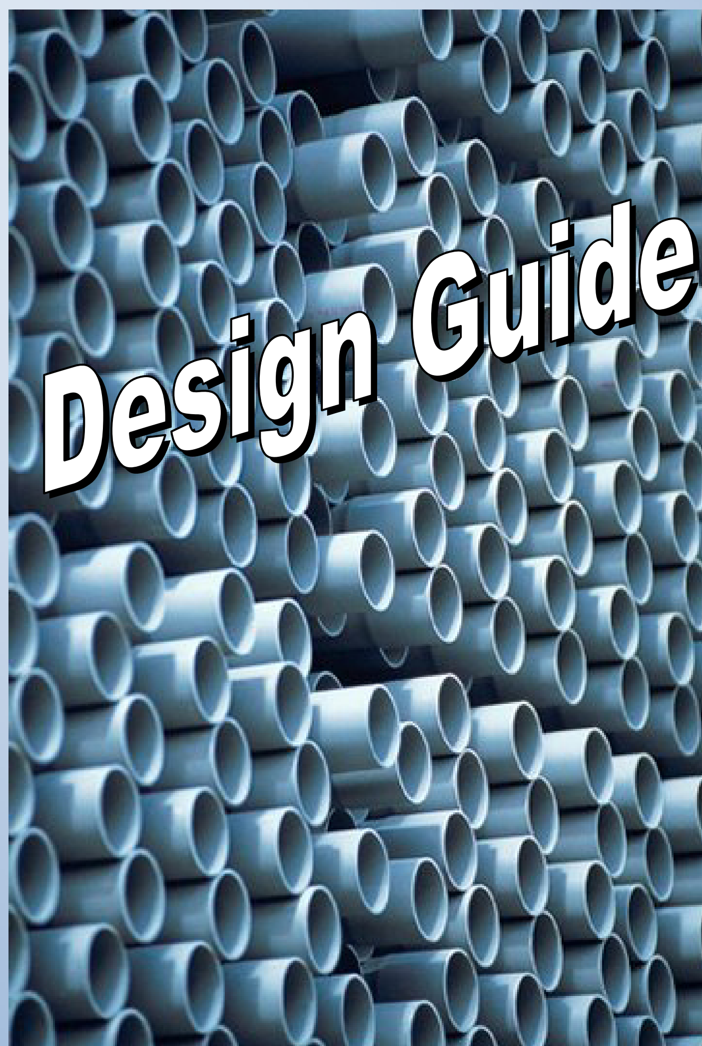
PVC Piping Systems for Commercial and Industrial Applications



PPFA

Plastic Pipe and Fittings Association

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Using the *Design Guide*
The *Design Guide* was created to assist engineers, installers, end-users, engineering students and building code officials in learning more of the dos and don'ts of PVC piping systems. The *Design Guide* is comprised of ten sections including:

- Introduction
- Features and Benefits
- Engineering Design
- Joining Methods
- Installation
- Testing and Repair
- Applications
- Building Codes, Standards, and Sample Specifications
- PVC Piping and the Environment
- Other Plastic Piping Systems

In addition, in the back of the guide is the most complete appendix and glossary of PVC piping systems ever assembled.

Other PPFA Educational Materials
The PPFA offers a wide range of other educational materials developed to assist the engineering and construction industry to become more proficient in the use of the preferred piping system...plastics! On-site seminars, Webinars, CD-based seminars, workbooks, online tutorials and product and technical literature are available. For more information on these educational tools, visit PPFA's website at www.ppfahome.org.

Disclaimer
The material in the *Design Guide* has been prepared for the general information of the reader/user. The information is believed to be technically correct; however, the authors, PPFA and their directors, officers, staff, and agents do not warrant the *Design Guide* or any of its contents suitable for any specific applications. The presented material is published as an information guideline only. It shall be the responsibility of the reader/user to incorporate prudent and generally accepted engineering practices and to meet the requirements of all involved regulatory agencies and their codes and standards.

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INTRODUCTION

Background of PPFA and PVC piping systems.

The Plastic Pipe and Fittings Association (PPFA) is composed of more than seventy-five companies involved in the manufacturing of products for plastic piping systems. PPFA has been a major force in educating the North American market since 1978 in thermoplastic residential, commercial, and industrial piping products and installations. The *Design Guide* has been published by the PPFA with the express purpose of educating the engineering and construction community to the design benefits of Polyvinyl Chloride (PVC) piping systems in commercial and industrial projects.

