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Ductile Iron Pipe For Horizontal Directional Drilling A Successful Paradigm Shift

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ABSTRACT: The Canyon Regional Water Authority, New Braunfels, Texas, contracted with Holloman Corporation, Converse, Texas, for construction of a major system expansion that included a combination of 35,242-linear feet of 24-inch and 41,625-linear feet of 30-inch ductile iron pipe. Along the planned route there were four (4) sections designed as horizontal directional drilling (HDD). The originally designed HDD installations required transitions from ductile iron pipe to high-density polyethylene (HDPE), the perceived standard piping material for HDD.

Having identified this material paradigm within the trenchless industry, one of the co-authors, a principal of Holloman Corporation, approached the engineer to request a material change for the HDD portions of the new transmission system. Informed about the suitability of ductile iron pipe for trenchless installation[i], a submittal was initiated which proposed that the HDPE pipe be replaced with AMERICAN's Flex-Ring® flexible restrained joint ductile iron pipe for the HDD portions of the project. This requested change was extensively evaluated by the owner and engineer, whose affirmative decisions to proceed started the momentum of this paradigm shift. This paper will discuss the process by which the material change was evaluated from an engineering perspective, and from the perspective of the installing contractors, and the constructibility issues with installing ductile iron pipe by HDD.

INTRODUCTION: Canyon Regional Water Authority (CRWA) was created in 1989 by the 71st Texas Legislature to acquire, treat and deliver potable water to its member entities. To the four original member entities including Green Valley Special Utility District (GVSUD), Springs Hill Water Supply Corporation (SHWSC), Crystal Clear Water Supply Corporation (CCWSC) and East Central Water Supply Corporation (ECWSC), the Cities of Marion, Cibolo, La Vernia, and Martindale and Bexar Metropolitan Water District (BMWD), Maxwell Water Supply Corporation (MaxWSD), and County Line Water Supply Corporation (CLWSC) were added later. The number of member entities now totals eleven. David Davenport, the general manager for CRWA, is responsible for coordinating CRWA's Mission. The mission of the authority also includes the responsibility to encourage water conservation, reduce the reliance on a future uncertain supply of groundwater, and to protect, preserve and restore the purity of water.

In October 2000, CRWA received notice of approval for a $35,000,000 loan from the Texas Water Development Board for improvements to the Authority's water distribution system. River City Engineering (RCE), the Authority's engineer, in their preliminary system study required approximately 90,000' of 24" and 12" pipe. Final design of Phase II of the Mid-Cities Transmission Project was the responsibility of Roger Engelke, P.E., project manager and primary contact for CRWA. This phase of the two part Mid-Cities Water Regionalization Project, Phase II-B Transmission Lines, included the construction of what would ultimately include 42,000' of 30" and 38,000' of 24" ductile iron pipe, and four of the longest horizontal directional drill (HDD) installations of larger diameter ductile iron pipe accomplished at that time. Now this completely ductile iron pipe transmission line segment is part of a system that will bring treated water from CRWA's Lake Dunlap, on the Gaudalupe River in McQueeney, Texas, to portions of northeast Bexar County.

PRE-BID/POST BID: During October-November, 2003, CWRA advertised and accepted bids for Phase II-B Transmission Lines. Project bid documents prepared by River City Engineering established a base bid of ductile iron pipe requiring a minimum working pressure of 170 psi with a 100 psi surge pressure.

CRWA and RCE, cognizant of several potentially environmentally sensitive crossings of Saltrillo Creek, Woman's Hollow Creek, and a crossing of a wetland area, also included an additive alternate for pipeline installation by horizontal directional drilling (HDD). The project specifications required that only high density polyethylene (HDPE) was a consideration for the trenchless installation portion of the project. However, atypical to most specifications (by others), RCE clarified that the minimum ID for the 30" installation would be 30" and the same concept for 24" installation, the minimum ID would be 24". This would require, one nominal size larger for both the 30" and 24" crossing to obtain similar flow property inside diameters and volume from substitute pipe materials, especially HDPE (see Table 1).

