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TAPPING

Direct Service Connection Installation Comparison Ductile Iron Pipe vs. Polyethylene Pipe

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During July 2001, the Ductile Iron Pipe Research Association (DIPRA) conducted tests comparing direct tapping of Ductile Iron Pipe and polyethylene pipe. Time, internal pressure, material strength, and other factors of both materials were compared with respect to tapping. All tests were conducted using prescribed recommendations and procedures for each material.

Service taps on Ductile Iron Pipe are easily made either before or after installation. The procedure simply involves strapping on the tapping machine, drilling/tapping the pipe, and inserting the corporation stop. The minimum Pressure Class of all diameters of Ductile Iron Pipe may be direct tapped for 3/4-inch services. Standard corporation stops can be screwed directly into the tapped and threaded pipe.

Unlike Ductile Iron Pipe, direct threading of polyethylene pipe is not recommended. Sidewall fusion is used to install service connections on polyethylene pipe. The Plastics Pipe Institute recommends that sidewall-type fusion joints be made only with a mechanical assist tool.[1] The fusion process requires a saddle fusion machine, heater saddle adapters, heater plate, AC power source, surface temperature measuring device, utility cloth, denatured alcohol, and a sidewall fusion fitting. This process should not be attempted under dirty or wet (rain, etc.) conditions, even in emergencies, without enclosures.

Procedure

Ductile Iron Pipe specimens were 6-inch diameter Pressure Class 350 with a standard cement-mortar lining. It is significant to note that the nominal number of threads engaged for the 6-inch Pressure Class 350 Ductile Iron Pipe (0.25-inch wall thickness) would be equivalent to 3.5 threads for 3/4-inch taps. Considering the pipe curvature, full thread engagement is 2.76 for 3/4-inch taps.

The polyethylene specimens were 6-inch diameter, DR 11, Pressure Rating 160 made from PE 3408 polyethylene material. This material is the highest-rated polyethylene material in ANSI/AWWA C906. Tapping of the Ductile Iron Pipe specimens was conducted with a Mueller B-100 drilling and tapping machine. Fittings were joined to the polyethylene specimens by thermal heat fusion utilizing a TDW OutRider™ 1500 sidewall fusion unit and TD-3 heating assembly.

All specimens were 4 feet in length, sealed with mechanical joint end caps, and secured in a test press. Service connections were 3/4-inch. The corporation stops on the Ductile Iron Pipe specimens were installed with two layers of 3-mil-thick thread sealant tape.

Installation Time

A comparison of the respective times for installing direct service connections to Ductile Iron Pipe and polyethylene pipe was conducted. All procedures were done according to recommendations provided. A moderate, thorough pace was used by the same operator for all tests to achieve a representative comparison.

Specimens were placed in the test press and the service connections installed under 70 psi internal water pressure. All taps were performed on each specimen at the 12 o'clock position as set in the test press. Three corporations were installed in each specimen. The Mueller B-100 drilling and tapping machine and the TDW OutRider™ 1500 sidewall fusion unit were positioned and mounted prior to timing.

The end of the tapping time for the Ductile Iron Pipe specimens was signaled after the corporation stop was inserted and torqued to 30 ft-lbf. Ending time for the polyethylene specimens was determined when the fusion area reached the same temperature as the remaining pipe (as recommended by the pipe manufacturer).[2] For Ductile Iron Pipe, the procedure simply involves strapping on the tapping machine, drilling/tapping the pipe, and inserting the corporation stop.

