6: Ductile iron pipe pullback — entering the bore path*

## Drilling Mud

Drilling fluids, also known as “drilling mud,” normally utilized in HDD applications are characterized by their viscosity, gel strength, filtration, fluid loss, fluid density, pH, and lubricity. The principal functions of drilling fluids used in HDD are:

1. Stabilizing the bore path, especially in loose or soft soils, by building a low-permeability filter cake and exerting a positive hydrostatic pressure against the bore path wall. The filter cake and positive hydrostatic pressure reduce obstruction of the bore path and prevent

groundwater from seeping into the bore path. They also prevent drilling fluids from exiting the bore path.

2. Transporting drill cuttings to the surface by suspending and carrying them in a slurry that flows in the annulus between the bore wall and the Ductile iron pipe.
3. Cleaning build-up on drill bits or reamer cutters by directing fluid streams at the cutters.
4. Cooling the downhole tools and electronic equipment.
5. Lubricating to reduce the friction between the pipe and the bore wall.
6. Providing hydraulic power to downhole mud motors.

The proper drilling fluid mixture and delivery pressure are typically formulated for the anticipated geological conditions. For simplicity, soil conditions may be defined as either a coarse soil, such as sand and gravel, or a fine soil, such as clay, silt, and shale. In general, for coarse soils, bentonite is the primary additive, which is a naturally occurring clay mineral that forms a mud when mixed with water. For fine soils, polymers or other materials (possibly added to a bentonite base) are usually recommended.

Drilling mud mixing systems are usually used to feed the HDD rigs with mud (Figure 7). These systems consist of a hopper equipped with a bag cutter used to empty powder bags like bentonite, a tank to store the drilling fluid, and a pumping system to circulate and mix the drilling mud product.



*Figure 7: Drilling mud mixing systems*



## Installation Methods for HDD of Ductile Iron Pipe

Actual installation of Ductile iron pipe in an HDD application involves maintaining an unobstructed bore path that the pipe is pulled through as smoothly and quickly as possible. HDD installations with Ductile iron pipe have an advantage over other pipe materials since the installation can be readily accomplished by either the cartridge method, unique to segmented pipe like Ductile iron pipe, or an assembled-line method where pipes are pre-assembled on an adjacent right-of-way, then pulled in as a single unit.



Figure 8: Cartridge method

### Cartridge Method

Ductile iron pipe's flexible restrained joints are quickly and easily assembled for "cartridge" installations where limited space is available. The cartridge method involves connecting the joints during installation, one at a time, and is preferred in locations where rights-of-way or easements are limited (Figures 8 and 9). Ductile iron pipe restrained joint systems can be assembled as the drill string is retracted. During pull-back the joint assembly normally takes about the same time that it takes to disassemble the drill stem sections, store them on the rack and make up the connection to the next drill rod. This installation method requires significantly less space or right-of-way than the assembled-line method.

When using the Cartridge method for installing Ductile iron pipe, the field crew makes up the next restrained pipe joint in the trench when the drill operator stops the machine to change out the drill rod.



Figure 9: Cartridge method with Ductile iron pipe

### Assembled-Line Method

The assembled-line method involves stringing out the connected pipe on the ground or on rollers prior to pull-back (Figure 10). With this method it is necessary to have substantial space available to pre-string the pipe above ground in alignment with the end of the drill path. This is normally the only option for welded-steel and fused-joint PVC and polyethylene pipes due to the significant



Figure 10: Assembled-line method, pipe built on polyethylene and covered with drilling fluid to facilitate installation

time required to position and properly weld or fuse individual pipe sections. Since polyethylene encasement is a part of HDD installation, a layer of polyethylene on the ground where the assembled line is readied can reduce the friction between the pipe and the earth.

### Encasing Ductile Iron Pipe in V-Bio® Enhanced Polyethylene

After making up the restrained joint, be sure the V-Bio® enhanced polyethylene encasement is properly overlapped using Modified Method A for Wet Trench Conditions as described in ANSI/AWWA C105/A21.5 (AWWA 2018) and in DIPRA's brochure "[Polyethylene Encasement.](#)"



Figure 11: Pipe has been pulled through the bore path, ready to attach to the remainder of the pipeline

### Joint Applications and Deflections

Flexible restrained joints (Figure 12) are the key to successful installations of Ductile iron pipe by HDD. These joints result in good distribution of thrust or pulling forces around the bell and barrel of the pipe and offer greater allowable pulling forces than other pipe options. They also relax longitudinal bending moments and do not add axial tension or compression (Ariaratnam, 2003).