Table No. 1 - Ductile Iron Pipe vs. HDPE Dimensions

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On November 13, 2003, CRWA opened bids on Phase II-B, which was estimated at $7,220,000 by RCE. Holloman Corporation, San Antonio, Texas, was the lowest, responsible bidder having submitted a bid of $5,128,000 for the ductile iron pipe "Base Bid (see Table No. 2)." American Ductile Iron Pipe would be supplying the ductile iron pipe to Holloman Corporation.

Table No. 2 - Project Bid Results

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River City Engineering made a recommendation to CRWA to accept Additive Alternate No. 1 and have approximately 3,500' of 30" and 24" high-density polyethylene pipe installed using horizontal directional drilling. Holloman Corporation chose Trans American Underground (TAUG) – HDD as their sub-contractor of choice for installing the transmission line using HDD. Holloman personnel had experience working with TAUG-HDD and their reputation in the industry is outstanding. Steve Gerdes, from Normal, Illinois, who has a significant amount of experience in HDD installation of water lines, has said "the key to any successful HDD installation is directly related to the quality and expertise of the HDD contractor."[i] Although Mr. Gerdes was referring to a different HDD contractor, his words of wisdom would prove to be the applicable on the Mid-Cities transmission main project as well.

VALUE ENGINEERING: Holloman Corporation key personnel routinely attend programs and conferences where technical papers related to underground construction are presented. In the paper "The Versatility of Ductile Iron Pipe in Trenchless Construction"[ii], Carpenter and Conner describe how AMERICAN Flex-Ring®, flexible restrained joint ductile iron pipe (see Figure No. 1) had been used in installations using HDD. Rodney Schwarzlose (one of the authors of this paper) stated that, "Our initial motivation for changing the HDD portion of the project from HDPE to ductile iron pipe was obviously a cost saving in the material. Therefore, we were interested in a cost benefit analysis between HDPE and ductile iron pipe, weighing the pros and cons in respect to price difference for materials, installation, and the feasibility of the HDD methodology with larger diameter ductile iron pipe."

Now a paradigm is defined as a "clear or typical example"[iii] and the paradigm in this situation is the clear example that, in the water industry, ductile iron pipe is usually preferred for every tough installation methodology, e.g.: open-cut, river crossing, pipe bursting, aerial crossing, high pressure, deep bury, shallow bury, rough or rocky trench, extreme live loads, etc., but the one significant, <u>perceived</u> exception is HDD. It was clear to Holloman personnel that any change in pipe materials ultimately had to be approved by David Davenport, general manager, Canyon Regional Water Authority, with technical support from River City Engineering.

Holloman, having completed the cost-benefit analysis that firmly supported the flexible restrained joint ductile iron pipe option, initiated the value engineering change by contacting AMERICAN for reference information related to applicability of AMERICAN Flex-Ring joint pipe for HDD. The information that AMERICAN provided included: numerous technical papers (several are referenced throughout this document) presented at such venues as the ASCE Pipeline Division Conference, No-Dig, and UCT; "Suggested General Guidelines Horizontal Directional Drilling (HDD) Installations of Ductile Iron Pipes"[iv], and a list of reference for completed projects. Next they submitted this information to RCE Project Manager for review and consideration. Following several telephone and in-office conferences it was clear that RCE and CRWA both were very interested in having a transmission line consisting of first, their preferred material, ductile iron pipe, and secondly, having one single pipe material for the entire transmission line. The final decision came down to evaluating two issues; the first was related to the ability of the Flex-Ring joint to withstand the pulling loads during pullback through the borepath; the second issue specifically questioned the ability of the polyethylene (PE) encasement to survive undamaged after being pulled through the borepath. The PE would be required on the pipe due to the corrosive nature of the insitu soil.