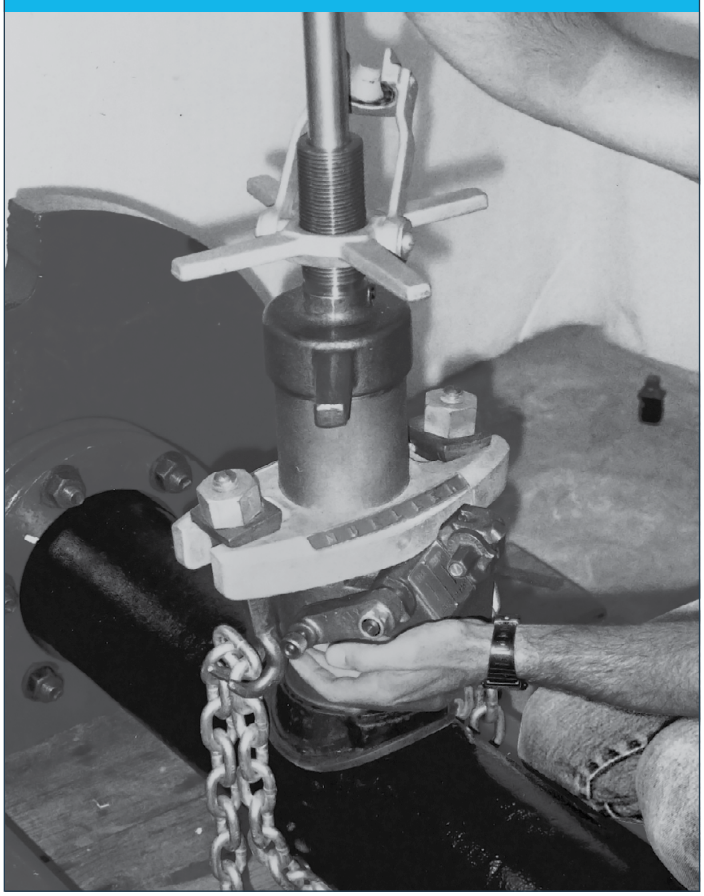
Tapping Installation Time

SPECIFICATIONS	
Ductile Iron Pipe Pressure Class 350, cement-mortar lined	**Polyethylene Pipe** DR 11, Class 160
TEST RESULTS	
Corporation #1 = 17 minutes	Tee #1 = 15 minutes tapping 50 minutes cooling* 65 minutes total
Corporation #2 = 17 minutes	Tee #2 = 17 minutes tapping 55 minutes cooling* 72 minutes total
Corporation #3 = 17 minutes	Tee #3 = 15 minutes tapping 55 minutes cooling* 70 minutes total
Average time = 15.67 minutes	Average time = 69 minutes

*During the cooling time, the fusion machine has to remain in place on the pipe in order to continue to hold a prescribed force on the fitting.

FIGURE 1

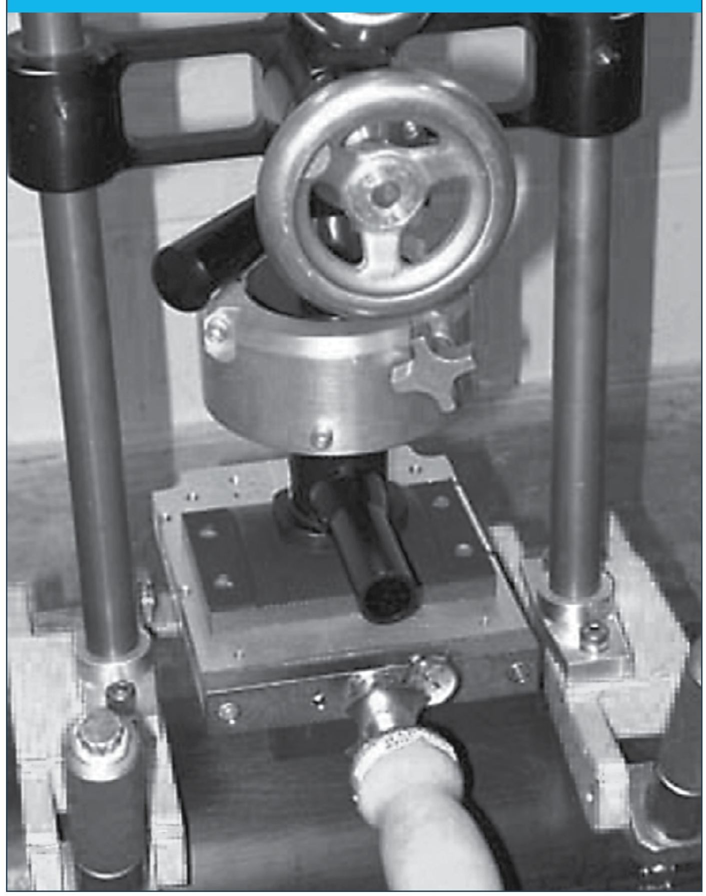
Tapping Ductile Iron Pipe



Each material was tapped according to recommendations. The average time to tap Ductile Iron Pipe (above) was 16 minutes.

