UNI-BELL PVC PIPE ASSOCIATION

More than 20 years experience with water utility operations and management.

Steve Cooper, P.E., MSCE
Regional Engineer
PVC PRESSURE PIPE

TOPICS

• Introduction
• History/Standards
• Manufacturing/Testing
• Pressure Pipe Design
• Engineering Properties
• Installation
• Conclusions: Condition Assessment
UNI-BELL PVC PIPE ASSOCIATION

• Founded in 1971
• Authoritative source of information on PVC pipe
• Serves engineering, regulatory, standardization, and public health communities
• Mission: Our mission is to promote use of longer-life, lower-maintenance, corrosion-proof PVC piping in water and wastewater systems – for real sustainability, strength and long-term asset management
UNI-BELL PVC PIPE ASSOCIATION

- Provide users with information on the design and installation of PVC pipe
- Produce technical publications
- Active in standards-development organizations
- Sponsor research in the areas of:
  - buried pipe
  - deflection
  - pipe longevity
  - cyclic performance
PVC PRESSURE PIPE

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HISTORY OF PVC PIPE

WATER PIPE

• PVC water pipe available in North America since the 1950s.

• PVC pipe’s first major market was rural water sector.

• 1960s: National Sanitation Foundation (NSF) certifies PVC pipe for potable water. Entry into the municipal market.

• Additional standards adopted in 1970s through 1990s by the American Water Works Association (AWWA).
**STANDARDS**

**PRESSURE PIPE STANDARDS SHEET**

- Available up to 48”

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### PVC PRESSURE PIPE STANDARDS

<table>
<thead>
<tr>
<th>Standard</th>
<th>Performance Designation</th>
<th>Nominal Diameter Range</th>
<th>Outside Diameter (OD)</th>
<th>Pressure Class (PS)</th>
<th>Pressure Rating (PR)</th>
<th>Minimum Cell Classification</th>
<th>Joining System</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM D-2466</td>
<td>PVC Water Distribution and Transmission Pipe</td>
<td>Pressure Class (PC)</td>
<td>4&quot; - 12&quot;</td>
<td>Cast iron Compatible (CIC)</td>
<td>PC 185 psi</td>
<td>PC 215 psi</td>
<td>PC 300 psi</td>
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<tr>
<td>ASTM D-2466</td>
<td>PVC Water Distribution Pipe &amp; Fabricated Fittings</td>
<td>Pressure Class (PC)</td>
<td>94&quot; - 60&quot;</td>
<td>Cast iron or loadable</td>
<td>Cast iron pipe, size compatible (CIC) or IPS</td>
<td>PP 60 psi</td>
<td>PP 90 psi</td>
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<td>PP 90 psi</td>
</tr>
<tr>
<td>ASTM D-1493</td>
<td>PVC Pressure Rated Pipe</td>
<td>Pressure Rating (PR)</td>
<td>4&quot; - 16&quot;</td>
<td>Cast iron or loadable</td>
<td>Cast iron pipe, size compatible (CIC) or IPS</td>
<td>PR 150</td>
<td>PR 200</td>
</tr>
<tr>
<td>ASTM D-1493</td>
<td>PVC Pressure Rated Pipe (PVC-U)</td>
<td>Pressure Rating (PR)</td>
<td>4&quot; - 16&quot;</td>
<td>Cast iron or loadable</td>
<td>Cast iron pipe, size compatible (CIC) or IPS</td>
<td>PR 150</td>
<td>PR 200</td>
</tr>
<tr>
<td>ASTM D-1249</td>
<td>Pressure Rated PVC (PVC-U)</td>
<td>Pressure Rating (PR)</td>
<td>4&quot; - 12&quot;</td>
<td>Cast iron or loadable</td>
<td>Cast iron pipe, size compatible (CIC) or IPS</td>
<td>PR 50 psi</td>
<td>PR 90 psi</td>
</tr>
<tr>
<td>ASTM D-5155</td>
<td>Schedule 80 PVC</td>
<td>Schedule (SCH)</td>
<td>1.5&quot; - 24&quot;</td>
<td>Cast iron or loadable</td>
<td>Cast iron pipe, size compatible (CIC) or IPS</td>
<td>SCH 1.5&quot;</td>
<td>SCH 20&quot;</td>
</tr>
</tbody>
</table>