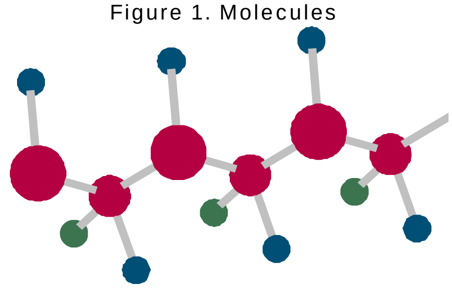
PVC or vinyl can be found in just about every home or business, in hundreds of applications. Because of the physical nature of this amazing plastic, it can be rigid, flexible, weather or heat resistant, impact resistant, thick or thin, and any color one can imagine. PVC's major uses are in the following industries: medical, automotive, electronics, toys, packaging, and construction.

Over ¾ of PVC compounds produced in North America go into the construction industry with such products as siding, conduit, window frames, roofing, wire and cable insulation, flooring, wall coverings, gutters and downspouts, landfill liners, decking, fencing, and piping. Of these products, piping is the largest user of PVC resin. Presently, PVC pipe accounts for more than 70% of newly buried water distribution and 75% of newly installed sanitary sewer systems in North America. Why? Because it is durable, easy and safe to install, environmentally sound, and cost effective.

Definitions

Plastic: Plastic is a material that contains organic, polymeric substances of large molecular weight, is solid in its finished state, and at some stage in its manufacture or processing into a finished article, can be shaped by flow.

Figure 1. Molecules



Thermoplastic: A plastic that can be repeatedly softened by heating and hardened by cooling through a temperature range characteristic of the plastic, and that in the softened state can be shaped by flow into an article by molding or extrusion. PVC, CPVC, ABS, PP, PE, and PVDF are thermoplastic piping materials.

Thermoset: A plastic that, when cured by application of heat or by chemical means, changes into a substantially infusible product. PEX and Reinforced Fiberglass piping are thermoset materials.

Monomer: A relatively simple compound and resin building block that can react to form a polymer. Vinyl Chloride is the monomer used in making PVC.

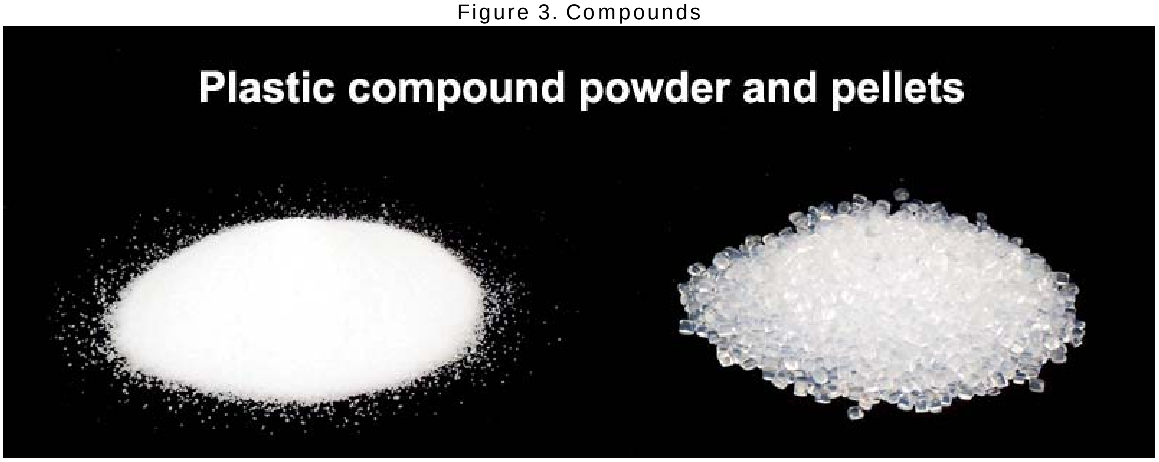
Polymer: A substance consisting of molecules characterized by the repetition of one or more types on monomeric units. PVC is a polymer made from the polymerization of the monomer vinyl chloride.

Resin: Broadly stated, the term designates any polymer that is the basic material for a plastic.

Figure 2. Resin

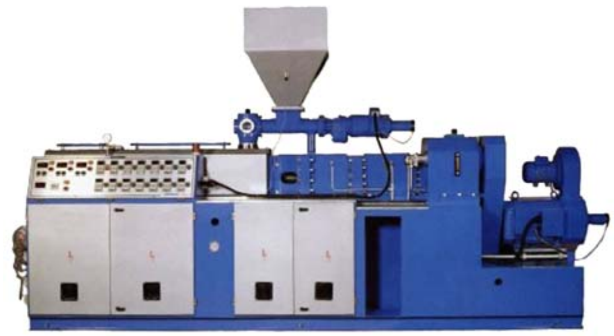
Compound: A mixture of a thermoplastic resin with other additives or ingredients. All certified PVC piping products are manufactured from compounds formulated by manufacturers to ASTM and PPI standards.

