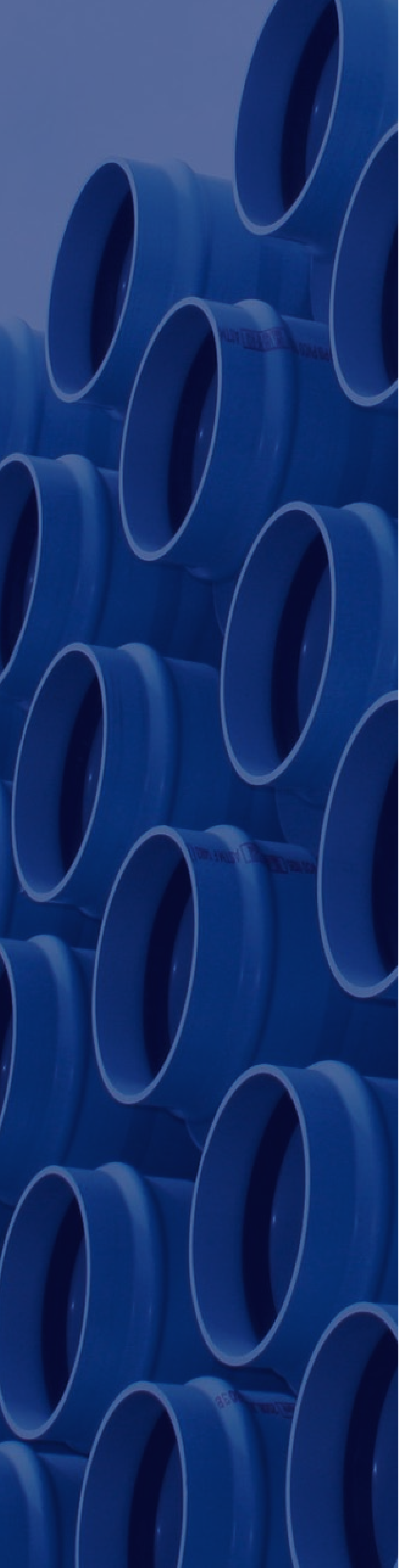
Introduction to

Molecularly Oriented Polyvinyl Chloride (PVCO) Pipe

PVCPIPE association



History of PVCO Pipe

More Than Forty Years of Use in North America

Molecularly oriented polyvinyl chloride pipe (PVCO) has been used in North America for more than four decades, with more than 20,000 miles of pipe installed. There are many similarities between polyvinyl chloride (PVC) and PVCO pipe. For instance, ingredients and cell classifications for PVC water pipe and PVCO pipe are the same. PVCO begins as an equivalent PVC compound, which is extruded into PVC pipe and then physically modified to become molecularly oriented pipe. As a result, the starting stock for PVCO and PVC both qualify for cell class 12454 per ASTM D1784 and have a hydrostatic design basis (HDB) of 4,000 psi.

The manufacturing process for PVCO causes realignment of the molecular structure from random orientation to circumferential orientation. This increases the material's mechanical strength and toughness. Once completed, PVCO pipe has an HDB of 7,100 psi. Owing to PVCO's different HDB values, the dimension ratio (DR) classification for conventional PVC is not used for PVCO. Instead, PVCO is referenced only by pressure class (PC) or pressure rating (PR).

In North America, Cast Iron Outside Diameter (CIOD) products are commercially available 4-inch through 30-inch in pressure classes 165, 235, and 305 psi; Iron Pipe Size (IPS) products are available 4-inch through 16-inch in pressure ratings 160, 200, and 250 psi. PVCO and PVC are commonly used in distribution systems requiring open-cut installations while PVC can also be used in trenchless installations.

First North American Installation — Kansas, 1979

PVCO pipe was developed in Europe in the early 1970s and first installed there in 1974. The earliest installation of PVCO pipe in North America took place in Kansas in 1979. By the 2000s, PVCO pipe was available from multiple manufacturers in North America.

Published in 1993, ASTM F1483 was the first product standard available for PVCO pipe. Initial applications were mostly rural water and irrigation piping. The new standard used ASTM D2241 as a template, having the same PRs, safety factors, and product quality control testing. In 1998 AWWA C909 was published, becoming the first PVCO municipal water pipe standard. AWWA C909 modeled much of its requirements from AWWA C900, using the same PCs, safety factors, diameter regimen, product quality control testing, and joint qualification testing. The AWWA C909 standard has been updated over the years to include larger sizes and to conform to the revised design procedures of the C900 standard. In 2009, CSA published PVCO standard B137.3.1.

