DUCTILE IRON PIPE VERSUS PVCO PIPE

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Introduction

Design engineers face a myriad of decisions when designing and specifying a potable water pipeline, including initial cost of the system, operating requirements, maintenance costs, dependability, and long-term performance.

This brochure compares the short- and long-term structural and performance attributes of Ductile Iron pipe and molecularly oriented polyvinyl chloride (pvco) pipe. It provides valid current information to engineers who must determine a basis for selecting piping materials.

In addition to providing physical test data comparing the two pipe products, this article also compares applicable AWWA design standards for each pipe, including ANSI/AWWA C150/A21.50[1] for Ductile Iron pipe and ANSI/AWWA C909[2] for pvco pipe.

The following data is drawn from several sources, including AWWA standards, published information from pipe manufacturers and associations, and physical testing from the Ductile Iron Pipe Research Association, Structural Composites Inc., and Plastics Engineering Laboratory.[3] The tests reported in this brochure were conducted on 6-inch and 12-inch diameter Pressure Class 350 Ductile Iron pipe (the lowest Pressure Class available), and 6-inch and 12-inch diameter Pressure Class 150 pvco pipe. An attempt was made to obtain and test Pressure Class 200 pvco pipe (the highest rated in ANSI/AWWA C909); however, it was not available.

This brochure presents sound engineering information that will prove that all materials are not equal.

Comparison Of Standards

The following table compares the requirements of ANSI/AWWA C150/A21.50 and ANSI/AWWA C151/A21.51[4] to ANSI/AWWA C909.

TABLE I
Comparison Of Ductile Iron Pipe And pvco Pipe Standards

TOPIC	Ductile Iron Pipe ANSI/AWWA C150/A21.50 ANSI/AWWA C151/A21.51	pvco Pipe ANSI/AWWA C909
Sizes	3″- 64″	4″- 12″
Laying Lengths	18′, 20′	20′
Pressure Class/ Ratings	Rated up to 350 psi. Pressure Class 150, 200, 250, 300, & 350. Higher pressures may be designed.	Rated at 100, 150, & 200 psi at a service temperature of 73.4°F. For service temperatures greater than 73.4°F, the pressure rating must be appropriately reduced.
Method of Design	Designated as a flexible conduit. Separate design for internal pressure (hoop stress equation) and external load (bending stress and deflection). Casting tolerance and service allowance added to net thickness.	Designed as a flexible conduit. Separate design for internal pressure (hoop stress equation) and external load (deflection) – **external load design is not covered by a standard.** No consideration for bending stress.
Internal Pressure Design	Pressure Class: stress due to working pressure plus surge pressure cannot exceed the minimum yield strength of 42,000 psi ÷ 2.0 safety factor.	Pressure Class: stress due to working pressure plus surge pressure cannot exceed the Hydrostatic Design Basis (7,100 psi) ÷ 2.5 safety factor (Hydrostatic Design Stress=2,840 psi).
Surge Allowance	Nominal surge allowance is 100 psi (based on an instantaneous velocity change of approximately 2 fps), however, actual anticipated surge pressures should be used.	23, 27, or 31 psi surge allowance for pressure class 100, 150, & 200 psi respectively. Based on an instantaneous velocity change of approximately 2 fps.
External Load Design	Prism load + truck load. Ring bending stress limited to 48,000 psi, which is 1/2 the minimum ultimate bending strength. Deflection is limited to 3% of the outside diameter of the pipe, which is 1/2 of the deflection that might damage the cement-mortar lining. The larger of these two thicknesses governs and is taken as the net thickness.	**Design not covered in the standard.** Reference is made to AWWA M23 for design procedures. Prism load + truck load. Utilizes the Modified Iowa Deflection Equation, however, provides no deflection limits for design and defines no safety factors.
Live Load	AASHTO H20, assuming a single 16,000 lb. concentrated wheel load. Impact factor is 1.5 for all depths.	**Design not covered in the standard.** Reference is made to AWWA M23 for design procedures. AASHTO H-20, assuming two 16,000-lb. wheel loads 6 feet apart with contact patches of 18-by-20 inches. Considered for depths of cover of "usually 4 ft. and less." Impact factor is not discussed.
Factor of Safety	**Pressure Design:** 2.0 (including surge) based on minimum tensile yield strength of 42,000 psi. **External Load Design:** 2.0 for bending based on minimum ultimate ring bending strength of 96,000 psi, or 1.5 for bending based on minimum ring yield bending strength of 72,000 psi. 2.0 for deflection for cement-mortar-lined pipe. **Note:** Actual safety factors are greater than the nominal safety factors due to the addition of the service allowance and casting tolerance in the design procedure.	**Pressure Design:** 2.5 (including surge) based on Hydrostatic Design Basis of 7,100 psi. ASTM D2837 allows pipe with a Hydrostatic Design Basis of 7,100 psi to actually have a Hydrostatic Design Basis as low as 6,810 psi. **External Load Design:** No safety factors can be calculated. No external load criteria are defined. **Note:** Safety factors and strength greatly affected by temperatures, surface scratches, and extended exposure to sunlight. Pipes under cyclic loading likely have lower safety factors than those under static loading.