Figure 3. Compounds



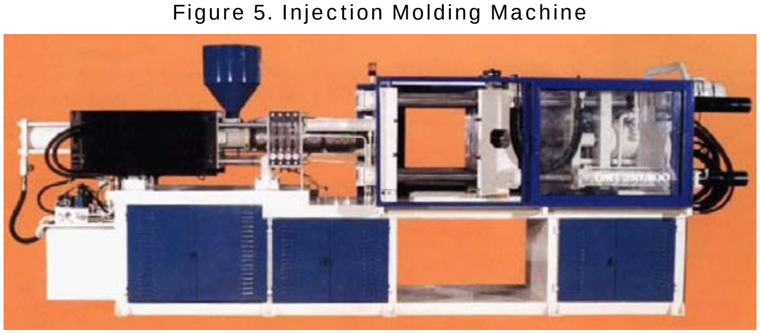
Extrusion: All PVC pipe is manufactured by the extrusion process. In this process, PVC compounds, in pellet or powder form, are fed by a hopper into a heated barrel containing a rotating screw (a.k.a. extruder). The compounds are uniformly heated under pressure by the screw and barrel until uniform melting and mixing is achieved. The molten plastic is then forced under extreme pressure through a die and sizing sleeve where the desired shape is obtained. The product is then cooled through downstream cooling techniques (typically under vacuum in a water bath) to maintain the dimensions of the desired shape. Further downstream from the cooling process, the pipe is cut to length. Extrusion is a continuous process where long runs of pipe are typically manufactured once conditions are optimized.

Figure 4. Extruder



Injection Molding: Most voluminous thermoplastic non-pipe products are injection molded. Injection molding is the process of forming a material by forcing it, under pressure, from a heated cylinder through a sprue (runner) into the cavity of a closed mold. All standard PVC fittings from ¼ inch to 12 inches in diameter and most valves are injection molded. For most PVC non-standard or larger diameter fittings and valves, fabrication methods using pipe, rod, and sheet create the desired product.

Figure 5. Injection Molding Machine



For other definitions and plastic acronyms, see the Glossary as well as Appendix B.

History

In 2007 the plastic industry celebrated its 100-year anniversary. Dr. Leo Baekeland, a Belgium-American, created the first all-synthetic plastic, Phenol Formaldehyde (Bakelite), in 1907. His discovery set forth a movement to jump-start the nascent plastics industry throughout the world.

Table 1. History and Highlights of PVC Water Piping Systems

Year	Highlights
1907	First all synthetic plastic – a phenolic named Bakelite
1932	First tubes made from PVC in Germany
1935	First pipes made from PVC in Germany
1936	First installation of PVC piping for potable water and waste pipelines in Germany—most piping systems are still in service
1949	Initial use of PVC pipe in North America
1952	First PVC water distribution pipes laid in the USA
1960	ASTM 1785 Standard Specification for PVC Schedule Pipe introduced
1964	ASTM D2241 Standard Specification for SDR Series Pipe introduced
1968	AWWA Standards Committee on Thermoplastic Pressure Pipe was established
1970	Canadian Standards Association (CSA) publishes first edition of CS B137.3—"Rigid PVC Pipe for Pressure Applications"
1971	Uni-Bell Plastic Pipe Association had first meeting
1978	Plastic Pipe and Fittings Association founded
1996	PVC water pipes (>3 in.) market share exceeds 50% in USA and Canada
2004	PVC water pipes (>4 in.) have 78% share of water distribution market in North America (over 71,100 miles of buried pipe)
2005	PVC is the largest volume plastic pipe material in North America with annual sales in excess of 6.8 billion pounds

Source: Adapted from AWWA data

PVC was discovered in the late 1800s and as with many discoveries in chemistry—accidentally. Scientists, observing the newly created chemical gas, vinyl chloride, discovered that when the gas was exposed to sunlight, it underwent a chemical reaction (recognized now as polymerization) leading to a whitish solid material. After decades of inaction to this new discovery, in the 1920s Waldo Semon was hired by BF Goodrich to develop a synthetic rubber. His experiments then proved successful and yielded plasticized or flexible PVC.