A radius of curvature can be accommodated with Ductile iron pipe (Figure 13) through longitudinal angular deflection of these flexible restraint joints. When using the assembled-line method, the joint deflection capability allows the contractor to lay the pipe on rollers on sites

where sweeping turns are required or changes in ground level exist (Figure 14).

[DIPRA member companies](#) have proprietary flexible restrained joints that they recommend for HDD applications. Contact the individual member company manufacturers for their recommended joint for your project. They can provide maximum deflections, pulling capacities, etc., that you may need for your design. Some of the joints that are recommended for HDD installations by DIPRA member companies are shown below in Figure 12.

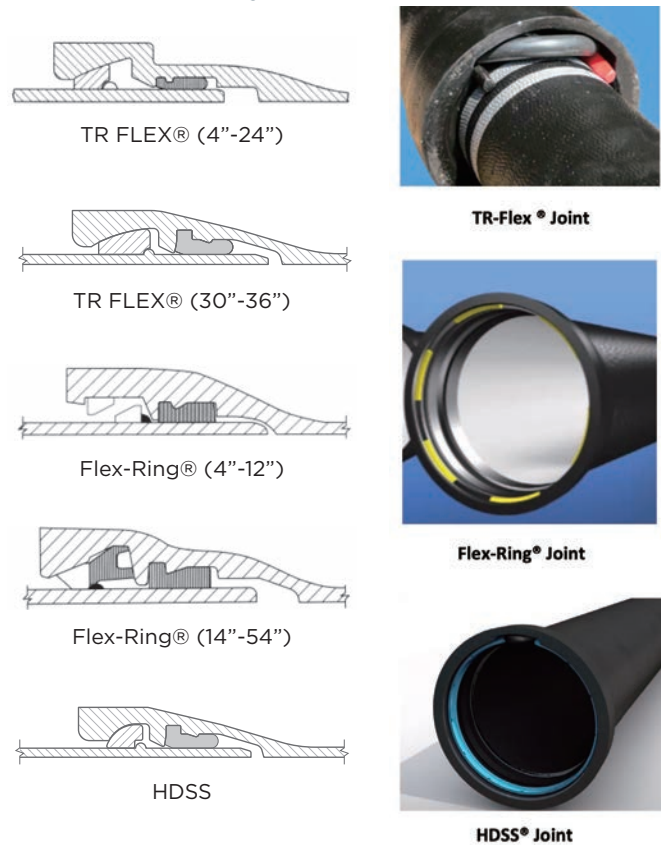


Figure 12: Flexible Restrained Joints

Gripping push-on joint gaskets that utilize stainless- steel teeth locking segments are *not recommended* for HDD installations.

### Radius Pulls

The preparation site and drill path must be designed so that the manufacturer's allowable deflection for the Ductile iron pipe joint is not exceeded when the pipe is pulled into position. When crossing a body of water, for example, HDD pulling operations can be easier to install than restrained joints with similar deflection



capabilities installed in an open-cut installation. Contractors cannot as readily over-deflect the joints in the HDD pulling operation.

The normally close-fitting horizontal directional drilling bore path effectively restricts lateral movement of the joints and pipes. Unlike welded or fused-pipe strings, the restrained joints of Ductile iron pipe are flexible. They act like a chain. By conforming to a properly designed radius of curvature of a Ductile iron pipe bore path, the applied pulling load creates little or no added tensile stress in the walls of Ductile iron pipe due to bending moments. With Ductile iron pipe, the primary design concern in pulling the pipe through a properly designed radius of curvature is the pulling load encountered, plus any impact effects, if applicable (Conner, 1998).

Some pipe manufacturers may caution against extremely long curved pull radii and recommend that radius turns be made with several straight pulls to eliminate the possibility of over-deflecting the joints and exceeding the maximum pulling force. Also, the manufacturers generally recommend some reduction of the maximum joint deflection to allow for future movement in the deflected direction and for unknowns during construction. In practice, the radius of curvature for Ductile iron pipe HDD installations is typically minimized because the pipe feed and receiving pits are dug to a normal pipe depth, thus minimizing the radius of curvature. Table 1 shows maximum allowable radii of curvature as a function of the available joint deflection for 18- and 20-foot lengths of pipe.