* Certain dimensions listed are available in any PVC Schedule or Schedule. 
* All classifications specified are for the compounded and molded piping stock. 
* The service line PPR parameters required. 
* Pressure ratings are dependent upon pipe size and schedule. See ASTM D-2466. 
* Note: Some diameters and load classes may not be readily available due to market demand. Check with U-Bil Baltimore member companies regarding load class availability.
STANDARDS
PRESSURE PIPE HISTORY

• ASTM D2241  published in 1964
• AWWA C900  published in 1975
• AWWA C905  published in 1988
• ASTM C907  published in 1991
• ASTM C909  published in 1998
PVC PRESSURE PIPE

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MANUFACTURING AND TESTING

PRESSURE PIPE TESTING

• Hydrostatic Proof-Testing
  ▪ Every length of AWWA gasketed pipe is tested on line
  ▪ Test pressure is two times the pipe’s pressure class
MANUFACTURING AND TESTING

FLATTENING TESTING

• A 2-inch ring is placed between two parallel plates and compressed until the distance between the two plates is 40% of the pipe OD.
MANUFACTURING AND TESTING

LEAK-TIGHT JOINTS

• Gasketed joints must meet ASTM D3139 requirements
• Joints must maintain a vacuum pressure of -10.8 psi (-75kPa)
• Joints must withstand a hydrostatic pressure equal to 2.5 times the pressure class of the pipe for 60 minutes
• Joints must withstand the minimum burst pressure of the pipe
MANUFACTURING AND TESTING

PVCO PIPE

• Same PVC compound

• Same extrusion process

• Same cooling, cutting, and chamfering

• Difference is pipe is expanded to twice original OD
  ▪ Batch process
  ▪ Continuous process
MANUFACTURING AND TESTING

PVCO PIPE

• Expansion - PVC molecules realigned

• Improved properties
  ▪ Tensile strength
  ▪ Impact resistance
PVC PRESSURE PIPE

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• **Pressure Pipe Design**
• Engineering Properties
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PRESSURE PIPE DESIGN

- Long-term strength
- Short-term strength
- Cyclic strength
- Force main design
PRESSURE PIPE DESIGN

HYDROSTATIC DESIGN BASIS (HDB)

- All PVC pressure pipe

- Process
  - Testing per ASTM D1598
  - Analysis of test results per ASTM D2837
  - Listing by Hydrostatic Stress Board (HSB)

- Result: HDB
  - Stress category for pipe design
  - 4000 psi for most PVC pressure pipe
PRESSURE PIPE DESIGN

STRESS REGRESSION LINE

![Graph showing stress regression line with 2000 psi highlighted.](image-url)
PRESSURE PIPE DESIGN

ALLOWABLE STRESS

\[
S = \frac{HDB}{F} = \frac{4,000}{2} = 2,000 \text{ psi}
\]

Where:
- \( S \) = Allowable Stress, psi
- \( HDB \) = Hydrostatic Design Basis, psi
- \( F \) = Factor of Safety
PRESSURE PIPE DESIGN

PIPE DIMENSION RATIO (DR)

\[ \text{DR} = \frac{\text{OD}}{t} \]
PRESSURE PIPE DESIGN

ISO EQUATION FOR PRESSURE PIPE

PC = \frac{2S}{(DR-1)}

Where:

S = hydrostatic design stress, psi = HDB/F
DR = dimension ratio = D/t
PRESSURE PIPE DESIGN