At first, PVC was used to make shoes, raincoats, golf balls, insulation of electrical wiring and other uses (all applications of plasticized PVC). In wasn't until the late 1930s that rigid PVC was considered for piping material. In the beginning, PVC pipe manufacturers used plasticizers as a resin additive. A few years later, plasticizers were eliminated, and the overall performance of PVC showed a marked improvement. All rigid North American PVC pipe for the last four or five decades has been made without any plasticizer or heavy metal stabilizers.

Due to the features of durability, ease and safety of installation, environmental soundness, and cost-effectiveness, PVC piping and all other vinyl products have grown enormously in use throughout the world. Today, PVC is the preferred piping material in water mains, sewer lines, drains, vents, irrigation, water service, swimming pools, and water well casings.

Besides, owning to its excellent long-term strength, higher stiffness, resistance to a broad range of chemicals, and competitive price, PVC accounts for over 70% of the linear footage of all thermoplastic piping. And due to its popularity, PVC has the broadest range of valves, fittings, and other piping appurtenances compared to most other piping materials.

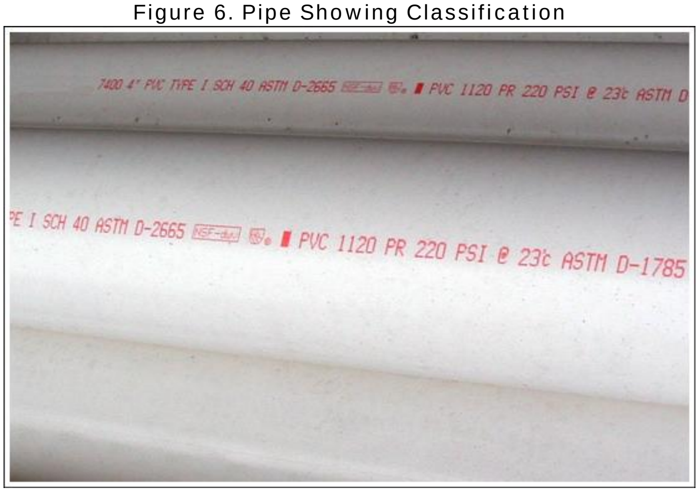
Material Characteristics

PVC is made to ASTM International standards, which classify piping material by common physical characteristics. Over the past decade, there has been a movement to refine the classifications in a more meaningful way; however, the old designations are still in use.

The old ASTM designation for PVC is made up of four digits:

- First digit = Material
- Second digit = Grade
- Third/Fourth digit = Hydrostatic design stress divided by 100
- Example: PVC 1120

Figure 6. Pipe Showing Classification



The new ASTM designation cell classification (per ASTM D1784):

- First digit = Material
- Second digit = Impact strength
- Third digit = Tensile strength
- Fourth digit = Modulus of elasticity
- Fifth digit = Heat deflection temperature
- Example: PVC 12454 (Equivalent to PVC 1120)

In this text, all charts and tables for PVC piping will mostly be characteristic of PVC type 1, grade 1 or cell classification—12454. Since PVC compounds can be formulated many different ways, there are other types of solid PVC that exhibit different physical characteristics, such as: Type II (cell classification 14333) which has higher impact strength but reduced physical properties in other areas than Type I: and Type III (cell classification 13233) which has fillers that increase the stiffness but lower the tensile and impact strengths and reduce the chemical resistance. There are several other PVC piping products that are available as listed in Figure 7 through Figure 11 that can and are used in certain commercial and industrial applications; still, the *Design Guide* will only cover the more commonly used commercial and industrial PVC piping materials.