TABLE I (CONTINUED)
Comparison Of Ductile Iron Pipe And pvco Pipe Standards

TOPIC	Ductile Iron Pipe ANSI/AWWA C150/A21.50 ANSI/AWWA C151/A21.51	pvco Pipe ANSI/AWWA C909
Specified Trench Conditions	Five specified laying conditions (Types 1-5). Conservative E′ and soil strength parameters listed. Type 1 (flat bottom trench, loose backfill) or Type 2 (flat bottom trench, backfill lightly consolidated to centerline of pipe) are adequate for most applications.	**Not covered in the standard.** The Foreword and Appendix A of the standard references AWWA M23 and ANSI/AWWA C605.[5] C605 contains five trench conditions referred to as "common embedment types." These trench types are copies of the trench types used in the Ductile Iron pipe design standard (AWWA C150), however, AWWA C605 uses much less conservative trench values for the bedding constant (K) and soil modulus (E′).
Hydrostatic Testing	Each pipe tested to a minimum of 500 psi for at least 10 seconds at full pressure.	Each pipe tested at 4 X designated pressure class for at least 5 seconds at full pressure. There is a provision (Section 5.1.9.) for the "purchaser or supplier" to allow the manufacturer to conduct hydrostatic proof tests for pipes at test frequencies other than the requirements stated. In other words, **not every piece of pvco "must" be pressure tested.**
Factory Tests	At least one sample during each casting period of approximately 3 hours shall be tested for tensile strength; must show minimum yield of 42,000 psi, minimum ultimate of 60,000 psi and a minimum elongation of 10%. At least one Charpy impact sample shall be taken per hour (minimum 7 ft-lb.), with an additional low-temperature impact test (minimum 3 ft-lb.) made from at least 10% of the sample coupons taken for the normal Charpy impact test.	Sustained pressure tests (1,000 hour) is run semiannually at approximately 3.25 - 3.5 times the Pressure Class. Quick burst strength (at approximately 5 times the Pressure Class) tested once every 24 hours. Flattening resistance tested once every 8 hours as specified in ASTM D2412. Extrusion quality tested once every 8 hours as specified in ASTM D2152.

Ductile Iron Has More Than 10 Times The Tensile Strength Of pvco

The pipe material's tensile strength is a very important basic property because it resists the forces caused by internal hydrostatic pressure and water hammer.

Figure 1 compares the tensile strength of Ductile Iron and pvco. Shown for comparison are minimum values per the applicable standards as well as test data from specimens taken from the wall of a 6-inch Pressure Class 350* Ductile Iron pipe, and 6-inch Pressure Class 150 pvco pipe. All pipe materials were tested in accordance with ASTM E8.[6] In addition, the pvco pipe was tested in accordance with ASTM D2290[7] and ASTM D638.[8] ANSI/AWWA C151/A21.51 specifies that the ultimate tensile strength, yield strength, and elongation of Ductile Iron pipe be determined in accordance with ASTM E8. ANSI/AWWA C909 does not specify tests to determine tensile strength or elongation.

The tensile strength values for pvco in Figure 1 represent "short-term values." "Long-term values" would be much less. Unlike Ductile Iron, pvco experiences "tensile creep," even at relatively low stress levels. As the rate of loading on pvco is decreased, or when pvco is subjected to a constant load over a longer period of time, the molecules have time to disentangle, which will lower the stress needed to deform the material.

* Pressure Class 350 is the lowest available Pressure Class for 6-inch diameter Ductile Iron pipe.

Typical Variations In Operating Or Installation Temperature Do Not Affect The Strength Of Ductile Iron Pipe

Since Ductile Iron pipe has a moderate and dependable coefficient of thermal expansion, few problems are created by changes in service temperatures. Also, in a typical range of waterworks operating temperatures (32° F to 95° F) or even a conceivable extreme range of installation temperatures (-10° F to 140° F), there is no significant difference in the tensile strength of Ductile Iron pipe.

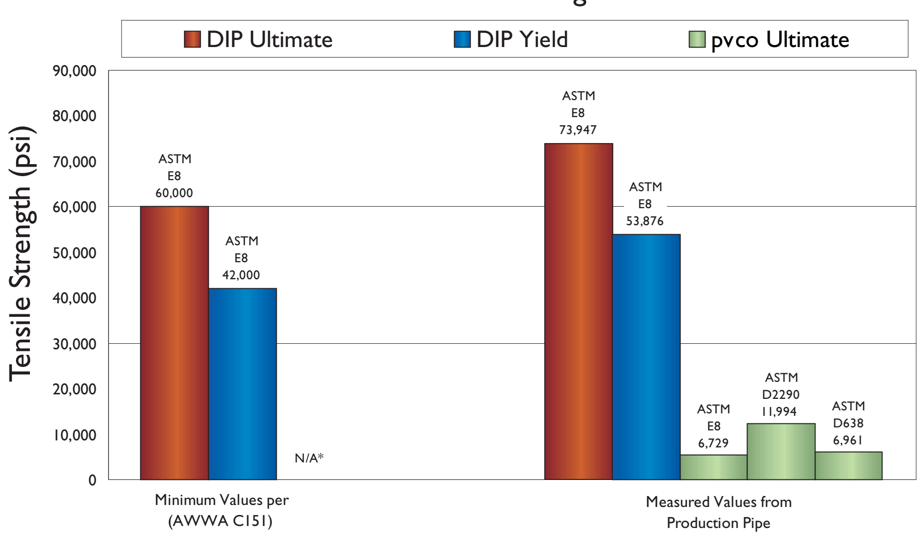
On the other hand, because of pvco pipe's thermoplastic polymeric nature, its performance is significantly related to its operating temperature.[9] Also, for service at temperatures greater than 73.4°F, pvco loses tensile strength, pipe stiffness, and dimensional stability. Thus the pressure capacity of the pvco pipe is reduced, and more care must be taken during installation to avoid excessive deflection.[10] Conversely, at temperatures less than 73.4°F, pvco loses impact strength and becomes less ductile, necessitating greater handling care in colder weather.[11]

Because the thermal expansion coefficient of pvco pipe is approximately five times that of Ductile Iron pipe,[12] it is conceivable that, when exposed to extreme temperature changes, pvco will experience undesirable structural movements such as joint buckling or disengagement due to expansion or contraction.

Figure 2 shows the relationship based on the standard tensile strength of 11,100 psi and the Hydrostatic Design Basis (HDB) of 7,100 for pvco pipe. At 110°F, the tensile strength and HDB of pvco pipe is approximately half (50 percent) of the tensile strength and HDB at 73.4°F. This reduction in strength has to be incorporated into the design of pvco pipe systems.

FIGURE 1

Tensile Strength



* AWWA C909 (pvco) contains no minimum strength values.

Ductile Iron Pipe Resists Up To 5.6 Times The Hydrostatic Burst Pressure Of pvco Pipe

The burst test is the most direct measurement of a pipe material's resistance to hydrostatic pressure. Tests were conducted in accordance with ASTM D1599[13] by fitting the pipe specimens with gasketed, unrestrained end caps, and securing them in a hydrostatic test structure to resist the end thrust. This arrangement produced stresses primarily in the circumferential direction in the walls of the pipes as internal hydrostatic pressure was applied.

All of the Ductile Iron pipe specimens (6- and 12-inch diameters) burst in the form of a fracture 15- to 41-inches long.