Holloman's strategy addressed both issues with the assistance of AMERICAN. The ability of the Flex-Ring restrained joint to handle the pullback loads was addressed by researching the joint capabilities along with an estimate of the pullback loads. "The capability of the joint is best explained by using a finite element analysis (FEA) of the Flex-Ring joint that confirms the ability of the joint to effectively distribute the thrust or pulling loads (Gaines and Oliver 2002). Confirmation of this analysis was made possible by hydrostatically testing, to failure, Flex-Ring pipe in straight and fully deflected alignment. When taken to actual failure the deflected configuration failed within 10 to 20 psi of the failure pressure in straight alignment with virtually identical failure modes."[i] The FEA provides an indication that the stresses are uniformly distributed through the joint and into the pipe barrel. Ariaratnam and Carpenter summarized the capability of the Flex-Ring joint as follows: "This distribution is critical in HDD installations in that it dramatically reduces any concentration of stress around the joint and pipe barrel during pullback."[i]

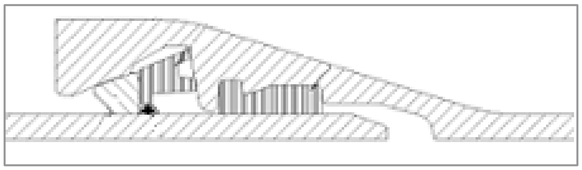
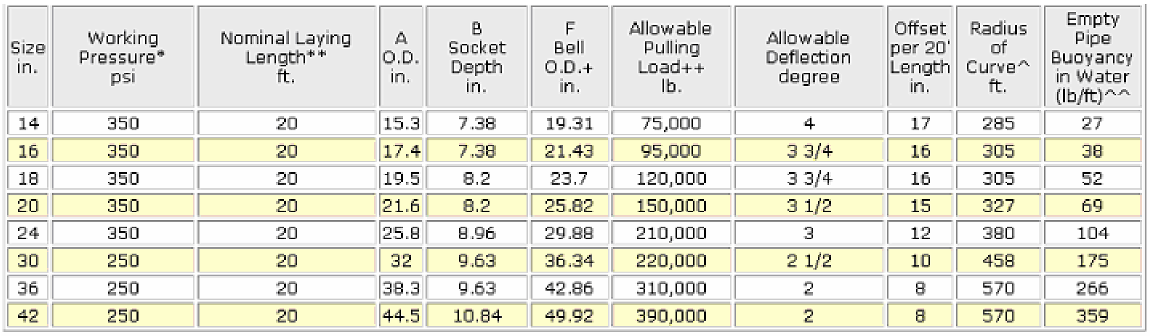


Figure No. 1 - 14" - 42" Flex-Ring



Size in.	Working Pressure* psi	Nominal Laying Length** ft.	A O.D. in.	B Socket Depth in.	F Bell O.D.+ in.	Allowable Pulling Load++ lb.	Allowable Deflection degree	Offset per 20' Length in.	Radius of Curve^ ft.	Empty Pipe Buoyancy in Water (lb/ft)^^
14	350	20	15.3	7.38	19.31	75,000	4	17	285	27
16	350	20	17.4	7.38	21.43	95,000	3 3/4	16	305	38
18	350	20	19.5	8.2	23.7	120,000	3 3/4	16	305	52
20	350	20	21.6	8.2	25.82	150,000	3 1/2	15	327	69
24	350	20	25.8	8.96	29.88	210,000	3	12	380	104
30	250	20	32	9.63	36.34	220,000	2 1/2	10	458	175
36	250	20	38.3	9.63	42.86	310,000	2	8	570	266
42	250	20	44.5	10.84	49.92	390,000	2	8	570	359

Table No. 3 - 14" - 42" Flex-Ring Dimensions and Capacities

When calculating pullback force necessary to overcome the resistance of the ductile iron pipe being pulled through the borepath, the designer, in the most simplistic terms, needs to take into consideration the length of pipe being pulled back, the unit buoyancy of the pipe (empty) within the fluid filled borepath, and an appropriate coefficient of friction. The equation (Equation No. 1) below allows the designer to calculate the approximate required pulling force necessary for the pipe to be pulled in on relatively gentle radii.