Figure 7. Coextruded Drain-Waste-Vent Piping

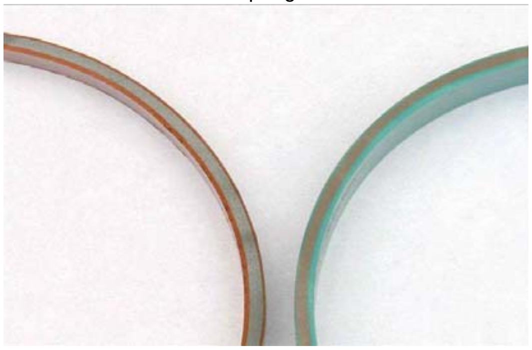


Figure 8. Clear Piping Systems

Figure 9. Purple Pipe for Reclaimed and Gray Water

Figure 10. Perforated Piping

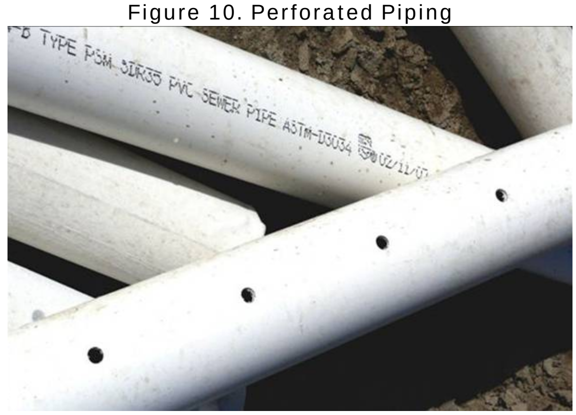


Figure 11. Double Containment Piping

Physical Characteristics

ASTM test methods and standards are nationally recognized and utilized to define plastic characteristics. The physical values listed may differ slightly (+ or – 5%) due to variations of manufacturers' compound formulations but still within the standards of ASTM product classification.

Specific Gravity: The ratio of the density of a material to the density of water at standard temperature (ASTM D-792 Test Method). PVC = 1.40 (Water = 1)

Tensile Strength: The pulling force necessary to break a specimen divided by the cross-section area at the point of failure (ASTM D-638 Test Method). PVC = 7,000-7,500psi @ 73°F

Figure 12. Tensile Testing Machines

Modulus of Elasticity: The ratio of the stress to the elongation per inch due to this stress, in a material that deforms elastically (ASTM 638 Test Method). PVC = 400,000 – 433,000-psi @ 73°F

Izod Impact Strength: The resistance that a notched test specimen has to a sharp blow from a pendulum hammer (ASTM D-256 Test Method). PVC = 0.65 – 0.75 ft-lb/in

Figure 13. Izod Testing Machine

Flexural Strength: The strength of a plastic material in bending as expressed by the tensile stress of the outermost fibers of a bent test sample at the instant of failure (ASTM D-790 Test Method). PVC = 13,000 - 14,500-psi

Coefficient of Thermal Expansion: The fractional change in a length of a specimen due to a unit change in temperature (ASTM D-696 Test Method). PVC = 2.9 - 3.0 in/in/°F x 10^{-5}

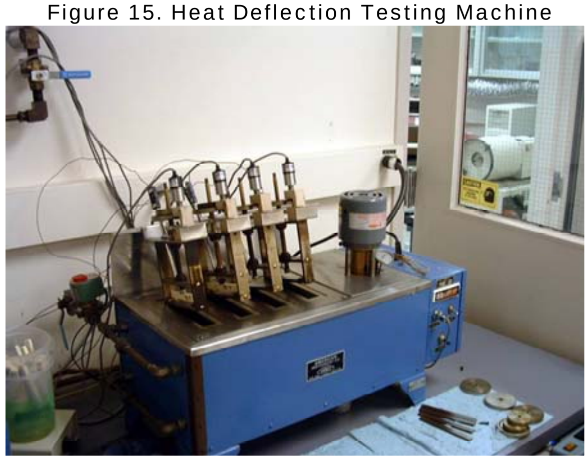
Thermal Conductivity: The time rate of moving heat by conduction through a material of a given thickness and area for a given temperature difference (ASTM C-177). PVC = 1.02 - 1.20 Btu in/hr/ft^2/°F

Figure 14. Heat Resistance Testing

Thermal Conductivity via Modulated Differential Scanning Calorimetry (DSC)

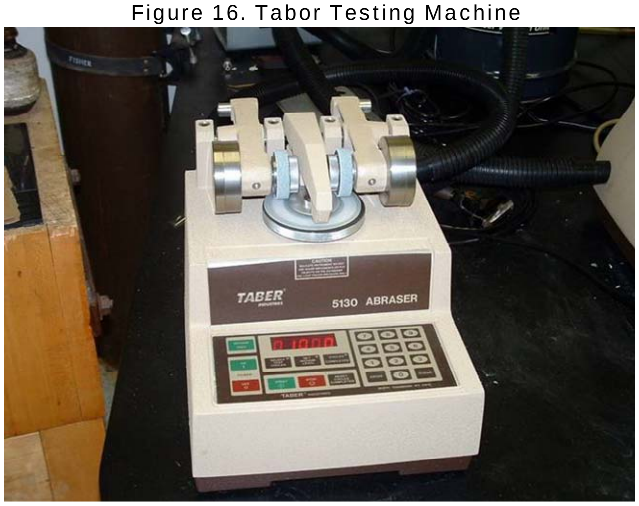
Heat Resistance: The general maximum allowable temperature of a piping system in which 20-psi working pressure or less may be used. PVC = 140°F Deflection temperature under load, °F @ 264 psi (ASTM D 648) = 160 - 170

Figure 15. Heat Deflection Testing Machine



Abrasion Resistance: Using the Taber Abrasion Test, the weight loss of a material is measured after being exposed to an abrasive wheel for 1000 cycles. PVC = 15-20 mg. The lower the number, the more abrasion resistant. (Stainless Steel is 50 mg.)