Four of the 6-inch diameter pvco specimens ruptured in spiral configurations. Another specimen ballooned and bowed causing leakage at the test seal and a permanent increase of 4.49% in pipe diameter. A bell end was incorporated in the last 6-inch pvco hydrostatic test by fitting it over a Ductile Iron spigot. As the pressure was increased, the bell appeared to have swelled enough that the gasket was forced out and leaked.

One of the 12-inch diameter pvco specimens burst and four others failed by "ballooning" with some also bowing and snaking, causing the pipe to pull away from the end closures and leak at the test seals. The use of blocking and tie downs in conjunction with short sections of pipe were unsuccessful in restricting the movement of the pvco pipe. This illustrates the difficulties in achieving dependable jointing of pvco pipe. Ballooning of the pipe caused permanent deformation in the four 12-inch diameter pvco pipe specimens. The permanent increase in diameter of the pvco specimens (after release of the internal pressure and removal from the hydrostatic test structure) ranged from 4.09% to 12.96%.* A bell end was incorporated in the last 12-inch pvco hydrostatic test by fitting it over a Ductile Iron spigot. As the pressure was increased, the bell appeared to have swelled enough that the gasket was forced out and leaked.

*Note: Under higher pressures, the diameter would have been even greater.

FIGURE 2

Strength-Temperature Relationship For pvco

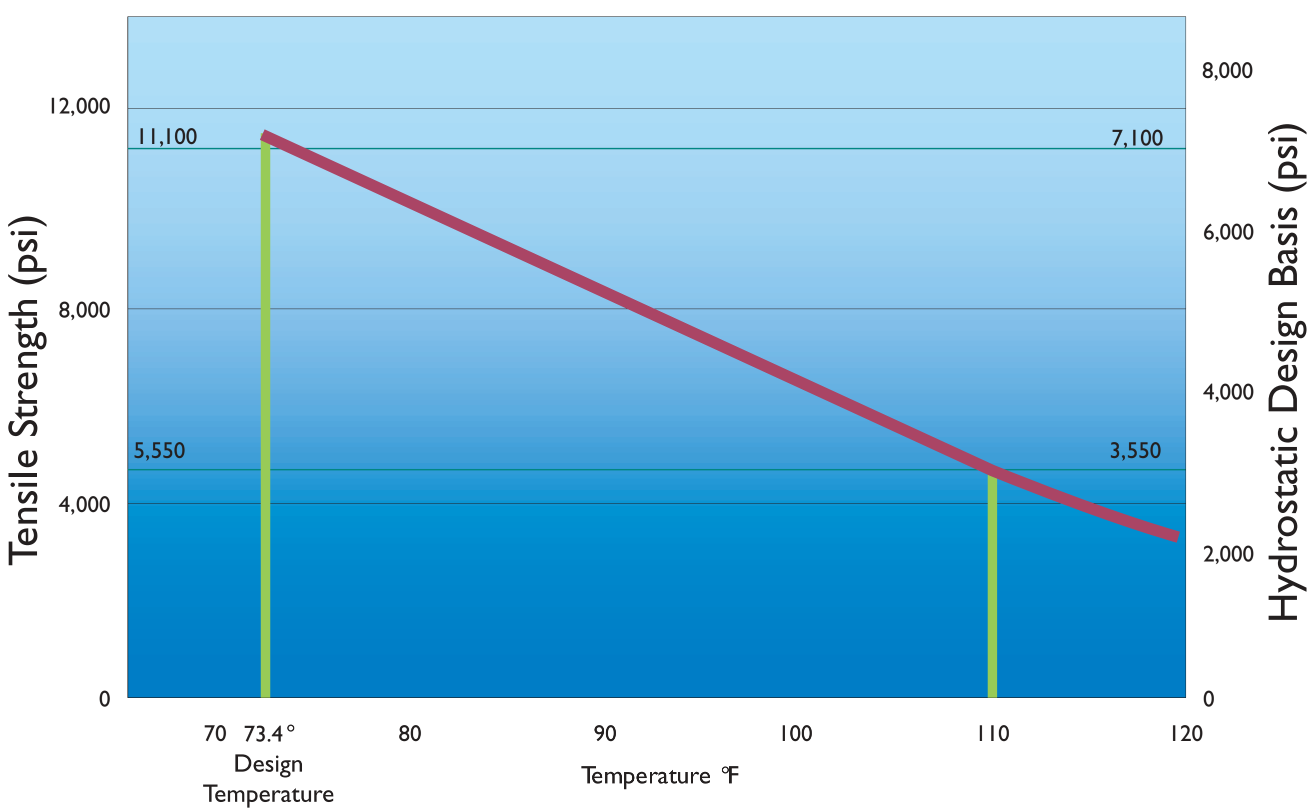
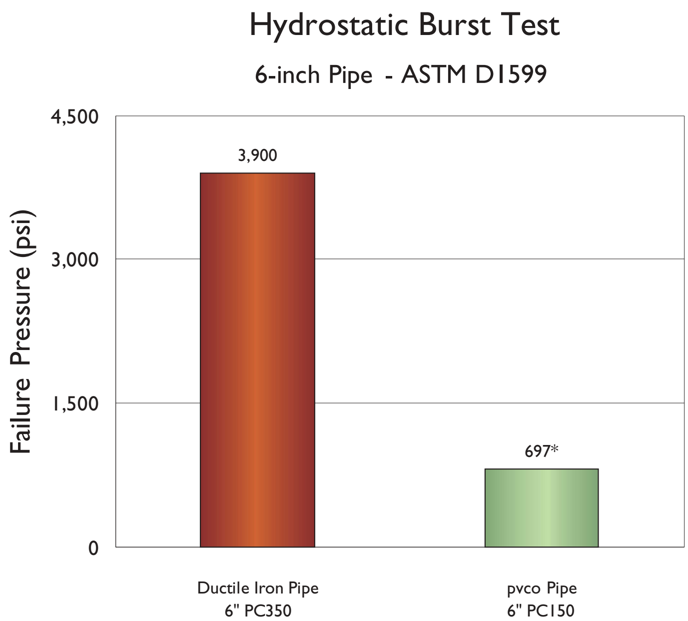