FIGURE 2

Tapping Polyethylene Pipe



The average time to tap polyethylene pipe (above) was 69 minutes (4.4 times longer than Ductile Iron Pipe).

For polyethylene pipe, there are eight sequential steps published in the Plastics Pipe Institute brochure “Polyethylene Joining Procedures.”[1] At the risk of making this article tedious, we think it is important to include those eight steps to illuminate the differences between the two materials. They are:

1. Clean the pipe: Remove any dirt or coating.
2. Install the heater saddle adapters: Install the saddle adapters on the heater plate, being careful not to over tighten and ensuring that the surfaces are clean and flush (any dirty or rough surface will retard and limit heat transfer and thereby affect joint integrity). Allow the heater to come to the specified temperature. [This will take several minutes.]
3. Install the saddle fusion machine: Use manufacturer’s instructions to straighten and round the pipe using caution not to flatten the pipe.
4. Prepare surfaces: Remove any contaminants and use 50 or 60 grit utility cloth (sandpaper or other abrasive materials are likely to leave grit or deposits of other foreign materials on the pipe surface) to clean and roughen the pipe surface and fitting saddle contour to expose fresh material. [Clean the surfaces with denatured alcohol.]
5. Fitting alignment: Inspect to ensure a precise fit to the pipe.
6. Heating: Check the heater temperature periodically to verify the proper surface temperature using a pyrometer or other surface temperature measuring device. Place the heater tool in position to heat the pipe and fitting surfaces following the manufacturer’s instructions carefully.
7. Fusion: After the prescribed heating requirements have been met, remove the heater from the heated pipe and fitting surfaces and quickly inspect the melt pattern on both the fitting and the pipe. Join the fitting to the pipe with the prescribed fusion force.
8. Cooling: Continue to hold the force during the cooling cycle. Allow the joint to cool to ambient temperature (this may take approximately 30 minutes). Do not subject the joint to any external stresses until the fusion joint has cooled. After it has cooled, cut the service hole in the pipe.

Following recommended procedures, the researchers determined that tapping polyethylene pipe took approximately 4.4 times longer than tapping Ductile Iron Pipe. The increase in tapping time was attributed to the fact that the fusion machine had to remain in place, applying force to the fitting, until the fusion area reached the same temperature as the remaining pipe (as recommended by the manufacturer[2]). Obviously, tapping Ductile Iron Pipe is easier and faster than tapping polyethylene pipe.

Leak Test

Three service connections were installed on each 4-foot specimen of each material, which were initially pressurized at 70 psi. After completion of each service connection, the Mueller B-100 drilling and tapping machine and the TDW OutRider™ 1500 sidewall fusion unit were removed and the service connections inspected.

Under constant observation and inspection the initial internal water pressure of 70 psi was increased incrementally on each material up to and including their rated working pressures (350 psi for Pressure Class 350 Ductile Iron Pipe and 160 psi for Pressure Rated 160 polyethylene pipe). The water pressure was further increased at a moderate rate and inspected for leakage. Leakage was defined as water escaping at a rate of at least one drop per minute.

Ductile Iron Pipe

Three 3/4-inch direct service connections were made on one 4-foot Ductile Iron Pipe specimen using recommended procedures. All corporation stops were installed with two layers of 3-mil-thick thread sealant tape and torqued to 30 ft-lbf. The initial internal water pressure of 70 psi was increased to 100 psi after the first inspection. Internal pressure was then increased slowly at 100 psi increments to 500 psi under constant observation and inspection. The pressure was then increased to 1,000 psi in an attempt to cause failure. No leaks occurred until an internal pressure of 600 psi was obtained. At this point, the closed plug keys leaked on two corporation stops. There was no evidence of leakage at the threaded tap on any of the three corporations up to and including 1,000 psi internal pressure (see Table 1).

TABLE 1 **Leak Tests — Ductile Iron Pipe Specimens** **3/4-Inch Corporation Stops With Two Layers of 3-Mil-Thick Thread Sealant Tape** **(All Corporation Stops Were Torqued To 30 Ft-Lbf)**			
Internal Pressure (PSI)	Corp. #1	Corp. #2	Corp. #3
70–500	No Leaks	No Leaks	No Leaks
600	Leakage around closed plug key*	No Leaks	Leakage around closed plug key*
700	Leakage around closed plug key	Leakage around closed plug key*	Leakage around closed plug key
800–1,000**	Leakage around closed plug key	Leakage around closed plug key	Leakage around closed plug key

*When leakage around the closed plug key was observed, the plug key stem nut was carefully tightened; however, the leak could not be stopped. The manufacturer of the corporation stops was contacted in order to obtain a maximum allowable torque value but no such information was available. The manufacturer did divulge that the plug key stem nut was designed so that over tightening would strip the threads.

