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Ductile Iron Pipe
Research Association

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TAPPING

Direct Tapping of 6-Inch Pressure Class 350 Ductile Iron Pipe

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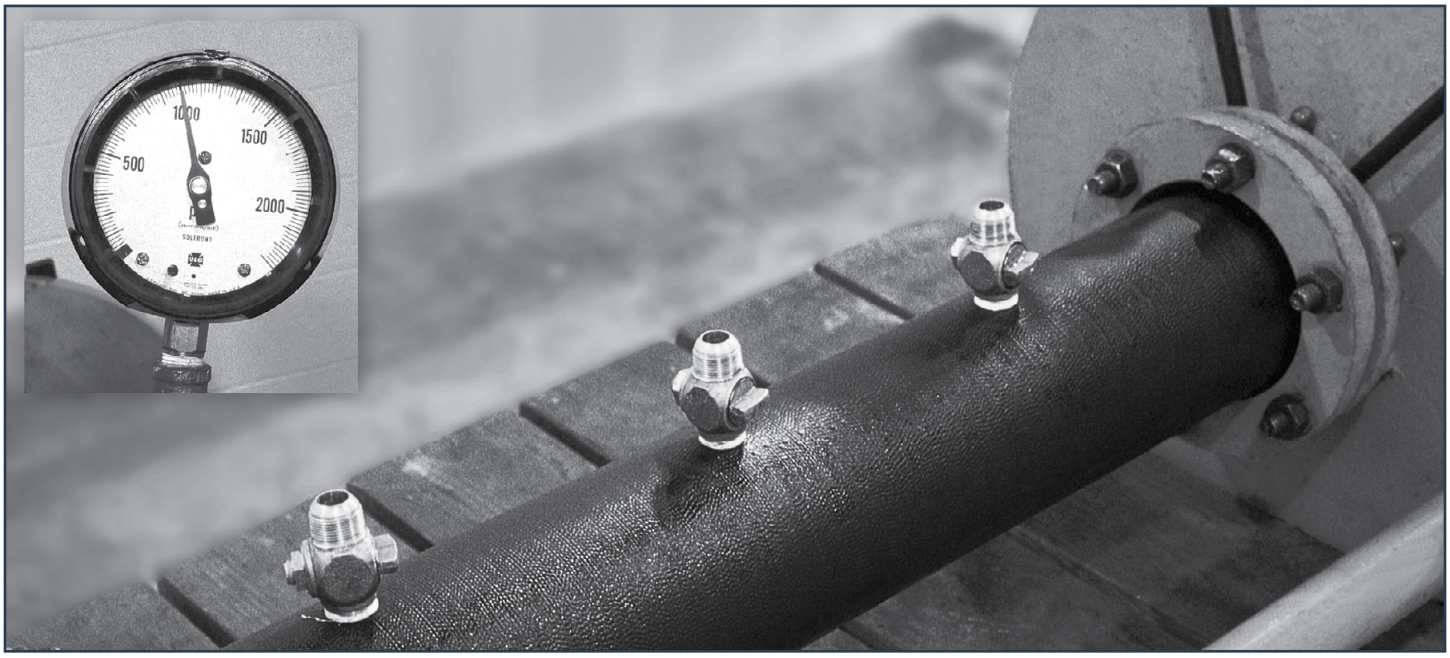
In 1976 the Ductile Iron Pipe Research Association (DIPRA) conducted tapping tests on 6-inch "Special Thickness Class 50" Ductile Iron Pipe. For years prior to those tests, there had been no consensus among utilities concerning the number of engaged threads required for direct tapping. Some utilities had arbitrarily required engagement of four full threads, some had required three, and others were undecided. DIPRA's tests confirmed the 3/4-inch and 1-inch direct tapping integrity of 6-inch Ductile Iron Pipe with a nominal 0.25-inch wall thickness.

In 1987 DIPRA conducted similar tests that clearly showed the direct tapping superiority of Ductile Iron Pipe over PVC pipe. Since those first two groups of tests were run, pressure classes of Ductile Iron Pipe have been introduced. Thus, to update data from the previous testing and to validate the established confidence in Ductile Iron Pipe, DIPRA conducted extensive direct tapping tests on 6-inch diameter Pressure Class 350 Ductile Iron Pipe in February 1999.