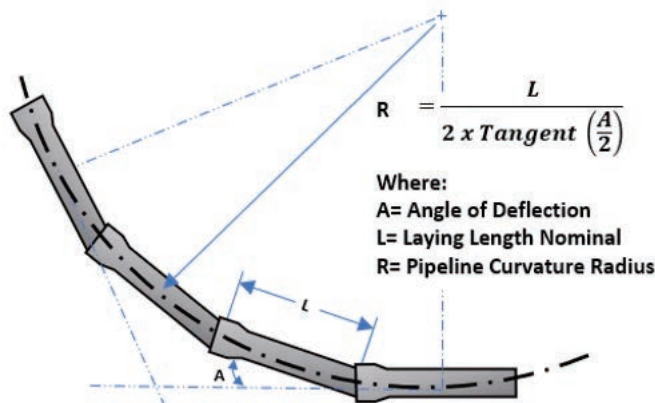


Figure 13: Radius of curvature of Ductile iron pipe



Figure 14: Sweep turns with Ductile iron pipe, shows radius of curvature.

**TABLE 1**  
**Minimum Allowable Radius of Curve**

Maximum Allowable Joint Deflection (degrees)	Minimum Allowable Radius of Curve For 18-Foot Pipe (feet)	Minimum Allowable Radius of Curve For 20-Foot Pipe (feet)
1.50	688	764
1.75	589	655
2.00	516	573
2.25	458	509
2.50	412	458
2.75	375	417
3.00	340	380
3.25	317	352
3.50	295	330
3.75	275	305
4.00	258	285
4.25	243	270
4.50	229	255
4.75	217	241
5.00	205	230

### Pipe Bore Path Friction

Case histories have given indications “that pulling loads were less for Ductile iron pipe than they typically were for similar size HDPE pipe (Carnes 2002).” One reason for this is that the bulk density of empty Ductile iron pipe is normally closer to that of the soil/fluid slurry than it would be with lighter pipe materials. Therefore, there may often be lower normal forces from gravity or buoyancy to result in increased friction against the walls of the bore hole as the Ductile iron pipe is pulled back (Ariaratnam, 2003).

Substitute pipe materials that are lighter than Ductile iron pipe are also more buoyant, which may result in increased friction due to the pipe contacting the top of the bore path. As such, it may be necessary to fill the pipe with water or other ballast to reduce the borehole friction and pull-back forces for those pipes.

In HDD installations, restrained joint pipe bells can be oriented to minimize friction of the bell in pulling through the bore hole. This allows the drilling fluid and excavated material to flow easily over the smooth contour of the bells. With low-profile, internal ring joint designs this is normally the spigot-forward orientation, but may vary by joint design. For more information [DIPRA member companies](#) should be consulted.

### **Pulling Force Capability**

Today, some HDD machines are capable of tremendous pulling forces. The pipe joint must be capable of withstanding those forces. DIPRA member company proprietary restrained joints recommended for HDD applications have substantial strength, which results in a high pull capacity. Contact the individual member companies for their recommended maximum allowable pulling force.

### **Pulling Head**

After the pre-reaming operations have been completed, a swivel connector is attached between the final reamer and the pulling head (Figure 15). The pulling head is then attached to the spigot end of the first piece of pipe. There are many different pulling head designs. Pulling heads may be fabricated by the installer or obtained from the pipe manufacturers.

### **Corrosion Control**

If the native soil or drilling mud is considered corrosive to Ductile iron pipe, corrosion protection is warranted. Numerous HDD installations and inspections have demonstrated that Ductile iron pipe can be successfully installed when encased in polyethylene that meets the ANSI/AWWA C105/A21.5 standard. With some minor modifications, “Modified Method A for Wet Trench Conditions” as described in ANSI/AWWA



*Figure 15: Pulling head attached to polyethylene encased Ductile iron pipe*

C105/A21.5 (AWWA 2018) should be specified for applying polyethylene encasement to Ductile iron pipe for HDD installations.

The initial length of pipe will require the polyethylene tube to be securely attached to the spigot end of the pipe barrel using an appropriate tape. The tape should be applied directly, attaching the polyethylene to the barrel of the pipe. Several circumferential wraps of tape should be provided to secure the encasement along the length of pipe. This will help control any tendency for drilling fluids or cuttings to get under the polyethylene tube. When applying polyethylene encasement to the assembled joint, the polyethylene overlap should be placed so that the forward pipe’s polyethylene tube overlaps the polyethylene installed on the next adjacent pipe. This is to ensure that drilling fluid and cuttings are not forced under the polyethylene tube during the pull-back.