Figure 16. Tabor Testing Machine



Flash Ignition Temperature: The lowest temperature of a substance at which sufficient combustible gas is developed to be ignited by a small external flame. (ASTM D 1929) PVC = 730°F. Most wood products ignite at 500°F and lower.

Figure 17. Flash Ignition Testing Machine

Flammability Rating: One of Underwriter Laboratories' tests (UL94) to measure a material's resistance to burning, dripping, glow emission, and burn-through. The 94V-0 designation is the most resistant to burning. PVC = 94V-0

Flame Spread / Smoke Development Indices: These material characteristics are determined by testing the surface flame spread of and smoke developed by plastic piping as compared to fixed index elements of mineral fiber cement board and red oak flooring (ASTM E-84, NFPA 255, UL 723, ULCS 102, and UBC 8-l) (42-1 Test Method) PVC 15−20 Flame Spread Index; PVC >300 Smoke Development Index. (Note: There is a special PVC compound that is specially formulated to give improved flame spread and/or smoke development characteristics.)

Safety and Systems Design

PVC piping, when installed and tested properly, is one of the most durable piping systems available. Yet, PVC has physical characteristics different than other piping materials that need to be addressed for a safe and long lasting installation. In the *Design Guide* there are steps showing the proper techniques of safely joining, installing and testing PVC piping systems. However, it is imperative that the manufacturer's joining, installation and testing instructions be completely followed. Failure to follow the instructions could cause life threatening personal injuries or severe property damage. There is no subject more important than user safety. Therefore, the *Design Guide* offers in Appendix A commonly listed warnings that are shown in most PVC product manufacturer's literature. These safety warnings do not profess to address all possible situations or risks that may be encountered in the use of PVC piping systems.

Table 2. PVC Piping Physical Properties

Properties	Units	PVC	Test Method
GENERAL			
Cell Classification		12454	ASTM D-1784
Maximum Service Temperature	°F	140	
Water Absorption	% increase in 24 hrs @72°F	0.05	ASTM D-570
Hazen-Williams Factor	C Factor	150.00	
MECHANICAL			
Specific Gravity	g/cm	1.40± .02	ASTM D-792
Tensile Strength*	psi@73°F	7,000-7,940	ASTM D-638
Modulus of Elasticity – Tensile*	psi@73°F	400,000-430,000	ASTM D-638
Flexural Strength	psi@73°F	13,000-14,500	ASTM D-790
Flexural Modulus	psi@73°F	360,000-420,000	ASTM D-790
Compressive Strength	psi@73°F	9,500-9,600	ASTM D-695
Izod Impact*	Ft-lbs/in of notch	0.65-1.00	ASTM D-256
Hardness	Rockwell "R"	110-120	ASTM D-785
Poisson's Ratio	@73°F	0.38-0.41	
Taber Abrasion (1000 cycles)	mg	15-20	
THERMAL			
Coefficient of Linear Expansion	in/in/°F	2.8 -3.0 x 10^{-5}	ASTM D-696
Coefficient of Linear Conductivity	BTU/in/hr/ft^2/°F	1.02-1.3	ASTM C-177
Heat Distortion Temperature*	@ 264 psi	158	ASTM D-648
FLAMMABILITY			
Burning Rate	in/min	Self-Extinguishing	
Average Time of Burning*	sec.	<5 -10	ASTM D-635
Average Extent of Burning*	mm	<10 -25	ASTM D-635
Flammability Rating (.062)		V-0	UL - 94
Flame Spread Index		<10	
Flame Spread		<10 -25	ASTM E84/UL 723
Smoke Generation		80-225	ULC
Limiting Oxygen Index (LOI)		43	ASTM D-2863
Softening Starts (approx.)	°F	250	
Becomes Viscous (approx.)	°F	350	
Material Carbonizes (approx.)	°F	425	
Flash Ignition Temperature	°F	730	ASTM D-1929
ELECTRICAL			
Dielectric Strength	volts/mil	1,400 -1,413	ASTM D-149
Dielectric Constant	60Hz@ 30°F	3.7	ASTM D-150
Volume Resistivity	ohm/cm@73°	1.2 x 10^{12}	ASTM D-257

*The underlined properties are defined as minimum values for PVC with a cell classification of 12454 in compliance with ASTM D-1784. The range of physical property values reflects the slight differences of manufacturer's certified piping system compounds.