DIPRA's direct tapping tests were conducted on 4-foot Ductile Iron Pipe specimens 6 inches in diameter. Tests involved three 3/4-inch taps on one specimen and three 1-inch taps on the other specimen as shown here. The initial internal water pressure of 70 psi was gradually increased to 1,000 psi (inset photo) in an attempt to cause failure.

Procedures

Two 6-inch diameter, Pressure Class 350, cement-mortar lined Ductile Iron Pipe specimens were used for these tests. A concerted effort was required to procure specimens with a wall thickness below the nominal specified in ANSI/AWWA C151/A21.51, "Ductile-Iron Pipe, Centrifugally Cast, For Water." Each specimen was 4 feet long, sealed with mechanical joint end caps, and secured in a test press. The direct tapping was performed with a Mueller B-100 drilling and tapping machine. Detailed procedures for each testing category follow.

Tapping Time

The time involved to drill, tap, and install corporation stops under pressure was recorded for three 3/4-inch and three 1-inch connections. The specimens were pressurized to 70 psi internal water pressure. A moderate, thorough pace was utilized by the same operator for each time trial. The completion of each direct tap was signaled after the threaded corporation stop connection was torqued appropriately. Results are shown in Table 1

TABLE 5
Tapping Time

3/4-Inch Taps			1-Inch Taps		
Corp. #1	Corp. #2	Corp. #3	Corp. #1	Corp. #2	Corp. #3
17 minutes	15 minutes	15 minutes	19 minutes	17 minutes	20 minutes
Average = 15.67 minutes			Average = 18.67 minutes		

LEAK TESTS

3/4-Inch Taps

Tests of the 3/4-inch direct taps were conducted on a 4-foot Ductile Iron Pipe specimen with an average wall thickness of 0.231 inches. Three 3/4-inch taps were made approximately 10 inches apart in the specimen, which was initially pressurized at 70 psi. The first test (see Table 2) utilized standard corporation stops installed with two layers of 3-mil thread sealant tape and torqued to 30 ft-lbf. Upon completion of each tap, the inserted corporation stop was inspected for leakage. Leakage was defined as water escaping at a rate of at least one drop per minute. If leakage was detected, the corporation stop was then tightened in 10 ft-lbf increments until the leakage stopped.

TABLE 2
Leak Tests: 3/4-Inch Corporation Stops with Two Layers of 3-Mil Thread Sealant Tape

Internal Pressure (psi)	Corp. 1		Corp. #2		Corp. #3	
	Observation	Torque Needed to Stop Thread Leak	Observation	Torque Needed to Stop Thread Leak	Observation	Torque Needed to Stop Thread Leak
70 — 500	No Leak	N/A	No Leak	N/A	No Leak	N/A
600	Leakage around closed plug key*	N/A	No Leak	N/A	Leakage around closed plug key*	N/A
700	Leakage around closed plug key	N/A	Leakage around closed plug key*	N/A	Leakage around closed plug key	N/A
800–1,000**	Leakage around closed plug key	N/A	Leakage around closed plug key	N/A	Leakage around closed plug key	N/A

Tables 2-5

*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 to obtain a maximum allowable torque value, but no such information was available. The manufacturer did say 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. NOTE: All corporation stops referenced in Tables 2 and 4 were initially 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. At that point the pressure was increased to 1,000 psi in an attempt to cause failure.

Using the same pipe specimen, the 3/4-inch corporation stops with the thread sealant tape were removed and replaced with three new corporation stops with no thread sealant tape applied (see Table 3). Each was initially torqued to 40 ft-lbf and pressure tested from the initial 70 psi to 1,000 psi to duplicate the procedure previously detailed.

1-Inch Taps

The testing of the 1-inch direct taps was conducted on a 4-foot Ductile Iron Pipe specimen with an average wall thickness of 0.242 inches. Spacing between the three 1-inch corporation stops was 8 inches. The leak testing procedure for the 1-inch corporations (see Tables 4 and 5) was the same as that of the 3/4-inch corporations.