**At 1,000 psi, all corporation stops' closed plug keys were leaking severely but no evidence of leakage at the threaded tap was observed.

Polyethylene Pipe

Three 3/4-inch service connections were made on one 4-foot polyethylene pipe specimen using recommended procedures.

The first leakage test of the polyethylene pipe taps was conducted with the cutter valve closed and the cutter cap removed in order to observe any leakage past the cutter valve. Under constant observation and inspection, the initial internal water pressure of 70 psi was increased at 10 psi increments to 160 psi. The three taps began to leak through the cutter valve at 110, 140, and 150 psi, all prior to reaching the 160 psi Pressure Rating of the polyethylene pipe (see Table 2).

TABLE 2 **Leak Tests –Polyethylene Pipe Specimens** **Pressurized to Rated Working Pressure**			
Internal Pressure (PSI)	Butt Tap Tee #1	Butt Tap Tee #2	Butt Tap Tee #3
70–100	No Leaks	No Leaks	No Leaks
110	No Leaks	Leak at Outlet & Cutter Screw	No Leaks
120	No Leaks	Leak at Outlet & Cutter Screw	No Leaks
130	No Leaks	Leak at Outlet & Cutter Screw	No Leaks
140	Leak at Outlet	Leak at Outlet & Cutter Screw	No Leaks
150	Leak at Outlet	Leak at Outlet & Cutter Screw	Leak at Outlet & Cutter Screw
160	Leak at Outlet	Leak at Outlet & Cutter Screw	Leak at Outlet & Cutter Screw

The internal pressure was then reduced to 70 psi, the service connections were plugged, the cutting valves opened, and the cutter caps installed. The internal pressure was then increased to 100 psi and then slowly at 50 psi increments under constant observation and inspection. Leakage occurred at one cutter cap at 330 psi. The test had to be terminated at 375 psi due to the fact that the polyethylene pipe specimen began bowing and snaking, causing the pipe to pull away from the end closures and leak at the test seals (see Table 3).

TABLE 3
Leak Tests — Polyethylene Pipe Specimens
Maximum Attainable Pressure (Fittings Plugged and Capped)

Internal Pressure (PSI)	Butt Tap Tee #1	Butt Tap Tee #2	Butt Tap Tee #3
100–300	No Leaks	No Leaks	No Leaks
330	Leak at Cutter Cap	No Leaks	No Leaks
375	Leak at End Cap	Leak at End Cap	Leak at End Cap

Pull-Out Test

Pull-out tests were conducted in an effort to compare the strength and integrity of each direct service connection.

Three 3/4-inch service connections were installed on each 4-foot specimen, secured in the test press, filled with water, and brought up to 70 psi internal water pressure. A “pull-out” apparatus was mounted on the test press directly over the service connection. This apparatus utilized a 10-ton hydraulic ram that connected to a fixture attached onto the respective corporation stop. A hydraulic pump with a previously calibrated gauge was used to apply hydraulic pressure to the ram. The hydraulic ram’s effective ram area of 2.074 square inches enabled a conversion from pressure in psi to pounds of force pulling on the service connection. Under constant observation and inspection, the internal hydraulic pressure of the ram was applied incrementally on all service connections.

FIGURE 2

Pull-Out Test — Ductile Iron Pipe

Forces exerted during pull-out tests, when sufficient, resulted in failure of the corporation stop, not the Ductile Iron Pipe or threads. The photo on the left shows leakage at the plug key of the corporation stop. Ultimate failure occurred to the corporation stops’ threaded connection for the service line. The undamaged Ductile Iron Pipe and threads are shown on the right.

Ductile Iron Pipe

Three new 3/4-inch corporation stops were installed with two layers of 3-mil thread sealant tape and torqued to 40 ft-lbf. The apparatus utilizing the 10-ton hydraulic ram was connected to a fixture that was threaded onto the respective corporation stop.