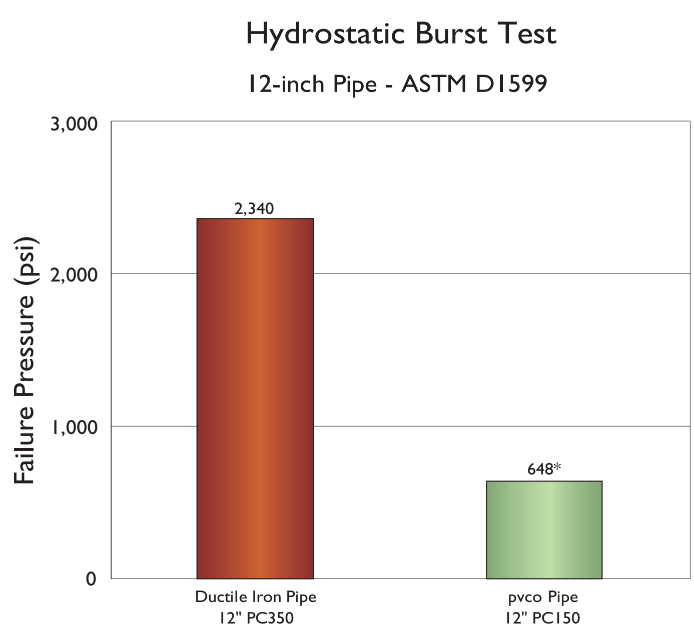
FIGURE 3



* Burst pressure at which pvco pipe failed by ballooning or fracturing.

Figures 3 and 4 compare the average hydrostatic burst pressure for Ductile Iron pipe to the burst pressure, or failure due to ballooning pressure, of pvco pipe. Note that Ductile Iron pipe is available in pressure ratings up to 350 psi in all sizes, 3-inch to 64-inch. No pvco pipe is manufactured with a pressure rating as great as that of Ductile Iron pipe in any size.

FIGURE 4



* Burst pressure at which pvco pipe failed by ballooning or fracturing.

The Strength Of Ductile Iron Pipe Is Not Compromised By Time

With Ductile Iron pipe, there is no measurable relationship between applied tensile strength and time to failure. Thus, the strength for hydrostatic design of Ductile Iron pipe is its minimum yield strength in tension, 42,000 psi.

Pvco responds to tensile stress by failing after a period of time inversely related to the applied stress. Thus, the strength used for hydrostatic design of pvco pipe is less than the yield strength of the material as established in a short time test.[14] The strength value used is called the Hydrostatic Design Basis (HDB).

The HDB value, which is defined as the stress that results in failure after 100,000 hours (11.4 years), is determined according to ASTM standard procedures by extrapolation from data accumulated from tests lasting up to 10,000 hours (1.14 years).[15] ANSI/AWWA C909 pvco pipe material is made from a pvc compound with a HDB rating of 4,000 psi which is circumferentially expanded to produce pvco pipe with a HDB of 7,100 psi. Pvco pipe that qualifies for a HDB of 7,100 psi may actually have a HDB of only 6,810 psi in accordance with ASTM D2837. The HDB should be reduced for pvco pipe used at temperatures greater than 73.4°F.[16]

Figure 5 shows a typical stress regression curve for pvco pressure pipe depicting the relationship between applied stress and time to failure. Note that after 11.4 years, pvco fails under almost one-half the stress that will cause failure initially.

Ductile Iron Pipe Resists Up To 41 Times The Short-Term Crushing Load Of pvco Pipe, And Much More For The Long-Term Crushing Load

The different theories of design of buried pipelines becomes most significant in relation to external load design. Ductile Iron pipe and pvco pipe, being flexible rings, respond to external load by deflecting. The interaction of the deflected ring with the surrounding soil is the complex question in the design theories.

The design procedure in ANSI/AWWA C150/A21.50 for external loads on Ductile Iron is based on limiting both the ring bending stress and deflection. External load is not addressed in ANSI/AWWA C909; however, generally the only parameter used in the design of pvco pipe is ring deflection.

The standard design procedure for Ductile Iron pipe limits the ring deflection due to external loads to 3 percent. This limit, which is based on the performance limit for cement-mortar linings typically specified for Ductile Iron pipe, includes an explicit safety factor of 2. This calculation employs the same conservative assumptions regarding soil parameters and earth loads used in the bending stress calculation.

The usual design procedure for pvco limits ring deflection to 5 percent — the only consideration given to external loading.

Both Ductile Iron and pvco design procedures employ the Iowa formula to predict deflection of the pipe.[17] In the Iowa formulation, both pipe stiffness and the stiffness of the fill material around the pipe contribute to limiting the deflection. Because pvco pipe has far less stiffness than Ductile Iron, the importance of soil stiffness is much greater for pvco. This