DESIGN CONSIDERATIONS FOR PVC

• Design Standards
• Hydraulic Smoothness
• Operating Pressures
• Transient Pressures
• Flexible Buried Pipe Theory
• Air-Release Valves
• Thrust Restraint
PRESSURE PIPE DESIGN

DESIGN : PVC FORCEMAIN

Design Checks

• Long-term pressure capacity
• Short-term pressure capacity
• Cyclic capabilities
PRESSURE PIPE DESIGN

EXTERNAL LOAD DESIGN

- PVC buried design is based on Flexible Pipe Theory (outlined in AWWA M23)

- Typically, external loads do not dictate the pressure rating of the pipe
PVC PRESSURE PIPE

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ENGINEERING PROPERTIES

HYDRAULICS

• The Hazen-Williams “C” value for new and previously used PVC pipe is: 155 to 165
• Conservative design is to use: C = 150
• Competitive materials have a lower “C” value initially and are subject to deterioration with time.
• PVC results in lower energy costs.
ENGINEERING PROPERTIES

CORROSION

- PVC does not rust or break down with time
- Any materials using metal for strength are subject to failure due to corrosion
PVC PRESSURE PIPE

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**INSTALLATION**

**BACKFILL**

**PVC Pipe**  
AWWA C605

**Ductile Iron Pipe**  
AWWA C600
INSTALLATION
PIPE ASSEMBLY

- Position pipe with print on top
- Provide a worker at both ends
- Clean the spigot and bell
- Lube per instructions
- Position in straight alignment
- Insert spigot into bell
- Push together to insertion line
INSTALLATION

GASKETED BELL JOINT GAP

• Should be a gap
• Spigot should not bottom in bell
• Point loading created can distort and cause leaks or breakage
• Insertion line must be visible
INSTALLATION

AIR/VACUUM RELEASE VALVES

• In long pipe lines with undulating grades, it is important to eliminate any entrapped air in the pipeline for the safety of the system

• Air trapped in the pipeline is a compressed gas and can be harmful to the pipeline, fittings, and pumps

• Air / vacuum release valves (for positive and negative pressure events due to instantaneous stoppage of flow) must be located at strategic points in the pipeline protect the system

• AWWA Manual M51 provides information on location and designing air valves
PVC PRESSURE PIPE

TOPICS

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• Conclusions: Condition Assessment
## Longevity

### Timeline for Type of Pipeline Materials

|---------------------------------|-------|----------|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|        |
| Steel                           | Welded| None     | None     |        |        |        |        |        |        |        |        |        |        |         |
| Steel                           | Welded| Cement   | None     |        |        |        |        |        |        |        |        |        |        |         |
| Cast Iron (pit cast)            | Lead  | None     | None     |        |        |        |        |        |        |        |        |        |        |         |
| Cast Iron                       | Lead  | None     | None     |        |        |        |        |        |        |        |        |        |        |         |
| Cast Iron                       | Lead  | Cement   | None     |        |        |        |        |        |        |        |        |        |        |         |
| Cast Iron                       | Leadite| None   | None     |        |        |        |        |        |        |        |        |        |        |         |
| Cast Iron                       | Leadite| Cement | None     |        |        |        |        |        |        |        |        |        |        |         |
| Cast Iron                       | Rubber| Cement   | None     |        |        |        |        |        |        |        |        |        |        |         |
| Ductile Iron                    | Rubber| Cement   | None     |        |        |        |        |        |        |        |        |        |        |         |
| Ductile Iron                    | Rubber| Cement   | PE Encasement |        |        |        |        |        |        |        |        |        |        |         |
| Asbestos Cement                 | Rubber| Material | Material |        |        |        |        |        |        |        |        |        |        |         |
| Reinforced Conc. (RCP)          | Rubber| Material | Material |        |        |        |        |        |        |        |        |        |        |         |
| Prestressed Conc. (PCCP)        | Rubber| Material | Material |        |        |        |        |        |        |        |        |        |        |         |
| Polyvinyl Chloride              | Rubber| Material | Material |        |        |        |        |        |        |        |        |        |        |         |
| High Density Polyethylene       | Fused | Material | Material |        |        |        |        |        |        |        |        |        |        |         |
| Molecularly Oriented PVC        | Rubber| Material | Material |        |        |        |        |        |        |        |        |        |        |         |