An average pulling force of 3,027 pounds initiated leakage around the closed plug key of the corporation stops (no leakage was observed at the threaded connection to the pipe). Actual failure occurred at an average of 6,969 pounds of pulling force (see Table 4). These failures occurred at the threaded flare connection of the corporation stops for the copper service line, not the threaded connection to the pipe.

FIGURE 4

Pull-Out Test — Polyethylene Pipe

The pull-out tests on the polyethylene specimen resulted in leakage at the cutter cap of the butt tap tees, rolled threads on the cutter caps, and destruction of the butt tap tees at an average of 1,065, 1,638, and 2,973 pounds of pulling force, respectively. Such failures in the field would require the pipeline to be taken out of service and a section of the polyethylene pipe cut out and replaced. Simple or quick mechanical clamps/couplings/sleeves might not work well on HDPE, and butt-fusion repair might be necessary – but not easy to accomplish – in some field conditions.

Polyethylene Pipe

Two separate pull-out tests on three butt tap tees were conducted on polyethylene pipe. One was achieved by a fixture that was attached under the cutter screw cap. The other test was performed utilizing a fixture that was attached under the service connection outlet. The tests on the polyethylene specimen resulted in leakage at the cutter cap of the butt tap tees, rolled threads on the cutter caps, and destruction of the butt tap tees at an average of 1,065, 1,638, and 2,973 pounds of pulling force respectively (see Table 5).

In all instances, the pulling force caused destruction of the butt tap tee or tee/pipe connection. Such failures in the field would require the pipeline to be taken out of service and a section of the polyethylene pipe cut out and replaced. These failures occurred at an average of 2,973 pounds of pulling force, less than half that required to cause failure to the corporation service line connection on the Ductile Iron Pipe. Repair of the failed corporation stops on the Ductile Iron Pipe would merely require a corporation replacement, as the Ductile Iron Pipe threads were not damaged.

TABLE 4
Pull-Out Tests — Ductile Iron Pipe

Pulling Force (lbf)	Corp. #1	Corp. #2	Corp. #3
1,900	No Leaks	No Leaks	No Leaks
1,947	No Leaks	Leak at corp. plug	No Leaks
2,655	No Leaks	Leak at corp. plug	Leak at corp. plug
4,480	Leak at corp. plug	Leak at corp. plug	Leak at corp. plug
6,512	Failure at corp. stop	Leak at corp. plug	Leak at corp. plug
6,554	—	Failure at corp. stop	Leak at corp. plug
7,840	—	—	Failure at corp. stop

NOTES:
1. Internal water pressure @ 70 psi.
2. All corporation stops torqued to 40 ft-lbf.
3. Average load to failure: 6,969 lbf.
4. All corporation stops failed in the same manner:
    a. In all tests, no leakage occurred at threaded connection with pipe.
    b. Leakage occurred at corporation plug.

TABLE 5
Pull-Out Tests — Polyethylene Pipe

Pulling Force (lbf)	Butt Tap Tee #1	Butt Tap Tee #2	Butt Tap Tee #3
1,000	No Leaks	No Leaks	No Leaks
1,037	No Leaks	Leak at Cutter Cap	Leak at Cutter Cap
1,120	Leak at Cutter Cap	Leak at Cutter Cap	Leak at Cutter Cap
1,617	Leak at Cutter Cap	Rolled Threads on Cutter Cap	Rolled Threads on Cutter Cap
1,680	Rolled Threads on Cutter Cap	—	—
2,904	Destruction of Butt Tap Tee	Destruction of Butt Tap Tee	—
3,111	—	—	Destruction of Butt Tap Tee (pipe/tee connection)

NOTES:
1. Internal water pressure @ 70 psi.
2. Average load to leak at cutter cap: 1,065.
3. Average load to roll cutter cap threads: 1,638.
4. Average load to failure: 2,973.
5. In all instances, the pulling force caused destruction of the butt tap tee or tee/pipe connection. Such failures in the field would require a section of the polyethylene pipe to be cut out and replaced.

Cantilever Load Test

Service connections were again installed on 4-foot pipe specimens of each material, secured in the test press, filled with water, and brought up to 70 psi internal water pressure. The corporation stops on the Ductile Iron Pipe were installed with two layers of 3-mil thread sealant tape and torqued to 40 ft-lbf.