FIGURE 5

Typical Stress Regression Curve For pvco Pipe

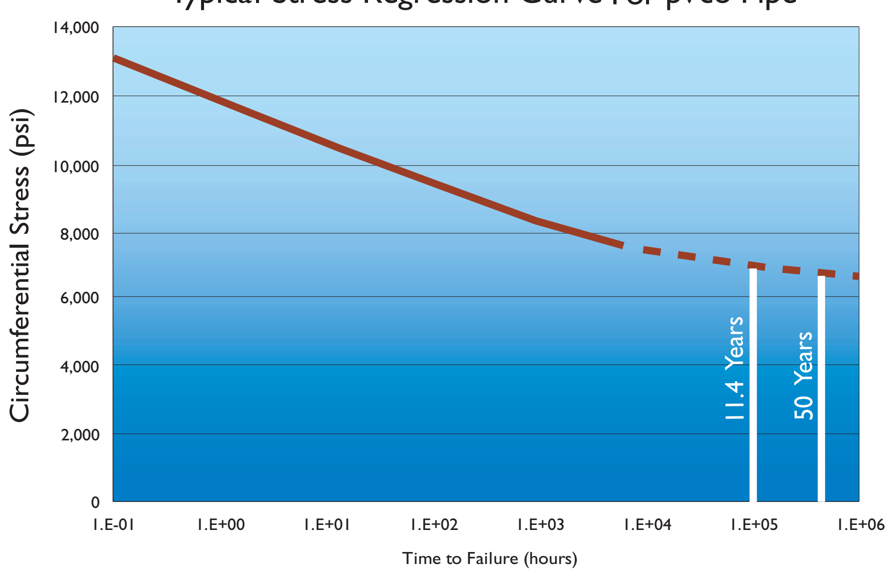


FIGURE 6

Pipe Stiffness

6-inch Pipe – ASTM D2412

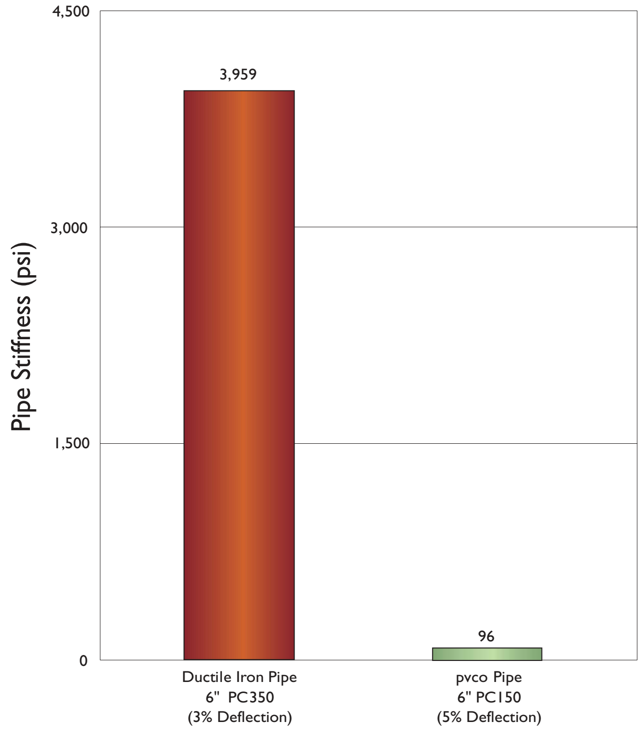
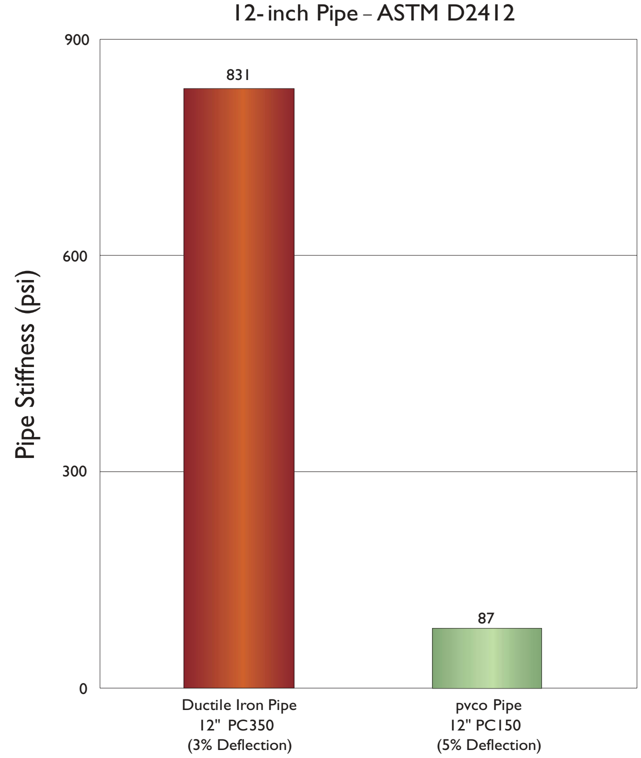


FIGURE 7

Pipe Stiffness

12-inch Pipe – ASTM D2412



means that with pvco pipe, bedding conditions and on-the-job installation inspection are much more critical.

The parallel plate ring crush test provides a simple comparison of the relative strengths of the two piping materials. Figure 6 compares pipe stiffness resulting from such tests conducted on 6-inch Pressure Class 350* Ductile Iron pipe and 6-inch Pressure Class 150 pvco pipe. Likewise, Figure 7 compares pipe stiffness of 12-inch Pressure Class 350* Ductile Iron pipe and 12-inch Pressure Class 150 pvco pipe.

In the case of Ductile Iron piping, the conventional tensile test is relied upon to define basic mechanical properties such as modulus of soil elasticity, proportional limit, and yield strength. These are basic constants for use in the many design equations that have been developed based upon elastic theory, where strain is always assumed to be proportional to stress. With plastics there is no such proportionality. The relationship between stress and strain is greatly influenced by duration of loading, temperature, and environment. The values of the modulus, yield strength, ultimate strength, and other short-term properties of plastics are for defining and classifying materials. Strength and stiffness values that have been determined by means of short-term tests are not suitable constants for use in the large body of equations that have been derived on the assumption of elastic behavior. However, most of these equations can be, and are, used with plastics provided their strength and rigidity are defined by property values that give consideration to their non-elastic behavior.[18]

Unlike Ductile Iron pipe, laboratory ring crush tests of pvco pipe, conducted with a rapid 0.5 radial inch-per-minute ring loading rate, would yield a higher value than the long-term ring stiffness due to pvco's inherent creep. The material property which ring stiffness is dependent on is the modulus of elasticity. When pvco is stressed, its modulus of elasticity decreases with time. The parallel plate ring crush test only represents the short-term ring stiffness of plastic pipe. The long-term ring stiffness would have to be calculated based on the long-term modulus.

Ductile Iron Has Up To 55 Times More Impact Strength Than pvco

Impact strength is another important characteristic of piping materials. This property relates more to conditions the pipe might encounter during handling, shipping, and installation, but can also be important if future work is conducted around an operating pipeline. It is critical because damage incurred during these activities can go undetected and later result in failures in the operating pipeline.