Equation No. 1 - HDD Force Required for Pullback

$$F_P = \mu (W_B)(L)$$

Where: F_P = pulling force, lbs.
μ = coefficient of friction between pipe and slurry between pipe and ground (typically 0.40*)
W_B = net unit downward (or upward) normal force on pipe, lb/ft
L = pull length, ft

*Note: While pulling tests have indicated coefficient of friction between polywrapped ductile iron pipe coupons and soil/mud mixes can be very low (on the order of approximately 0.10)[v], a higher, more conservative coefficient is traditionally assumed for more design conservatism, and to account for other complex factors that might somewhat increase loads.

River City Engineering designed each of the HDD installations with varying lengths with the longest consisting of 1,000' of 30" pipe. Based on this length the required pullback force was calculated to be approximately 70,000 lb.

$$F_P = \mu (W_B)(L) \qquad \text{(Equation No. 1)}$$

Where: F_P = pulling force, lbs.
μ = 0.40
W_B = 175 lb/ft
L = 1,000 ft

$$F_P = 0.40(175)(1{,}000)$$

$$\boxed{F_P = 70{,}000 \text{ lb}}$$

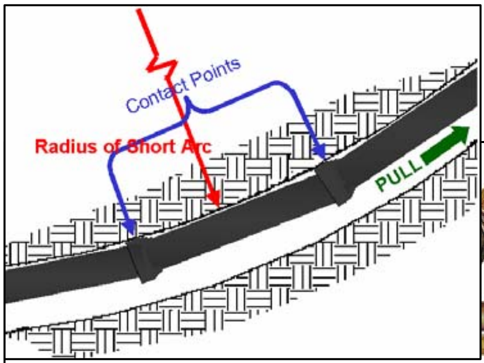


Figure No. 3 - Borepath

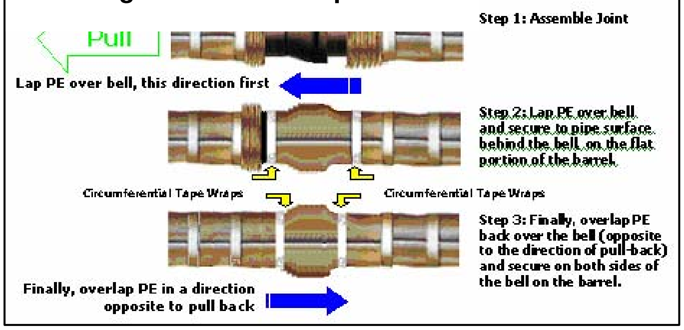


Figure No. 2 – Application PE Encasement

Comparing the calculated pullback force required for 1,000' of 30" ductile iron pipe, 70,000 lb, with the allowable pulling load from Table No. 3, 220,000 lb, it was easy for CRWA and RCE to see the substantial capacity of Flex-Ring joint ductile iron pipe for this application and to resist the pulling force exerted on the pipe during pullback while effectively redistributing the load around the bell and allowing joint articulation or flexibility up to 2-½ degrees per joint.

According to Holloman personnel, the issue regarding the concern about the survivability of the PE encasement was adequately addressed "with the help of AMERICAN who had historical information showing successful pulls maintaining the integrity of the wraps during installation. We also performed a pre-pull installation with the encasement and protected the first 100' of the 8 mil PE encasement by covering it with pipeline rock shield." Rock shield is an expanded, opened cell PE sheet that is available up to 40 mils in thickness. This sheet is formed over the bell and spigot end of the pipe. That is, pipe which has already been properly wrapped in accordance with AWWA C105, Appendix A and the applicable sections of AMERICAN's "Suggested General Guidelines Horizontal Directional Drilling (HDD) Installations of Ductile Iron Pipes."[vi]

CRWA, RCE, Holloman, and AMERICAN, in discussing the issue of PE encasement survivability, reviewed the detail provided in Figure No. 2. Steps 2 and 3 of this illustration involve the overlapping of the PE encasement resulting in a double thickness. Therefore, if applied as described, the pipe for HDD will always have a double layer of PE encasement over the bell area to resist abrasion and penetration.