- **Commerially available**
- **Predominantly in use**
LONGEVITY

PVC PIPE – LONG TERM PERFORMANCE

American Water Works Association Research Foundation recently quantified the life expectancy of PVC pipe at more than 110 years – making it excellent for long-term management and sustainability.
WATER MAIN BREAK STUDY 2012
UTAH STATE UNIVERSITY REPORT

• Largest Uni-Bell study undertaken
• Survey sent to 1050 utilities
• Respondents 188 (17.9%)
• Two survey instruments used
  • Basic survey 188
  • Detailed Survey 47
• Identified frequency of failures for different pipe materials
• Report disseminated widely - presentation to the U.S. Conference of Mayors
WATER MAIN BREAK STUDY 2012

UTOH STATE UNIVERSITY REPORT

• Average break rates per 100 miles of pipe
  • CI 24.4
  • DI 4.9
  • PVC 2.6
  • Steel 13.5

• DI rate is 1.9 times PVC rate

• Expected life of DI
  • DI much less than cast iron
  • Same rate of corrosion
  • Thinner wall of DI
• 76% said PVC is in their system
• 64% confirmed PVC is accepted
• 87% rated longevity as extremely important
• 52% indicated PVC is easiest to maintain
• 42% said PVC was used in trenchless projects
• 43% of respondents are experiencing corrosion problems
PVC PIPE ASSOCIATION PUBLICATIONS

1. Installation Guide for Solid-Wall PVC Sewer Pipe
2. Installation Guide for Gasketed-Joint PVC Pressure Pipe
3. Deflection: The Pipe/Soil Mechanism
4. PVC Pipe: The Right Choice for Trenchless Projects
INSTALLATION

INSTRUCTIONAL PUBLICATIONS

- UNI-PUB-9: “Installation Guide For Gasketed- Joint PVC Pressure Pipe”
- Chapter 10 and 11 of the Uni-Bell Handbook of PVC Pipe: Design and Construction
TECHNICAL BRIEFS AND FAQs

EXPANSION GAPS: ESSENTIAL TO PVC SEWER PIPE JOINT DESIGN

Inspections of PVC sewer pipelines often reveal small expansion gaps at the gasketed joints. These gaps are not flaws. In fact, they are key to PVC pipe design and ensure optimal joint performance, helping make PVC joints the most durable and watertight of all sewer pipes. With more than one million miles installed, 320 million gasketed joints in service, and over 40 years of proven performance, PVC pipe is the material of choice for today’s wastewater systems.

PVC PIPE JOINTS SHOULD HAVE GAPS

PVC sewer pipes are engineered with deep-insertion, push-together gasketed joints. When assembled, they should have expansion gaps between the end of the spigot and the neck of the bell. These gaps protect the integrity of the watertight joints, allowing room for expansion and contraction. They also provide for an angular offset at the joint, which is useful in unanticipated and aggressive ground movements and other adverse field conditions.

PVC SEWER PIPE SETS THE STANDARD FOR HYDRAULICS

Before the advent of PVC, engineers selected 0.013 for Manning’s n value for all sewer pipe (used to measure the friction coefficient of water or wastewater flowing through sewer pipe). PVC sewer pipe has recorded values as low as 0.007, confirming that the gap between the bell and spigot does not affect PVC pipes’ n value or its superior flow characteristics. The recommended design n value for PVC sewer pipe systems is 0.009.

OVER-INSERTION CAN COMPROMISE JOINT PERFORMANCE

Forcing the PVC pipe joints past the insertion line can compromise piping system performance, resulting in over-insertion which can reduce the joint’s flexibility, deflection allowances and ability to expand.