Manufacturing Processes

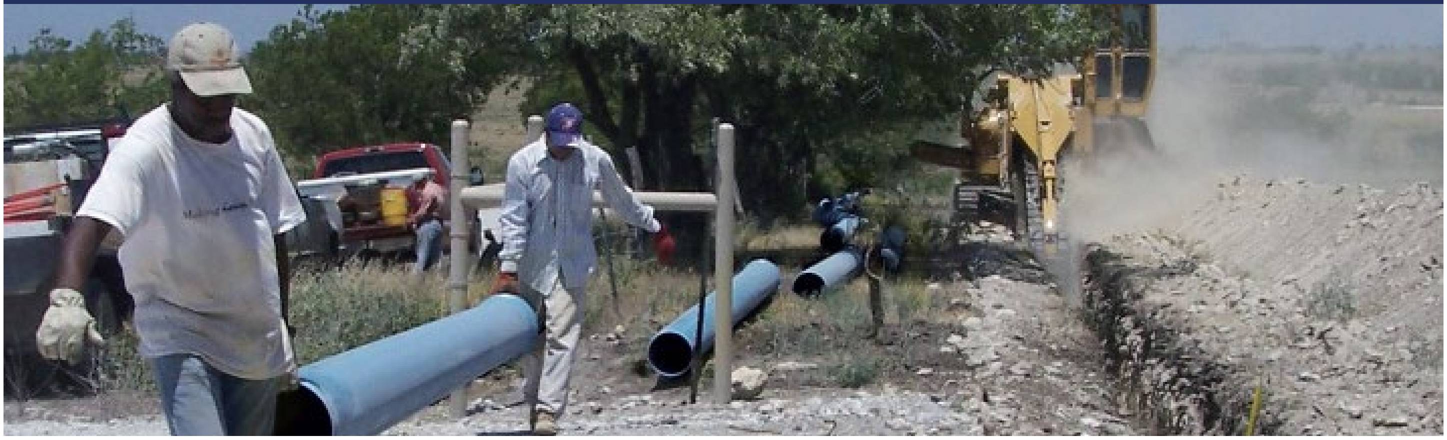
PVCO pipe starts out as PVC pipe. The extruded PVC pipe, called "starting stock," is approximately half the diameter and double the wall thickness of finished PVCO product. Molecular orientation occurs by expanding the starting stock in a radial direction. To optimize PVCO's material properties, expansion is carefully controlled through pipe temperature, expansion rate, amount of expansion, and cooling rate.

PVCO pipe is manufactured using either a batch or a continuous process. In the batch process, the starting stock is extruded and cut to a length several feet longer than the finished pipe. Each individual length of PVC stock is then placed into a mold where it is heated, expanded by internal pressure, and cooled. The bell is formed in the molding process, eliminating the need for a separate belling operation as with PVC pipe. The pipe is then cut to length. In the continuous process, partially cooled stock is drawn over a mandrel, expanding the pipe to approximately twice its original diameter. For C909 pipe made by either process, each length of pipe is hydrotested to the same pressure as the equivalent PC of AWWA C900 pipe.

FIGURE 1: CONTINUOUS MANUFACTURING PROCESS FOR PVCO

This expansion (or "stretching") causes the long PVC polymer chains to orient in the hoop direction (i.e., around the pipe circumference). This strengthens the material in the hoop direction. There also may be partial orientation in the longitudinal direction. The same gasket materials are used for both PVCO and PVC pressure pipes and must conform to ASTM F477 requirements for high-head applications.

FIGURE 2: MANUAL LIFTING AND PLACEMENT OF PVCO PIPE



Installation and Maintenance Considerations

Installation requirements for PVC and PVCO pipe are covered by AWWA C605 and AWWA Manual M23, with only one difference — direct tapping of PVCO for service connections is not permitted. PVCO pipe may be saddle tapped up to and including 2-inch taps. For taps larger than 2 inches, sleeve tapping may be used. Fittings for PVCO can either be PVC or ductile iron (DI) for CIOD/IPS sizes in North America. There are several joint restraint manufacturers that offer mechanical restraints approved for use on PVCO pipe.

PVCO vs DI Pipe

PVCO is not affected by corrosion and does not require corrosion mitigation. In contrast, the DI pipe industry recommends that utilities assess soil corrosivity to determine the appropriate method(s) of corrosion protection. As a result, protective coatings or cathodic protection may be required. Consideration should be given to construction damage to the coatings as well as long-term maintenance of the cathodic systems.

PVCO pipe is much lighter than DI pipe, eliminating the need for heavy equipment to move and install in the smaller sizes. See Table 1.

PVCO vs HDPE Pipe

PVCO is mainly used in open-cut installations, while HDPE is typically used in trenchless applications. The major difference between PVCO and HDPE pressure piping is the joining method. PVCO has bell-and-spigot joints, while HDPE pipe is butt-fused. Butt-fusion is time-consuming and requires special equipment and highly trained crews. Also, proper fusion requires mitigation of field construction conditions such as cold temperatures and wet environments. In contrast, joint assembly for PVCO pipe is simple, involving only the insertion of a spigot end into a bell.

TABLE 1: WEIGHT OF A 20-FOOT LENGTH OF 8-INCH PIPE

Pipe Product	Weight (lbs)
PVCO (PC 235)	110
DI (PC 350)	462
HDPE (PC 200)	182

Fittings and mechanical joint-restraints needed for connecting pipe to appurtenances are more readily available for PVCO pipe than for HDPE pipe. PVCO can be tapped using saddles or sleeves — simpler processes than the fusion required for HDPE.