Figure 8 compares the impact strength as specified and measured for Ductile Iron to that measured for pvco (impact strength is not specified in ANSI/AWWA C909 for pvco). Tests were conducted by both the Izod (cantilevered beam) and Charpy (simple beam) methods.[19] These values are representative of tests conducted at 70°F±10°F. As with tensile strength, there is no measurable relationship between impact-resistance and normal operating temperature ranges for Ductile Iron pipe. Pvco pipe, however, exhibits a measurable decrease in impact strength at temperatures below 73.4°F.[20] The impact strength of pvco is also measurably decreased after the pipe has been overexposed to sunlight — an important consideration in storing plastic pipe stocks.[21]

Direct-Tapping Ductile Iron Is Easier, Less Expensive, And Faster Than Tapping pvco

Service taps are easily made either before or after Ductile Iron pipe installation. The procedure simply entails 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. Additionally, the minimum Pressure Class of 6-inch and larger Ductile Iron pipe may be direct tapped for 1-inch services. Standard corporation stops can be used on all Pressure Classes of Ductile Iron pipe and can be screwed directly into the tapped and threaded pipe.

The ANSI/AWWA C909 pvco pipe standard requires the use of a tapping saddle on all sizes and Pressure Classes of pipe. On the other hand, the use of tapping saddles with Ductile Iron pipe for normal house services is unnecessary.

Energy Savings

The manufacturer of pvco has advertised that "pvco pipe's inside diameter is larger than Ductile Iron, providing greater flow capacity and lower head loss." This statement is not correct for all sizes and classes of pipe. The inside diameter of Ductile Iron pipe and pvco pipe are very comparable, with Ductile Iron actually having a larger inside diameter than 8-inch Pressure Class 200, and 10- and 12-inch Pressure Class 150 and 200 pvco pipe.

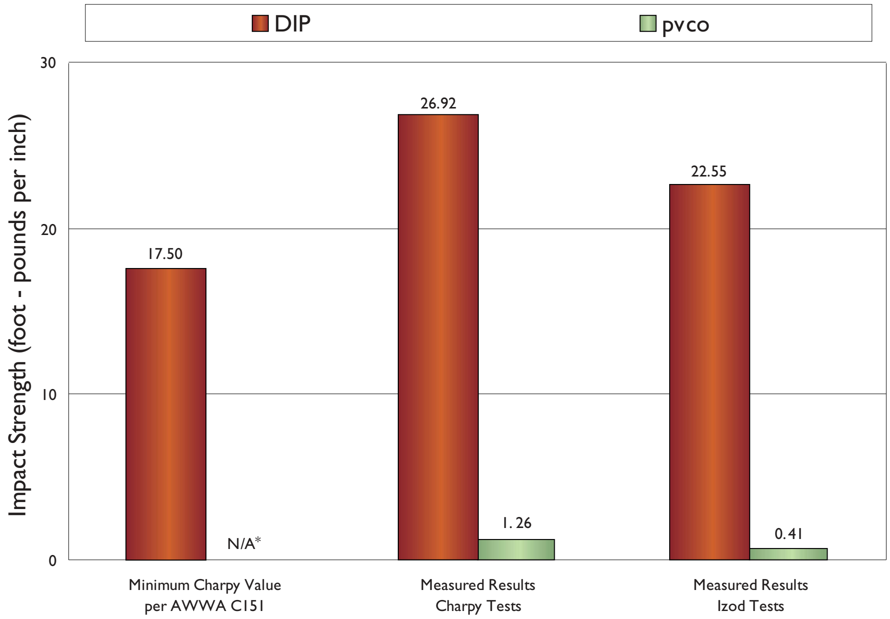
Also, both pvco and pvc manufacturers tout a Hazen-Williams "C" coefficient of 150. DIPRA and its predecessor, CIPRA, have long advocated a Hazen-Williams "C" value of 140 for use with cement-lined Gray and Ductile Iron pipe. This recommendation of a "C" value of 140 for design purposes is sound. It recognizes that the real world of pipelines is a far cry from the gun-barrel geometry of the laboratory pipeline. Furthermore, DIPRA's continued field testing of operational pipelines has shown a "C" value of 140 for cement-lined iron pipe to be realistic and one that is maintained over time — even when transporting highly aggressive waters. On the other hand, DIPRA has also conducted flow tests comparing Ductile Iron pipe to pvc pipe. The average Hazen-Williams "C" coefficient measured for pvc pipe from those tests was 139.53.

*The minimum Pressure Class available for 6-inch and 12-inch Ductile Iron pipe.

FIGURE 8

Impact Strength

ASTM E23



*AWWA C909 (pvco) contains no minimum impact strength values.

Other Considerations

Permeation

Pvco is highly permeable and should not be laid in contaminated land or in land on which hydrocarbons, including crude and fuel oils, gasoline, diesel fuel, and kerosene or the constituents of any of these hydrocarbon mixtures are used or stored. These chemicals can solvate and permeate into the walls of pvco and other plastic pipes, potentially swelling and weakening the pipe and/or adversely affecting the taste and/or odor of the potable water conveyed.

Unlike pvco, Ductile Iron pipe does not deteriorate and is impermeable when subjected to hydrocarbons. With Ductile Iron pipe systems, only the gasketed joints may be subjected to permeation. However, due to the gasket's large mass and the relatively small contact area between the gasket and soil, permeation through Ductile Iron pipe gasketed joints is not likely to be a significant source of contamination unless the gasket is exposed to neat organic chemicals for long periods of time. This is evidenced in the report titled, "Permeation of Plastic Pipes by Organic Chemicals," by Jenkins of the University of California, Berkeley, and published in the August 1991 issue of Journal AWWA under the title "Contamination of Potable Water by Permeation of Plastic Pipe."[22] The results of an extensive literature search together with a survey of U.S. water utilities revealed in this report that plastic pipe was the major piping material involved in permeation incidents with polybutylene, polyethylene, and polyvinyl chloride accounting for 43, 39, and 15 percent respectively of all the incidents reported. No incident of permeation of Ductile Iron pipe and only one incident of permeation of a gasket (type of pipe was not disclosed) was reported.

Some gasket materials resist permeation and degradation from hydrocarbons better than others. While tests on other gasket materials show promise, the results to date indicate that fluorocarbon rubber gaskets are the most resistant to permeation. Gaskets of this material are available for use with Ductile Iron pipelines installed in areas contaminated by or susceptible to contamination by hydrocarbons.

Water Hammer And Cyclic Loading

Both Ductile Iron and pvco pipe are subjected to cyclic stresses from water hammer caused by velocity changes in the system.