ASSEMBLING THE PVC JOINT PROPERLY

Figure 1 shows a properly assembled PVC joint. The spigot gasket is pushed into the bell until the insertion mark is positioned flush with the lip of the bell. If the insertion mark is not visible after assembly, the pipe has been over-inserted. If the mark falls short of the lip of the bell, the installer should push the pipe further until the mark is aligned.

Figure 2 shows a pipe that has been over-inserted. Neglecting the rules for proper PVC pipe installation can create stress points in the pipe, potentially affecting its performance.

Figure 1: Property Inserted Spigot

Figure 2: Over-Inserted Spigot

PP Pipe Doesn’t Measure Up: The recent introduction of PP into the sanitary sewer market should be cause for concern to wastewater utilities. Unsupported claims about performance, lack of rigorous studies and testing, questions regarding joint integrity, reduced safety factors, limited selection of fittings for connections, all point to the need to exercise caution when considering PP alternatives over PVC pipe.

Choose PVC Pipe: Today’s sewer utilities require piping products with a proven track record of performance. Supported by over 40 years of standards and testing, PVC pipe offers exceptional joint integrity, low maintenance, and a high safety factor, backed by stringent mandated and low-pressure air tests. With a broad assortment of fittings for connections, which help avoid compromising system integrity through use of cut-in fittings, PVC pipe is available in a wide array of options suitable for the most difficult applications.

### PVC VS. POLYPROPYLENE (PP) SEWER PIPE

**PVC: PROVEN PERFORMANCE MAKES IT THE RIGHT CHOICE**

**Material**
- PVC
- PP

**Density**
- PVC
- PP

**Tensile Mins.**
- PVC
- PP

**Modulus Mins.**
- PVC
- PP

**Pipe Siffness Min. @ 23°C / 70°F**
- PVC
- PP

**Impact Resistance**
- PVC
- PP

**Air Test**
- PVC
- PP

**Minimum Wall**
- PVC
- PP

**Meaning “N”**
- PVC
- PP

**Fatigue**
- PVC
- PP

**Recommed Max. Diameter Deflection**
- PVC
- PP

**Deflection Before Buckling**
- PVC
- PP

**Base ID**
- PVC
- PP

**3rd World**
- PVC
- PP

**Fittings**
- PVC
- PP

**Joints**
- PVC
- PP

*For pipe standards refer to ASTM D2241 appendix (F)B (1/8 in)
*Minimum wall thickness for PVC per the 2013 Code.

ASTM D2241-08: Standard Specification for Type P (H) Poly (Vinyl Chloride) (PVC) Sewer, Drain, and Vent Pipe and Fittings

ASTM F1446: Standard Specification for Type P (H) Poly (Vinyl Chloride) (PVC) Large Diameter Pipe and Fittings

ASTM F734-03: Standard Specification for Poly (Vinyl Chloride) (PVC) Pressure Sewer, Drain, and Vent Pipe and Fittings Based on Controlled Inside Diameter

ASTM F1619: Standard Specification for Poly (Vinyl Chloride) (PVC) Composite Sewer Pipe and Fittings Based on Controlled Inside Diameter

ASTM F1061-90: Standard Specification for Poly (Vinyl Chloride) (PVC) Closed-Profile Gravity Pipe and Fittings Based on Controlled Inside Diameter

ASTM F734-10: Standard Specification for Poly (Vinyl Chloride) (PVC) Composite Sewer Pipe and Fittings Based on Controlled Inside Diameter

ASTM F7269-10: Standard Specifications for 36-Inch 1500 psi Polypropylene (PP) Triple Wall Pipe and Fittings for Non-Pressure Sanitary Sewer Applications
WEBSITE
YOUR INFORMATION RESOURCE

www.uni-bell.org
www.pvcpa.org
THANK YOU FOR THIS OPPORTUNITY!

EXPERIENCE

PVC pressure piping installed:
More than 1 million miles