Source: Adapted from data of Charlotte Pipe, George Fischer Sloane, Harvel, IPEX, and NIBCO

Chapter

1

FEATURES AND BENEFITS

PVC is durable, safe and easy to install, environmentally sound, and cost effective.

For the past four decades, PVC has been one of the fastest growing piping materials in the world. The reasons for such success are due to PVC's durability, safe and ease of installation, environmental soundness and cost-effectiveness. Several of the listed features could have been listed under one or more of the four categories. For example, optimum flow can be a feature that could be included in the category of durability, environmental soundness, or cost effective. But, for brevity purposes, the *Design Guide* lists a feature under one category only.

Durability

Proven Performance: Millions of feet of PVC piping have been successfully installed in applications dating back a half a century or more.

Figure 18. Aquarium Piping with FRP Wrapped Fittings in Use for Over Four Decades

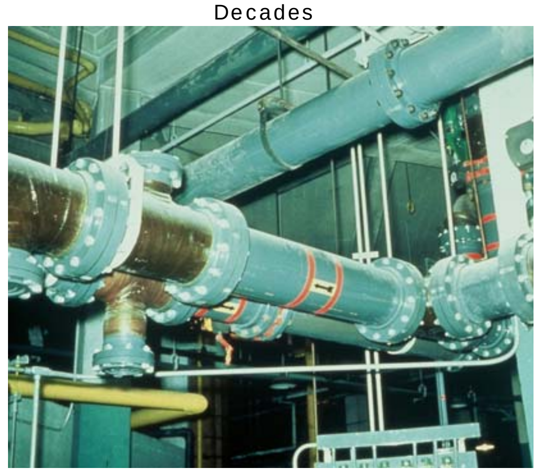
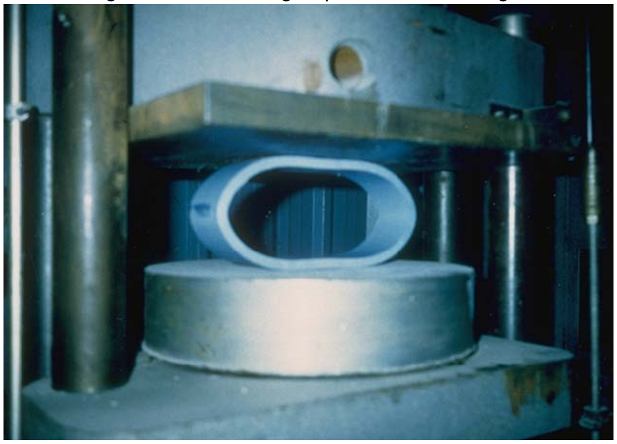


Figure 19. Testing Pipe Crush Strength



Tested to Rigorous Standards: Whether it is pipe, fittings, cements or valves, PVC piping products are thoroughly tested to ASTM International, NSF International, ANSI, and other code and standard agencies.

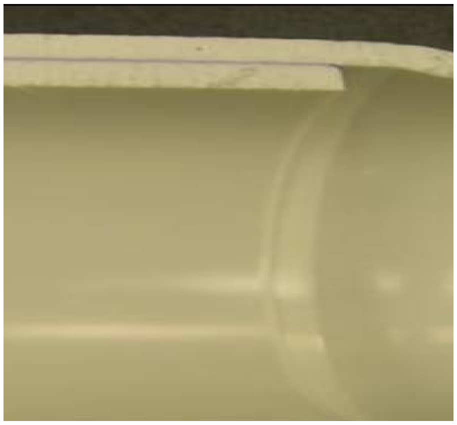
Resistant to Chemical Attack: Salt water, most acids, plating salts, and hundreds of other chemicals are not a concern to PVC piping. In most corrosive environments, interior or exterior coatings or liners are not needed.

Figure 20. PVC Pipes Transporting Chemicals

Figure 21. Corroded Metal Pipe

No Rust, Scale or Pitting: Unlike other piping materials, PVC doesn't rust, scale, or pit. This feature of not being attacked by galvanic or electrolytic corrosion negates the need for costly corrosion protection equipment and electric grounding concerns.