Ductile Iron pipe has a tensile yield strength of 42,000 psi and is designed against this value with a safety factor of 2.0. This sets the maximum internal stress at design operation levels at 21,000 psi. The cyclic fatigue limit of Ductile Iron has been reported in the literature to be between 28,000 psi and 35,000 psi.[23, 24, 25, 26] Therefore, Ductile Iron pipe is not susceptible to fatigue failures.

Pvc, on the other hand, has a fatigue limit of 1,500 psi.[27] When designed either for C900 or C905 pvc pipe, the maximum wall stress allowed is either 1,600 psi (C900) or 2,000 psi (C905). Clearly, the potential for cyclic fatigue exists. The maximum wall stress allowed for pvco is 2,840 psi. To our knowledge, no tests have yet confirmed the fatigue limit of pvco.

Bedding Requirements

Due to the inherent weaknesses in pvco pipe, bedding conditions are much more critical than with Ductile Iron pipe. Proper bedding is required to control deflection, which is the single criterion in design of pvco pipe for external loads. Standards dealing with recommended installation practices for plastic piping suggest that the pipe be surrounded by a soil with a minimum particle size, which is dependent on the pipe diameter, so that the soil can be sufficiently compacted to develop uniform lateral passive soil forces.[28] The soil also must be free of organic matter. The trench bottom must be smooth and free from large stones, large dirt clods, and any frozen materials, as these objects could cause a reduction in strength due to scratches or abrasions.[29] Such special bedding requirements are not practical or actually realized in many areas.

Because of Ductile Iron pipe's inherent strength, Type 1 (flat bottom, loose backfill) or Type 2 (flat bottom, lightly consolidated backfill) — essentially native trench conditions in accordance with ANSI/AWWA C150/A21.50 — are adequate for the vast majority of applications.

Joint Deflection

The deflection per joint for gasketed pvco pipe joints is about 2° according to Uponor's "Ultra-Blue CIOD" brochure.[30] Curves requiring greater deflection require special fittings or actual deflection of the pipe itself, which places stress (perhaps often not appropriately considered in the design) in the pipe wall. [31]

With Ductile Iron pipe, however, no joint or pipe barrel stress is required to obtain sufficient deflection. Depending on pipe diameter, push-on-joint Ductile Iron pipe has a joint deflection up to 5°.[32] Ductile Iron pipe fitted with ball and socket joints has a maximum deflection of up to 15° per joint in sizes up to and including 24-inch pipe; in sizes 30-inch and larger, maximum deflection varies from 12° to 15°.[33]

Restrained Joints

Because restrained joints are not readily adaptable to pvco pipe, only a limited number of joint restraining means are available for use with the pipe. Moreover, because all pvco restrained-joint mechanisms rely on grooved or serrated edges that dig into the pipe, they can potentially cause surface scratches to the piping material. Therefore, many utilities require that thrust blocks, rather than restrained joints, be applied to any point in the pvco piping system where the direction or cross sectional area of the waterway changes.

On the other hand, a wide variety of restrained joints are readily available for Ductile Iron pipe, giving the designer greater flexibility in pipeline design and installation.

Tracer Wires

Because it is a non-metallic substance, pvco pipe cannot be located using metal detectors. Thus, tracer wires must be placed in the trench so the pipe can be located with electronic metal detection devices. Because Ductile Iron pipe is metallic, it requires no tracer wires for location and detection.

Nearby Excavation

Existing pvco is substantially more vulnerable than is Ductile Iron pipe to puncture or damage during excavation and construction of nearby pipelines.

Buoyancy

Pvco pipe is buoyant — a concern when installing the pipe material in areas having a high water table or when trench flooding is likely to occur. To prevent loss of completed pipe embedment through flotation of pvco pipe, it must be anchored. Flotation is generally not a concern with normal installations of Ductile Iron pipe.

Sun Exposure

Special precautions must be taken when pvco pipe is exposed to sunlight for an extended period of time, because "when subjected to long-term exposure to ultraviolet (UV) radiation from sunlight, pvco pipe can suffer surface damage." This effect is commonly termed ultraviolet (UV) degradation.[34] According to the ASTM specification, if plastic pipe is stored outdoors, it may require protection from weathering in accordance with manufacturers' recommendations. And in warm climates, the covering should allow air circulation in and around the pipe.[35]

The J-M Installation Guide states that, "when pvc is exposed to the sunlight for long periods of time, a slow discoloration of the pipe may occur. This discoloration is an indication of a possible reduction in impact strength."[36]

Although the long-term effects on pvc or pvco pipe exposed to sunlight have not been clearly determined, changes in material properties obviously occur since warnings are given concerning impact strength.

Ductile Iron pipe is not vulnerable to effects of exposure to sunlight or weathering.

Effects Of Scratches

Compared to Ductile Iron pipe, pvco is a very soft material and is consequently much more vulnerable to abrasions, scratches, and other damage during shipping and installation. In fact, C909 states that "pipe surfaces shall be free from nicks and significant scratches."[37] This is the same statement which is found in C900 and C905 for pvc, and is an arguably impractical stipulation relative to many rugged construction sites.

According to Hucks, tests performed on plastic pipe have shown that a scratch 0.01 inches in depth and 10 inches in length on a 1-1/2-inch 160 psi pressure rated pipe reduced the cycles to failure from 52,000 to 9,600.[38] J-M Manufacturing Company recommends in its "Installation Guide for PVC Water Pipe" that "gouges which have a depth greater than 10 percent of the wall thickness of the pipe should be repaired."[39] This critical depth is about 0.02 inches for 6-inch Class 150 pvco pipe. According to J-M, the damaged section should be repaired with a clamp or removed.[40]

Because of Ductile Iron's great strength and durability, however, there is no measurable loss of strength due to scratches and gouges from normal handling.

Performance History

Man's ability to cast pipe probably developed from, or coincidentally with, the manufacture of cannons, which is reported as early as the year 1313. There is an official recording of Cast Iron pipe manufactured at Siegerland, Germany, in 1455 for installation at the Dillenburg Castle.

The earliest record of an AWWA standard for Cast Iron pipe is contained in the "Report of Proceedings of the Tenth Annual Meeting of the American Water Works Association" (1890). On September 10, 1902, the New England Water Works Association adopted a more detailed standard titled "Standard Specifications for Cast Iron Pipe and Special Castings."