TABLE 3
Leak Tests: 3/4-Inch Corporation Stops with No Thread Sealant Tape

Internal Pressure (psi)	Corp. 1		Corp. #2		Corp. #3	
	Observation	Torque Needed to Stop Thread Leak	Observation	Torque Needed to Stop Thread Leak	Observation	Torque Needed to Stop Thread Leak
70	Leak at Threads	60 ft-lbf	Leak at Threads	80 ft-lbf	Leak at Threads	70 ft-lbf
100	No Leak	N/A	No Leak	N/A	Leak at Threads	80 ft-lbf
200–400	No Leak	N/A	No Leak	N/A	No Leak	N/A
500	No Leak	N/A	Leakage around closed plug key*	N/A	No Leak	N/A
600	Leakage around closed plug key*	N/A	Leakage around closed plug key*	N/A	Leakage around closed plug key*	N/A
700–1,000**	Leakage around closed plug key	N/A	Leakage around closed plug key	N/A	Leakage around closed plug key	N/A

See Table 2 for footnotes.
NOTE: All corporation stops referenced in Tables 3 and 5 were initially torqued to 40 ft-lbf.

TABLE 4
Leak Tests: 1-Inch Corporation Stops with Two Layers of 3-Mil Thread Sealant Tape

Internal Pressure (psi)	Corp. 1		Corp. #2		Corp. #3	
	Observation	Torque Needed to Stop Thread Leak	Observation	Torque Needed to Stop Thread Leak	Observation	Torque Needed to Stop Thread Leak
70–400	No Leak	N/A	No Leak	N/A	No Leak	N/A
500	Leakage around closed plug key*	N/A	No Leak	N/A	Leakage around closed plug key*	N/A
600	Leakage around closed plug key	N/A	Leakage around closed plug key*	N/A	Leakage around closed plug key	N/A
700–1,000**	Leakage around closed plug key	N/A	Leakage around closed plug key	N/A	Leakage around closed plug key	N/A

See Table 2 for footnotes.

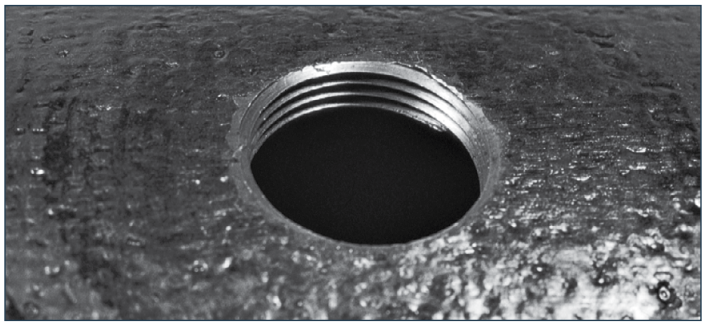
TABLE 5
Leak Tests: 1-Inch Corporation Stops with No Thread Sealant Tape

Internal Pressure (psi)	Corp. 1		Corp. #2		Corp. #3	
	Observation	Torque Needed to Stop Thread Leak	Observation	Torque Needed to Stop Thread Leak	Observation	Torque Needed to Stop Thread Leak
70	No Leak	N/A	No Leak	N/A	No Leak	N/A
100	Leak at Threads	50 ft-lbf	Leak at Threads	60 ft-lbf	Leak at Threads	60 ft-lbf
200	Leak at Threads	60 ft-lbf	No Leak	N/A	No Leak	N/A
300	No Leak	N/A	No Leak	N/A	Leak at Threads	70 ft-lbf
400	Leakage around closed plug key*	N/A	Plug key and thread leak*	80 ft-lbf	Leakage around closed plug key*	N/A
500	Leakage around closed plug key	N/A	Plug key and thread leak	110 ft-lbf	Leakage around closed plug key	N/A
600	Leakage around closed plug key	N/A	Leakage around closed plug key	N/A	Leakage around closed plug key	N/A
700	Plug key and thread leak	80 ft-lbf	Leakage around closed plug key	N/A	Leakage around closed plug key	N/A
800–1,000**	Leakage around closed plug key	N/A	Leakage around closed plug key	N/A	Leakage around closed plug key	N/A

See Table 2 & 3 for footnotes.