Cantilever load testing of the Ductile Iron Pipe was accomplished by utilizing the same set-up as the pull-out tests; however, the pipe specimen was rotated 90 degrees and a slightly different connection apparatus to the corporation stop was utilized. This connection apparatus had a pivot connection point at the corporation that allowed an approximate 15 degree deflection.

Cantilever load tests on the polyethylene specimens were accomplished through a set-up that placed the hydraulic ram between the specimen end cap and the service connection. This set-up provided a moment arm length of 0.7 inches.

Under constant observation and inspection, force was applied incrementally on each service connection. Hydraulic pressure was converted to inch-pounds moment at the interface between the pipe and the corporation stop.

Ductile Iron Pipe

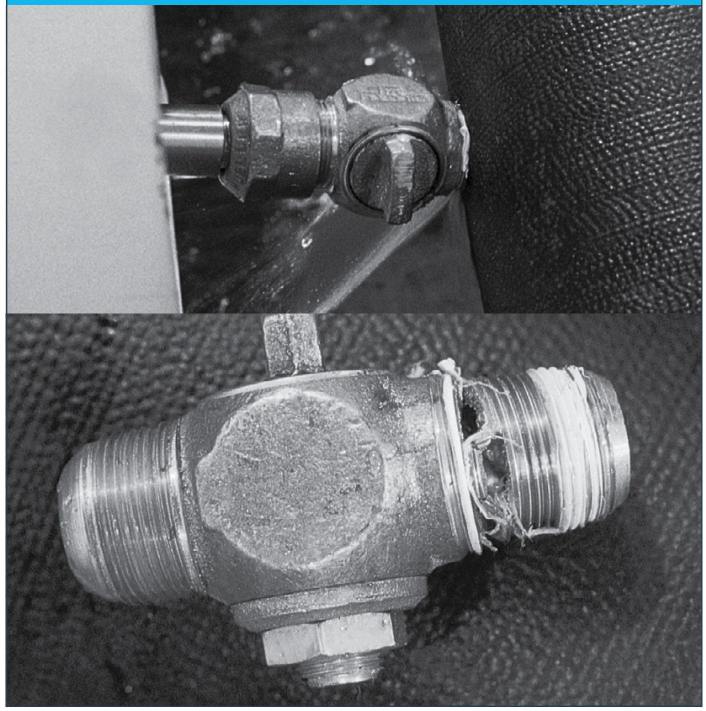
The average bending moment to cause leakage of the corporation stops for Ductile Iron Pipe was 3,125 in-lbf. There was no leakage at the threaded connection to the pipe. Failure of the corporation stops required an average bending moment of 4,784 in-lbf and occurred at the two or three exposed threads just outside of the threaded connection to the pipe (see Table 6).

Polyethylene Pipe

The butt tap tees subjected to the cantilever loading suffered non-repairable failure and leakage of the tees at an average bending moment of 2,052 in-lbf. (see Table 7). As in the pull-out tests, in all instances, such failures in the field would require the pipeline to be taken out of service and a section of the polyethylene pipe cut out and replaced. Repair of the failed corporation stop on the Ductile Iron Pipe would merely require replacement with a new corporation.

FIGURE 5

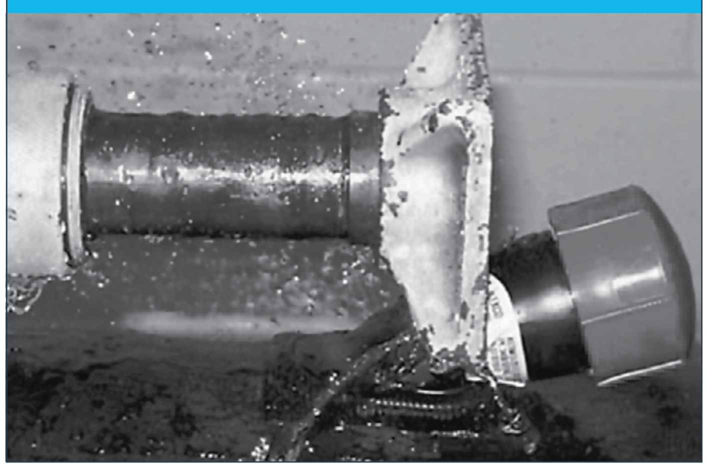
Cantilever Load Test — Ductile Iron Pipe



As was the case in the pull-out tests, sufficient cantilever forces damaged the corporation stop, causing the leakage seen in the photo above. Damage to the corporation stop is shown above (bottom).