Also discussed was the design of the borepath radius. The borepath can be so designed that the points of contact on either the soffit of the borepath, if the pipe has a positive buoyancy, or the invert of the borepath, if the pipe has negative buoyancy, may only be the bell ends of each pipe section as illustrated in Figure No.3, where the protection has multiple wraps. It was further discussed that adding water to the interior of the pipe during the pullback can control the total pipe weight and may approach a state of near neutral buoyancy may possibly be achieved. Along with further minimizing wrap damage this neutral buoyancy condition creates a situation where "there may often be a very limited normal force and corresponding less friction against the walls of the bore hole as the pipe is pulled-back."[vii]

On December 21, 2003, approximately one month after Canyon Regional Water Authority accepted bids on the Mid-Cities Water Transmission line, River City Engineering's Roger Engelke, gave Holloman the notice to proceed with Additive Alternate No 1, except that the pipe material was changed from HDPE to AMERICAN Flex-Ring flexible restrained joint ductile iron pipe. At approximately the same time, AMERICAN personnel informed CRWA, RCE, and Holloman that there were plans being finalized for a trenchless seminar sponsored by South-East Society for Trenchless Technology. The major attraction for this trenchless seminar would be a HDD demonstration at AMERICAN's plant facility.

On the 5th of February, representatives from CRWA, RCE, and Holloman, along with approximately 40 other industry professionals from all over the country attended the seminar demonstration at AMERICAN's 2000-acre facility in Birmingham, Alabama. There they witnessed the installation of approximately 160' of 6" Flex-Ring joint ductile iron pipe water main under several active rail lines servicing AMERICAN's pipe production facility; installed with loose PE encasement applied. Several thousand tons of train traffic, consisting of rail cars carrying raw materials and finished goods, are transported back and forth across these vital tracks every day. The demonstration was extremely successful with the pullback completed in less than 20 minutes. Additionally, after washing the drilling mud from the pipe in the receiving pit, the PE encasement was observed intact and undamaged. Personnel from CRWA, RCE, and Holloman also saw that the project went extremely well, reinforcing their decision to change from HDPE to Flex-Ring flexible restrained joint ductile iron pipe.

Pre-Construction/Construction: Rodney Schwarzlose, in the following statement, summarizes the cautious optimism of some of the Holloman personnel. "The most challenging aspect was making the decision to move forward with an untried installation. While we had the utmost confidence in the data we had gathered as well as confidence in AMERICAN and our HDD subcontractor, Trans American Underground – HDD (TAUG), to our knowledge, no one had completed a HDD of this length with this size ductile iron pipe. Failure would have been extremely costly with the loss of tens of thousands of dollars as well as valuable time."

To assure a successful project AMERICAN personnel initiated contact with Holloman and TAUG to arrange for a pre-construction meeting. It was this initial meeting where the projected HDD borepath lengths were first learned. Keith Whitaker, TAUG president, informed the group that, "We designed these bores on a 1,500' radius and lengths of the 30" borepaths would be approximately 1,020', 806', 692', and the length of the single 24" borepath approximately 960'." Whitaker, also informed AMERICAN that the bores would be completed in that same order. The longest and largest of the bores will be discussed in detail.