Pull-Out Tests

Pull-out tests were conducted on three 3/4-inch corporation stops (see Tables 6, 7, and 8) to evaluate the strength and integrity of those direct service connections. Three new 3/4-inch corporation stops were installed with two layers of 3-mil thread sealant tape in the 0.231-inch wall specimen and secured in the test press. An internal water pressure of 70 psi was maintained throughout the test. The corporation stops were torqued to 40 ft-lbf. A "pull-out" apparatus was mounted on the test press directly over the corporation stops to be tested. This apparatus utilized a 10-ton hydraulic ram connected to a fixture that was threaded 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 had an effective piston area of 2.074 square inches that was used to mathematically convert from internal pressure in psi to pounds of pulling force on the corporation stop connection. The internal hydraulic pressure was applied slowly in increments of 500 psi or approximately 1,000 pounds of force. Failure was indicated by the loss of hydraulic pressure being applied.



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

TABLE 6
Pull-Out Tests: Corporation #1

Ram Pressure (psi)	Pulling Force (lbf)	Observations
500	1,037	No Leak
1,000	2,074	No Leak
1,500	3,111	No Leak
2,000	4,148	No Leak
2,160	4,480	Leak at corporation plug key/ No leakage at threads
2,500	5,185	Leak at corporation plug key/ No leakage at threads
3,000	6,222	Leak at corporation plug key/ No leakage at threads
3,140	6,512	Failure at corporation stop

NOTE: On all pull-out tests, 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
Pull-Out Tests: Corporation #2

Ram Pressure (psi)	Pulling Force (lbf)	Observations
500	1,037	No Leak
940	1,947	Leak at corporation plug key/ No leakage at threads
1,000	2,074	Leak at corporation plug key/ No leakage at threads
1,500	3,111	Leak at corporation plug key/ No leakage at threads
2,000	4,148	Leak at corporation plug key/ No leakage at threads
2,500	5,185	Leak at corporation plug key/ No leakage at threads
3,000	6,222	Leak at corporation plug key/ No leakage at threads
3,160	6,554	Failure at corporation stop

NOTE: On all pull-out tests, 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
Pull-Out Tests: Corporation #2

Ram Pressure (psi)	Pulling Force (lbf)	Observations
500	1,037	No Leak
1,000	2,074	No Leak
1,280	2,655	Leak at corporation plug key/ No leakage at threads
1,500	3,111	Leak at corporation plug key/ No leakage at threads
2,000	4,148	Leak at corporation plug key/ No leakage at threads
2,500	5,185	Leak at corporation plug key/ No leakage at threads
3,000	6,222	Leak at corporation plug key/ No leakage at threads
3,500	7,259	Leak at corporation plug key/ No leakage at threads
3,780	7,840	Failure at corporation stop

NOTE: On all pull-out tests, 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.

Cantilever Load Tests

Again, three new 3/4-inch corporation stops were installed with two layers of 3-mil thread sealant tape in the 0.231-inch wall specimen and secured in the test press. Internal water pressure of 70 psi was maintained throughout the test. The corporation stops were torqued to 40 ft-lbf.

The cantilever load tests (see Tables 9, 10, and 11) utilized the same setup as the pull-out tests; however, the pipe specimen was rotated 90° and a slightly different connection apparatus to the corporation stop was used. This connection apparatus had a pivot connection point at the corporation allowing an approximate 15° deflection. Each of the three cantilever tests was conducted in increments of 25 psi internal hydraulic pressure that was converted to inch-pounds moment at the interface between the pipe and corporation stop. Failure was defined by the loss of hydraulic pressure being applied.