To prevent oxidation of HDPE pipe, utilities may also need to consider the type and amount of disinfection products used. Disinfection is not a concern for PVCO pipe.

Design Comparisons

The material properties of PVCO, DI, and HDPE differ, causing significant variations in system operations for pipes. This section provides two examples that highlight these differences.

Given:

- Pipe: 8-inch diameter CIOD pipe
- Products (based on most common PCs available):
  - PVCO pipe — AWWA C909 PC 235
  - DI pipe — AWWA C151 PC 350
  - HDPE pipe — AWWA C906 PC 200

Dimensions and properties:

- Pertinent data for these examples is shown in Table 2.

TABLE 2: DATA FOR 8-INCH CIOD PIPE						
Pipe Product	Outside Diameter (in.)	Minimum Wall Thickness (in.)	Average Wall Thickness (in.)	Approximate Inside Diameter (in.)	Approximate Flow Area (sq. in.)	Modulus of Elasticity (psi)
PVCO (PC 235)	9.05	0.290	0.305	8.44	56.0	465,000
DI (PC 350)	9.05	0.250	0.313	8.43	55.7	29,000,000
HDPE (PC 200)	9.05	0.823	0.864	7.32	42.1	130,000

Notes:

1. Average wall thickness for PVCO and HDPE pipe is 5% above minimum wall.
2. Average wall thickness for DI pipe includes 0.125-inch mortar lining, but no casting or service allowance.

Comparisons:

- Hydraulic friction loss — pressure loss due to flow in pressure pipe is calculated for each of the products.
- Occasional surge pressure — response of the three pipe products to an occasional (emergency) surge is provided.

Hydraulic Friction Loss

The first comparison between the pipe materials is hydraulic flow. For the same nominal size, each pipe product has different wall thicknesses, thus different flow areas. PVCO and DI have similar wall thicknesses, but PVCO has the advantage of better flow characteristics. Although PVCO and HDPE have the same flow characteristics, HDPE has the disadvantage of much thicker walls.

Given:

- Flow volume = 850 gpm

Solution:

For details on how to calculate the items in the next steps, see Chapter 9 of Uni-Bell's *Handbook of PVC Pipe*.

- The first step is to calculate the fluid velocity in each pipe for the given flow volume.
- Next the hydraulic radius for each pipe product is determined.
- Then the friction losses are calculated.

Results:

- Results are shown in Table 3.

TABLE 3: RESULTS FOR FRICTION LOSS EXAMPLE					
Pipe Product	Flow Velocity (fps)	Approximate Inside Diameter (ft)	Hydraulic Radius (ft)	Hazen-Williams Coefficient	Friction Loss (ft / 1,000 ft)
PVCO (PC 235)	4.88	0.703	0.176	150	7.98
DI (PC 350)	4.89	0.703	0.176	140	9.16
HDPE (PC 200)	6.47	0.610	0.153	150	15.9

Discussion:

- As expected, friction losses for PVCO and DI products are relatively close at 8.0 and 9.2 ft / 1,000 ft, respectively. HDPE is at 15.9 ft / 1,000 ft (about 99% higher than PVCO). PVCO's advantage over DI is about 15%, a value that would increase if DI suffered any internal corrosion.

Occasional Surge Pressure

AWWA C909 defines occasional surge as: "surge pressures caused by emergency operations, usually the result of a malfunction (such as power failure, sudden valve closure, or system component failure)." Design for occasional surge requires that the sum of working pressure plus surge pressure not exceed the pipe's short-term rating (STR).

The STR for each pipe product is determined from the product's geometry and material properties. Methods for determining STRs for PVCO, DI, and HDPE are provided in their respective product standards or design manuals. For PVCO, see AWWA C909 and Uni-Bell's *Handbook of PVC Pipe*.

The example below assumes a fire-flow condition with instantaneous velocity stoppage. This is a worst-case scenario for occasional surge pressures.

Given:

- Working pressure = 100 psi
- Flow volume = 1250 gpm
- Data for 8-inch pipe from Table 2

Solution:

For details on how to calculate the items in the next steps, see Chapter 5 of Uni-Bell's *Handbook of PVC Pipe*.

- The first step is to calculate the fluid velocity in each pipe for the given flow volume.
- Next the pressure wave velocity in each pipe product is determined.
- Then the surge pressures are calculated.

Results:

- Results are shown in Table 4.

TABLE 4: RESULTS FOR OCCASIONAL SURGE EXAMPLE

Pipe Product	Flow Velocity (fps)	Pressure Wave Velocity (fps)	Occasional Surge Pressure (psi)	Working Pressure (psi)	Total Pressure (psi)	Short-Term Rating (psi)	Total Pressure as % of STR
PVCO (PC 235)	7.17	1,100	106	100	206	376	55%
DI (PC 350)	7.19	8,820	377	100	477	450	106%
HDPE (PC 200)	9.53	1,050	135	100	235	400	59%

Discussion:

- Total pressure in the PVCO and HDPE products are at 55% and 59% of allowable, respectively. However, the DI pipe's total pressure is at 106% of the STR. Even if the DI pipe were able to withstand this excessive pressure, other components of the pipe system would be at risk.

References

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