The advent of Ductile Iron pipe in 1948 was one of the most significant developments in the pressure pipe industry. The first edition of ANSI/AWWA C150/A21.50 (the design standard for Ductile Iron pipe) and ANSI/AWWA C151/A21.51 (the manufacturing standard for Ductile Iron pipe) were issued in 1965.

The performance of Ductile Iron pipe extends over 45 years, and because of its close physical resemblance to Gray Iron pipe, the long-term record of Gray Iron can be used to predict the life of a Ductile Iron pipeline.[41] This comparison has been enhanced by extensive research on the comparative corrosion rates between Ductile Iron and Gray Iron, which has shown Ductile Iron to be **at least** as corrosion-resistant as Gray Iron.[42]

Gray and Ductile Iron pipe have withstood the test of time. On the other hand, the ANSI/AWWA C909 standard for pvco pipe was only first issued in 1998.

Conclusion

Ductile Iron pipe has long been recognized as the superior pipe material for water and wastewater applications. Its tremendous strength and durability allow it to be designed under conservative assumptions and installed with confidence that the actual service conditions it experiences will not compromise its ability to perform.

The exorbitant cost associated with early replacement of underground piping make the engineer's initial choice of the best available piping material the most economical decision over the long-term.

Ductile Iron pipe is a proven performer — a product with a performance history dating back more than 45 years, several centuries if its predecessor Gray Iron pipe is considered.

Regardless of the criteria — strength, durability, tapping, safety factor, or actual field experience — it is easy to understand what those who know pipe have long known. Ductile Iron pipe is the right decision!

References

1. ANSI/AWWA C150/A21.50, "American National Standard for the Thickness Design of Ductile Iron Pipe," American Water Works Association, Denver, Colorado (1996).
2. ANSI/AWWA C909, "American National Standard for Molecularly Oriented Polyvinyl Chloride (PVCO) Pressure Pipe, 4 In. (100 mm Through 300 mm), For Water Distribution," American Water Works Association, Denver, Colorado (1998).
3. Original tests were conducted by Structural Composites, Inc., an independent engineering testing firm, in 1999 in Melbourne, Florida, and American Cast Iron Pipe Company in Birmingham, Alabama, in 1999 and witnessed by Professional Service Industries, an independent consulting third-party witnessing/testing firm. Supplemental tests were conducted by Plastics Engineering Laboratory, an independent testing firm, in 2000 in Lawrenceville, Georgia, and United States Pipe and Foundry Company in 1999-2000 in Birmingham, Alabama.
4. ANSI/AWWA C151/A21.51, "American National Standard for Ductile-Iron Pipe, Centrifugally Cast, For Water," American Water Works Association, Denver, Colorado (1996).
5. ANSI/AWWA C605, "American National Standard for Underground Installation of Polyvinyl Chloride (PVC) Pressure Pipe and Fittings for Water," Denver, Colorado (1994).
6. ASTM E8, "Test Methods For Tension Testing of Metallic Materials."
7. ASTM D2290, "Apparent Tensile Strength of Ring or Tubular Plastics and Reinforced Plastics by Split Disk Method."
8. ASTM D638, "Tensile Properties of Plastics."
9. American Water Works Association Manual M23, "PVC Pipe-Design and Installation," American Water Works Association, Denver, Colorado (1980), p.9, Uni-Bell Plastic Pipe Association, "Handbook of PVC Pipe Design and Construction," Dallas, Texas, 1991, p.116.
10. AWWA M23, p.9.
11. AWWA M23, p.9.
12. "Handbook of PVC Pipe," p. 268.
13. ASTM D1599, "Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings."
14. "Handbook of PVC Pipe," p. 123.
15. ASTM D2837, "Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials."
16. ANSI/AWWA C909.
17. "Handbook of PVC Pipes," pp. 198-210.
18. "Engineering Properties of Polyethylene," Plastic Pipe Institute, p. 3-11.
19. ASTM E23, "Notched Bar Impact Testing of Metallic Materials."
20. "Handbook of PVC Pipe," p. 213.
21. "Handbook of PVC Pipe," p. 60.
22. D. Jenkins. "Permeation of Plastic Pipes by Organic Chemicals," Journal AWWA, August 1991.
23. "Ductile Iron Handbook," American Foundrymen's Society, Inc., 1992, pp. 25, 26.
24. ASM Handbook, Volume 19, "Fatigue and Fracture," ASM International, 1996, pp. 665-679.
25. ASM Specialty Handbook, "Cast Irons," ASM International, 1996, pp. 395-408.
26. Ductile Iron Compendum, Pont-a-Mousson S.A., 1986, A. 81.
27. Hucks, Robert T. Jr., "Designing PVC Pipe for Water-Distribution Systems," Journal American Water Works Association, July 1972, p. 447.
28. ASTM D2774, "Standard Practice for Underground Installation of Thermoplastic Pressure Pipe," 1994.
29. ASTM D2774. C909, Section 4.3.2.
30. Uponor, "Ultra-Blue CIOD."
31. Uponor, "Ultra-Blue Short Form Specification."
32. AWWA C600-99, pp. 12-14.
33. "Ductile Iron Pipe Subaqueous Crossings," Ductile Iron Pipe Research Association, Birmingham, Alabama, 1999.
34. "Handbook of PVC Pipe," p. 60.
35. ASTM D2774.
36. "Blue Brute PVC Class Water Pipe Installation Guide," Johns-Manville, Denver, Colorado, 1979, p.7.
37. C909, Section 4.3.2.
38. Robert T. Hucks, Jr. "Design of PVC Water Distribution Pipe," Civil Engineering, June 1972, p. 73.
39. "Blue Brute PVC Class Water Pipe Installation Guide," p. 37.
40. "Blue Brute PVC Class Water Pipe Installation Guide," p. 37.
41. Approximately 560 U.S. and Canadian utilities are members of the Cast Iron Pipe Century Club for having Cast Iron pipe in continuous service for 100 years or more. At least 16 utilities have gained membership in the Cast Iron Pipe Sesquicentury Club for having Cast Iron pipe in continuous service for 150 years or more.
42. E.C. Sears. "Comparison of the Soil Corrosion Resistance of Ductile Iron Pipe and Gray Cast Iron Pipe," Material Protection, October 1968.

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