TABLE 9
Cantilever Load Tests: Corporation #1 - Moment Arm Length = 4 15/16”

Ram Pressure (psi)	Pulling Force (lbf)	Bending Moment (in-lbf)	Bending Moment (ft-lbf)	Observations
25	52	256	21	No Leak
350	726	3,584	299	No Leak
375	778	3,840	320	Leak at corporation plug key/ No leakage at threads
450	933	4,608	384	Leak at corporation plug key/ No leakage at threads
460	954	4,711	393	Failure at corporation stop

NOTE: On all pull-out tests, 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 10
Cantilever Load Tests: Corporation #2 - Moment Arm Length = 4 7/8”

Ram Pressure (psi)	Pulling Force (lbf)	Bending Moment (in-lbf)	Bending Moment (ft-lbf)	Observations
25	52	253	21	No Leak
325	674	3,286	274	No Leak
340	705	3,438	286	Leak at corporation plug key/ No leakage at threads
450	933	4,550	379	Leak at corporation plug key/ No leakage at threads
460	954	4,651	388	Failure at corporation stop

NOTE: On all pull-out tests, 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 11
Cantilever Load Tests: Corporation #3 - Moment Arm Length = 4 13/16”

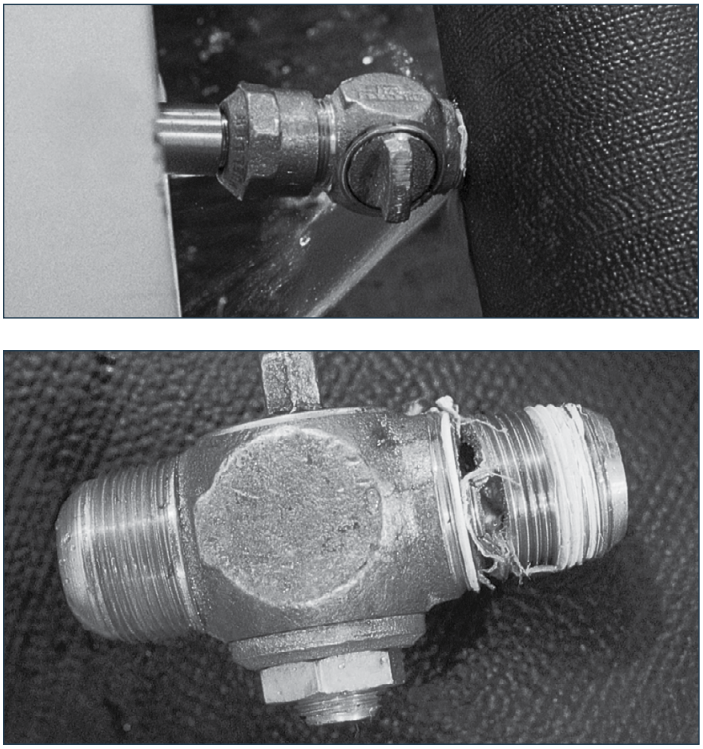
Ram Pressure (psi)	Pulling Force (lbf)	Bending Moment (in-lbf)	Bending Moment (ft-lbf)	Observations
25	52	250	21	No Leak
200	415	1,996	166	No Leak
210	436	2,096	175	Leak at corporation plug key/ No leakage at threads
475	985	4,741	395	Leak at corporation plug key/ No leakage at threads
500	1,037	4,991	416	Failure at corporation stop

NOTE: On all pull-out tests, 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.

DISCUSSION RESULTS

Leak Testing (Tables 2-5)

The three 3/4-inch direct taps, utilizing two layers of thread sealant tape, exhibited no leakage at the threaded connection for the full range of test pressures (70 to 1,000 psi) with the initial 30 ft-lbf of torque. The three 3/4-inch direct taps whose corporation stops did not receive any thread sealant tape required torques of 60 to 80 ft-lbf to stop leakage at the threaded connections. It is significant to note that for the test pipe with an average wall thickness of 0.231 inches, the "effective thread engagement" of 3/4-inch corporations was 3.23. Taking into account the pipe wall curvature, the "full thread engagement" for the 3/4-inch direct tap connections was 2.61 threads. The three 1-inch direct taps utilizing two layers of thread sealant tape also exhibited no leakage at the threaded connection for the full range of test pressures (70 to 1,000 psi) with the initial 30 ft-lbf of torque. The three 1-inch direct taps with no thread sealant tape applied required anywhere from 50 to 110 ft-lbf of torque to stop leakage at the threaded connection. The average wall thickness of the Ductile Iron Pipe specimen accommodating the 1-inch connections was 0.242 inches. For that wall thickness the "effective thread engagement" was 2.90 threads and the "full thread engagement" was 2.13 threads.