Figure No. 4 – Am. Augers DD140

This first HDD installation was the 30" that would run approximately 1,020' along Lower Sequin Road, under Woman's Hollow Creek, and directly adjacent to the runway for Randolph Air Force Base, Northeast of San Antonio, Texas. TAUG mobilized their American Augers DD140 drill along with a MP500 mud system the last week in February 2003 (American Augers has no affiliation with American Cast Iron Pipe Company or any of our divisions or subsidiaries). It is through the capacity of the 5" outside diameter drill rods, which are 30' in length, that the DD140 can reach pullback forces up to approximately 140,000 lb. Despite the fact that AMERICAN's 30" Flex-Ring joint pipe can handle pulling loads up to 220,000 lbs (see Table No. 1), compared to the American Auger machine that can only pull 140,000, there were still several individuals who had to witness the success before they could visualize ductile iron pipe installed using HDD installation methodologies.

The site conditions awaiting TAUG would prove to be challenging as they mobilized. According to National Weather Service data, during the time that the HDD installation was being prepared and installed, San Antonio experienced 1.5" of rain. In spite of poor site conditions caused by the inclement weather, they prepared the borepath by first drilling a pilot bore using a 9" jettable steering head. This 9" head cut through and simultaneously blended the excavated dark gray clay with the drilling fluid, which in this case was just water. All operations were controlled from TAUG's climate control operation trailer.

Having completed the 1,020' pilot bore without incident, TAUG then ran the first of three reamers through the borepath. The function of this reaming procedure is to enlarge the borepath to a final

Figure No. 6 - Borepath Ramp

inside diameter of approximately 44” to 46”. Shortly after beginning the back reaming, and at a depth of approximately 10’, the 24” reamer entered into a zone of cobbles ranging in size from 1” to 4” in diameter. From experience, the operator knew that they most likely hit cobbles as he read a dramatic increase in pressure on the torque gauge that measures the hydraulic pressure on the motor that rotates the drill rod. The operator slowed down the advance of reamer to facilitate the cobbles movement into the water-soil slurry and down the borepath to the exit pits. Once out of this 3’ thick vein the advance of the reamer was once again increased.

Drilling continued with subsequent passes of the 34” then the 44” reamers. Conscious of the importance of a good borepath for subsequent pullback, after the 44” ream was completed, TAUG operators “swabbed” the line by pushing a barrel reamer or packer back through the borepath. Figure No. 5 shows the quality of the borepath prior to the start of the pullback.

After identifying the strata of cobbles and gravels, the drilling process proceeded with little or no excitement with the exception of numerous frac-outs that saw drilling mud oozing through cracks in the ground along the centerline of the pipe’s alignment. A frac-out is leakage of drilling fluid from the borepath to the surface. This was a result of the mixed stiff clays and cobble strata, and it was also a time of year where the ground was very dry and fractured. The drilling fluid is under pressure as it enters the borepath through the 5” drill rods, the fluid mixes with the excavated material, and it normally flows to the exit and pipe assembly pits unless there is a shorter path of least resistance to the surface (which was the case in the “frac-outs”).

As with any construction project, the Critical Path Method (CPM) requires that many operations occur simultaneously to meet the project’s desired completion schedule. Such was the case with the HDD installations for CRWA. As TAUG continued with drilling of the borepath, Holloman’s crew was busy preparing for pipe assembly. On Thursday, March 4th one of the pipe laying crew began by preparing an entrance ramp down to the borepath entrance. The crew used the Cartridge installation method to assemble the pipeline, where one joint at a time is rapidly assembled, the joint wrapped, then immediately pulled into the borepath. This process is repeated until the line is completely pulled into place.