FIGURE 6

Cantilever Load Test — Polyethylene Pipe



Tests on the polyethylene pipe at above resulted in non-repairable failure and leakage of the tees at an average bending moment of 2,052 in-lbf. As in the pull-out tests, in all instances, such failures in the field would require the pipeline to be taken out of service and a section of the polyethylene pipe cut out and replaced. Simple or quick mechanical clamps/couplings/sleeves might not work well on HDPE, and buttfusion repair might be necessary in some field conditions. That is not always easy and can prove difficult. Repair of the failed corporation stop on the Ductile Iron Pipe would merely require replacement with a new corporation.

TABLE 6
Cantilever Load Tests — Ductile Iron Pipe

Bending Moment (lbf)	Corp. #1 (4-15/16" Arm)	Corp. #2 (4-7/8" Arm)	Corp. #3 (4-13/16" Arm)
0 to 2,075	No Leaks	No Leaks	No Leaks
2,096	No Leaks	No Leaks	Leakage at corp. plug No leakage at threads
3,438	No Leaks	Leakage at corp. plug No leakage at threads	Leakage at corp. plug No leakage at threads
3,840	Leakage at corp. plug No leakage at threads	Leakage at corp. plug No leakage at threads	Leakage at corp. plug No leakage at threads
4,650	Leakage at corp. plug No leakage at threads	Leakage at corp. plug No leakage at threads	Leakage at corp. plug No leakage at threads
4,651	Leakage at corp. plug No leakage at threads	Corp. failed @ threads external to pipe connection	Leakage at corp. plug No leakage at threads
4,7111	Corp. failed @ threads external to pipe connection	—	Leakage at corp. plug No leakage at threads
4,991	—	—	Corp. failed @ threads external to pipe connection

NOTE: On all cantilever load tests for Ductile Iron Pipe, corporation stops were initially torqued to 40 ft-lbf and had two layers of 3-mil thread sealant tape. Internal water pressure was maintained at 70 psi.

TABLE 7
Cantilever Load Tests — Polyethylene Pipe

Bending Moment (lbf)	Butt Tap Tee #1 (0.70" Arm)	Butt Tap Tee #2 (0.70" Arm)	Butt Tap Tee #3 (0.70" Arm)
0 to 2,025	No Leaks	No Leaks	No Leaks
2,033	No Leaks	Destruction of tee body	Destruction of tee body
2,091	Destruction of tee body	—	—

NOTE: Internal water pressure was maintained at 70 psi.

Summary

As a result of this comparative study on direct service connections to Ductile Iron Pipe and polyethylene pipe, a number of interesting observations were made:

1. Installation of service connections on polyethylene pipe will involve more time and care than direct tapping Ductile Iron Pipe – 4.4 times longer, according to this study.
2. Using recommended procedures, all service connection outlets on the polyethylene pipe specimens leaked past the closed cutting valve at a pressure less than the pipe's maximum working pressure (160 psi).
3. Using recommended procedures, all service connections on the Ductile Iron Pipe exhibited no leakage even with more than 350 psi of internal water pressure. Leakage around the corporations' closed plug key occurred between 600 and 700 psi. There was no evidence of leakage at the threaded tap on any of the three corporations up to and including 1,000 psi internal water pressure.
4. Both the pull-out and cantilever tests revealed that the service connections to the Ductile Iron Pipe exhibit greater strength and integrity than those made to the polyethylene pipe. Note that failures of the polyethylene service connections would necessitate the water main to be taken out of service while repairs were made. This might not be easily nor quickly accomplished with simple, effective sleeves and restraints (as it would be in a cut-in operation involving Ductile Iron Pipe), and wet conditions or weather can present further problems to HDPE repair. In the case of the Ductile Iron Pipe, only the corporation stops would have to be replaced. Service pull-outs have been observed to be a field problem with plastic pipes, similar to those detailed in this report.

References

[1] Polyethylene Joining Procedures, Plastic Pipe Institute.
[2] Recommended Heat Fusion Joining Procedures, *CSR PolyPipe.*

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

Ductile Iron Pipe Research Association

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