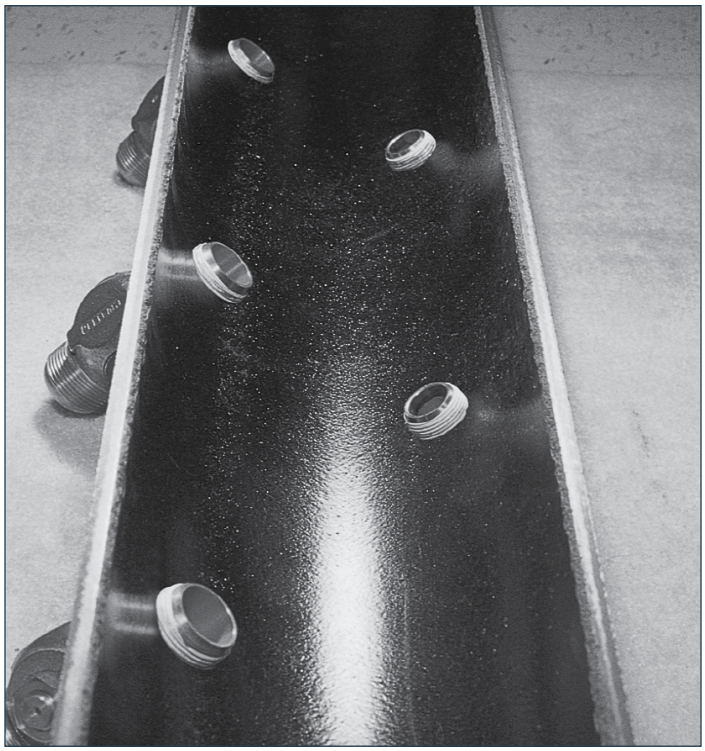
As was the case in the pull-out tests, sufficient cantilever forces damaged the corporation stop, causing the leakage seen in the photo above (top). Damage to the corporation stop is shown above (bottom).

Pull-out Tests (Tables 6–8)

The pull-out tests were conducted to evaluate the strength and integrity of the corporation stops' threaded connection to the pipe. An average pulling force of 3,028 lbf 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 lbf of pulling force. These failures occurred to the corporation stops' threaded connection for the service line, not the threaded connection to the pipe. These tests included only 3/4-inch corporations.

Cantilever Load Tests (Tables 9–11)

Similar to the pull-out tests, the cantilever load testing was conducted to evaluate the strength of the direct tap connection to the pipe. The three corporation stops subjected to the cantilever loading began to leak at an average bending moment of 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. These tests included only 3/4-inch corporations.



This cutaway view of the inside of a tapped Ductile Iron Pipe clearly shows that the corporation stops do not damage the cement-mortar lining of the pipe.

Summary

1. Pressure Class 350, 6-inch diameter Ductile Iron Pipe is the minimum thickness available. These tests clearly demonstrated that work crews can direct tap this pipe, under pressure, for installation of 3/4-inch and 1-inch corporations and can do so with total confidence.
2. The resultant thread engagement of 3/4-inch and 1-inch corporations tapped into 6-inch diameter Pressure Class 350 Ductile Iron Pipe is more than adequate to effect a structurally secure, watertight seal.
3. To achieve a watertight service connection utilizing minimal tightening torque, two layers of 3-mil thread sealant tape is recommended.
4. The threaded 3/4-inch and 1-inch direct service connections to 6-inch diameter Pressure Class 350 Ductile Iron Pipe withstood a test pressure of 1,000 psi without any leakage at the threaded connection to the pipe.
5. Direct tapping does not harm the cement-mortar lining. The lining remains intact and spalling does not occur.
6. Pull-out and cantilever forces, when sufficient, result in failure to the corporation stop, not the pipe or threads. This was also the case in direct tapping tests DIPRA conducted in 1976 and 1987.

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

Ductile Iron Pipe Research Association

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