Figure No. 5 - Borepath Opening

In preparation for installation, the pipe was staged conveniently near the borepath entrance ready to be lowered on to the borepath ramp for final assembly. Since each Flex-Ring joint required a Fastite gasket and the rubber-backed flex-ring segments installed into the bell (see Figure No. 1) prior to assembly, the crew pre-installed those components. To complete the pre-installation of the components, the crew then applied the PE encasement. The initial technique used to apply and secure the PE encasement on the first six joints proved to be problematic as will be discussed later. Holloman crewmembers wrapped the pipe with the PE tube and bundled up the excess on the bell end of the pipe. This excess PE encasement was eventually pulled over the bell and secured onto the PE encasement on the pipe being assembled. The next step that the crew members completed was to secure the encasement using cigarette wraps of tape about every 2’ to 3’ according to AWWA/ANSI C105/A21.05 Method A, for installation of ductile iron pipe below the water table.

On Friday, March 5th, multiple sections of 30" Flex-Ring joint pipe were prepared, staged, and ready for pullback, and simply waiting for the final "swabbing" of the borepath, which was not going to be completed until early Friday evening. To maximize the efficiency of the crew and to save assembly time on Saturday morning, Holloman began to assemble the first six Flex-Ring joint pipe sections. These six sections would be pulled across the dark gray clay surface soil as a single unit and onto the borepath ramp. The first piece assembled was the 30" Flex-Ring pulling head; it was assembled onto the first section of flexible restrained joint pipe. With spigots facing forward, the second pipe section was assembled. Joint integrity was checked by interior inspection to assure the gasket was properly seated, flex-ring segments were visually inspected to assure proper seating within the bell socket, and the bunched-up PE encasement on the bell end of pipe No. 1 was finally pulled over the bell (pipe no 1) and taped to the PE encasement on the spigot of pipe No. 2. Note that at that point the PE encasement was not secured to the pipe surface, nor was it securely strapped behind the bell of the first pipe; therefore it was simply a loose sleeve around the pipe barrel.

Figure No. 7
Assembly

With the completion of the swabbing of the borepath, on the following day (Saturday, March 6th) the crew was then ready to make the connections between the drill string, the swivel, and the Flex-Ring pulling head with the first sections of pipe already assembled. First, Holloman had to pull the six section pipe string, that was pre-assembled on Friday, up closer to where the drill string could be extended to facilitate the connection of the swivel to the pulling head. When Holloman moved the pipe over the soft, plastic, gray clay soil a problem alluded to previously became apparent. The pipe moved, but the PE encasement, which was simply an unsecured (no connection to the pipe surface nor secure strapping in the joint areas) sleeve over the pipe, remained in place. This turned out to be an opportunity for the Holloman-TAUG-American Team (Team) to solve what really was a very simple problem with a very simple solution.

The first thing that needed to be accomplished was to secure new PE encasement for the first six sections. This was done by first excavating a pit approximately 2' deep that was perpendicular to the borepath ramp. Then six sections of PE encasement were bundled in an "accordion" fashion, and placed over the nose of the pulling head. After the swivel was attached to the pulling head the pipe was pulled toward the borepath opening and the first bundle of PE encasement was secured to the pipe surface with multiple wraps of pvc tape making sure that the tape was alternated between the pipe surface to PE tube. As the pipe was pulled back, the bundles of PE encasement were moved along the pipe barrel, and in similar fashion, additional sections were secured (taped) to the pipe on the spigot ends, bells overlapped, and finally, sealed with additional cigarette wraps of tape. Although this method proved to be effective, it was very inefficient. These six pipe section proceeded down the borepath ramp and into the borepath without any additional problems. At approximately 2 p.m. on Saturday, the seventh joint was assembled using the revised PE encasement anchorage plan. It took approximately 20 minutes to assemble, check, complete the encasement of the joint, and pull forward the 20' necessary to assemble the next pipe section. By 3:30 p.m. the Holloman crew had this total assembly and wrapping cycle time down to between 5 and 8 minutes. This is inclusive of the 1 to 1.5 minutes necessary to break down one of the 5" x 30' drilling rods.