Using Modified Method A, there will be full circumferential wraps of tape around the barrel of the pipe at two-foot intervals. An alternative fastening method would be to continuously wrap tape spirally around the polyethylene on about one-foot centers (Figure 16). This permits air to escape at the overlap as the hydrostatic pressure of the drilling fluid applies a uniform pressure around the pipe.





Figure 16: Spiral installation of V-Bio® enhanced polyethylene encasement on Ductile iron pipe

DIPRA and others have inspected polyethylene encasement installed using this procedure with excellent results (Figures 17, 18 and 19):

*“...One of the primary concerns at the beginning of the project was to ensure that the polyethylene encasement made it through HDD process. While excavating the new water main to install 550 taps our concerns were put to rest when not a single instance was observed where the polyethylene encasement had been pulled or torn from the pipe, confirming that when properly installed, polyethylene encasement is a reliable measure for corrosion protection in HDD applications...”*  
*Paper A-1-05-7, NoDig Show 2012*

Horizontal directional drilling installations of Ductile iron pipe generally originate at a prepared assembly area immediately adjacent to the pipe pull-back entry pit. This allows for the polyethylene-encased pipe to immediately enter the slick, lubricating drilling fluid without being dragged on rough ground that could damage the encasement. Once the pipe is pulled into place, the pulling head is removed and further pipe installation can continue. If determined necessary



Figure 17: Polyethylene inspection and tapping on Ductile Iron pipe



Figure 18: Exposed V-Bio® enhanced polyethylene encasement after HDD installation—Polyethylene encasement uncompromised from installation



Figure 19: Exposed polyethylene encasement after HDD installation—Polyethylene encasement uncompromised from installation

by the [Design Decision Model](#), corrosion control for Ductile iron pipe installed by the HDD method can also be provided using sacrificial anodes or impressed current cathodic protection systems. This requires bonding the joints to provide electrical conductivity along the pipeline to be cathodically protected (Figure 20).

## Conclusion

Successful HDD installations have firmly established flexible restrained joint Ductile iron pipe as a viable, even superior, trenchless pipe option. The advantages of using flexible restrained joint Ductile iron pipe for HDD installations include (Ariaratnam, 2003):



*Figure 20: HDD Installation using bonded joints*

1. Standard pressure capabilities up to 350 psi (greater upon special request).
2. Great material strength for handling pull-back and external dead and live loadings.
3. Better distribution of thrust or pulling forces around the bell and barrel.
4. Greater allowable pulling forces than other pipe options.
5. Generous allowable joint deflections.
6. Quick, easy joint assembly.
7. “Cartridge” installation options for easier handling in limited easements.
8. Can be located from surface with commonly used locating equipment.
9. Performance capabilities are not impacted by elevated temperatures or the duration of pull.
10. Material strength that does not creep or decrease with time.
11. Ductile iron pipe’s wall is impermeable to volatile hydrocarbons, minimizing the potential of water system contamination.
12. No significant residual bending stresses remain in the pipe after the pull-back.
13. No significant “recoil” or pipe movement due to thermal expansion, allowing the pipe to be directly connected to existing infrastructure after the pull is complete.
14. Eliminates potential for shearing of tapped lateral outlets due to thermal expansion and contraction.

With the increasing demand for water and wastewater infrastructure and a movement to reduce the impact on the public that is often associated with open-cut construction, trenchless installation using HDD will certainly play an increasing role. For these installations, public works personnel and contractors have the option of installing superior Ductile iron pipe and, in so doing, making the right decision for their rate paying customers.





## References

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For more information contact DIPRA or any of its member companies.

### Ductile Iron Pipe Research Association

An association of quality producers dedicated to the highest pipe standards through a program of continuing research and service to water and wastewater professionals.

P.O. Box 19306  
Birmingham, AL 35219  
205.402.8700 Tel  
[www.dipra.org](http://www.dipra.org)

### Member Companies

AMERICAN Ductile Iron Pipe  
P.O. Box 2727  
Birmingham, Alabama 35202-2727  
[www.american-usa.com](http://www.american-usa.com)

Canada Pipe Company, Ltd.  
55 Frid St. Unit #1  
Hamilton, Ontario L8P 4M3 Canada  
[www.canadapipe.com](http://www.canadapipe.com)

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Coshocton, Ohio 43812-6001  
[www.mcwaneductile.com](http://www.mcwaneductile.com)

U.S. Pipe  
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