At the operating console, TAUG's operator watched his thrust and torque gauges for any pressure increases. Throughout the pull back, thrust or pulling loads never exceeded 69,000 lb, which is 1,000 lb less than was calculated using Equation No.1, and less than 1/3 of the allowable capacity of the pipe, see Table 3. Despite the minor set back caused by the unanchored PE encasement (on the first six pipe sections), the 1,020' of 30" Flex-Ring joint pipe was completed by approximately 10 p.m. Saturday evening.

Observation/Conclusions: This line was the first of the four HDD installations to be constructed, and, with the exception of the initial problem with the PE encasement, the installation went very well. Subsequent to this installation, two additional 30" HDD and one 24" HDD installations were successfully installed. According to Rodney Schwarzlose, the other installations were easier, were installed quicker, went in without incident, and all were successfully hydrostatically tested.

As a result of this first experience, Holloman personnel developed a new system for providing additional protection for the PE encasement on the first several pipe sections. After applying the PE encasement to the pipe, Holloman applied a PE material called "Rock Shield" that is available in various thicknesses and worked very well for this application.

The performance of the Flex-Ring joint ductile iron pipe was also very reassuring. The manner in which the sealing gasket and the restraining segment can be pre-installed in the Flex-Ring bell is a distinct advantage over other flexible restrained joints. The joint flexibility provides a hinge every 20', virtually eliminating any induced bending stresses. The bells have such a smooth transition that Keith Whitaker in a recent article made the statement that "We took extra time to swab and clean the borepath so the Flex-Ring bells would not produce unnecessary drag. This proved not to be an issue."[viii] As a major HDD contractor and well respected in the industry, he gave an unprecedented endorsement of Flex-Ring in this same article when he said, "I am very impressed with the Flex-Ring joint pipe, in fact, I wouldn't be afraid to pull it on the next job."

Roger Engelke, project manager, River City Engineering, when asked how satisfied both CRWA and RCE were with the ductile iron pipe HDD installation stated that "The project was excellent! It was professionally done with excellent support; we will recommend again."

Again the paradigm that ductile iron pipe can be used for every tough installation methodology, with the one significant, <u>perceived</u> exception being HDD has been challenged to the extent that the momentum is clearly indicating a paradigm shift. The following is a partial list of the benefit of flexible restrained joint ductile iron pipe.

- ✓ Standard pressure capabilities up to 350 psi (2.4 MPa), or greater upon special request
- ✓ Better distribution of thrust or pulling force around the bell and barrel, and greater allowable pulling forces than other pipe options
- ✓ Liberal, allowable joint deflection with simultaneous joint restraint
- ✓ Quick, easy joint assembly
- ✓ "Cartridge" installation option for limited easements or right of way
- ✓ Can be located from surface with commonly used locators
- ✓ Performance capabilities of the pipe are not impacted by elevated temperatures
- ✓ Material strength for handling pullback and external dead and live loadings
- ✓ Material strength which does not creep or decrease with time
- ✓ Greater ductile iron pipe flow characteristics unchanged at HDD crossings
- ✓ Pipe wall impermeable to volatile hydrocarbons, minimizing the potential of water system contamination in the present and future
- ✓ No significant residual bending stresses that could adversely affect future serviceability remain in the pipe after the pullback
- ✓ No significant "recoil" and minimal pipe movement after installation due to thermal expansion and "Poisson" pressure-testing effects
- ✓ Lack of movement and the inherent strength of ductile iron eliminates potential for shearing of tapped lateral outlets or breakage of pipe due to thermal expansion and contraction

Acknowledgments: The authors would like to give special thanks to David Davenport, General Manager, Canyon Regional Water Authority for his support of the change to Flex-Ring joint ductile iron pipe for this project. We would also like to give special thanks to Roger Engelke, project manager, River City Engineering for his technical support of the change and for his contributions to this paper.

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[i] Ariaratnam and Carpenter (2003). “Field Evaluation And Testing Of Ductile Iron Pipe For Trenchless Applications In Municipal Engineering” No-Dig 2003 New Orleans, LA
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