Figure 22. Cemented Joints



Joint Integrity: When properly installed, cemented joints are stronger than either the pipe or fitting being joined. Solvent welded joints are the strongest method for joining PVC piping products and provide years of trouble-free service. In most studies of underground piping installations, there is less leakage and breakage with PVC piping systems than alternate non-plastic piping materials.

Abrasion Resistant: In tests using the Taber Abrasion testing method, PVC has less wear and outlasts most non-plastic piping materials in handling solids and high velocity flow rates.

Figure 23. Plastic Pipe in Abrasive Environment

Figure 24. Smooth Interior of PVC Pipe

Optimum Flow: With a Hazen and Williams internal bore "C" Factor of 150, PVC has less turbulence and lower friction loss than many other piping materials. In several cases this feature may allow piping downsizing and lower horsepower pumps. In other words, less energy is used over time.

Flexibility: PVC's pipe flexibility often allows for greater burial depth and loading of underground installations. Also, the pipe flexibility can allow less damage and better tolerance to earth movements or shifts. Pipe lining of existing non-plastic piping is also possible due to PVC's flexibility.

Figure 25. Pipe Lining

Figure 26. PVC Piping can Handle Earth Movement

Flame and Combustion Resistant: PVC has an ignition temperature of 735°F (200°F higher than most wood), does not support combustion, and has a low flame spread.

Integrated System: Dozens of products exist in PVC including pipe, fittings, valves, pumps, tanks, duct, scrubbers, fans, blowers, and others. This breadth of offering often eliminates the need for any non-plastic material to be involved with the fluid flow.

Figure 27. PVC Complete Air Handling System

Figure 28. Pump and Pipe System

Safe and Easy to Install

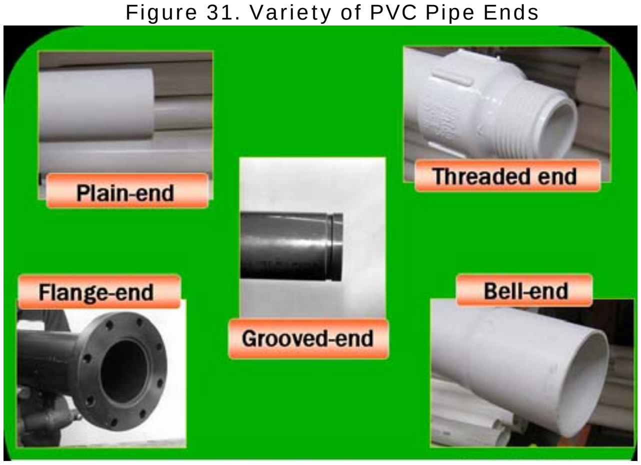
Lightweight: PVC (1/6th the weight of most non-plastic piping) minimizes on-site heavy equipment, allows easier installation in close quarters, and eliminates many job-site safety issues.

Figure 29. PVC—Lightweight

Ease of Joining: Whether it is solvent cementing, flanging, bell-gasketing, threading, or other joining methods, PVC needs no expensive or clumsy joining tools or heavy equipment. In many installations, an electrical or heat source is not required to join the piping.

Figure 30. PVC Requires Simple Joining Tools

Figure 31. Variety of PVC Pipe Ends



Variety and Breadth of Line: PVC is available in many diameters, working pressure ratings, pipe lengths, and pipe ends to facilitate the installation in a cost-effective manner.

Figure 32. Variety of Colors

Variety of Colors: The PVC manufacturing piping process allows color to be an integral part of the piping system. This feature allows easy identification of piping systems and can act as a visual safety factor in critical applications.

Ease of Fabrication: PVC piping materials can be easily built into many diverse fluid-handling products. Manifolds, specially engineered fittings, tanks, valve boxes, and other special products are available. If you can draw what you want, a capable plastic fabricator can make it.

Figure 33. Variety of PVC Fabrications

Code Acceptance: There are dozens of PVC piping standards referenced in plumbing and mechanical codes. These building codes and third-party certifiers require conformance to consensus standards.

Figure 34. Partial Listing of PVC Standard and Code Agencies

Product Identification: Almost all PVC piping products have surface markings showing country of origin, material, pipe size, pressure rating, manufacturer, applicable certification or listing agency, and manufacturing process cycle. This feature makes it easier to determine product traceability and allows installers and maintenance personnel to communicate directly with the manufacturer for technical information or ordering additional products.

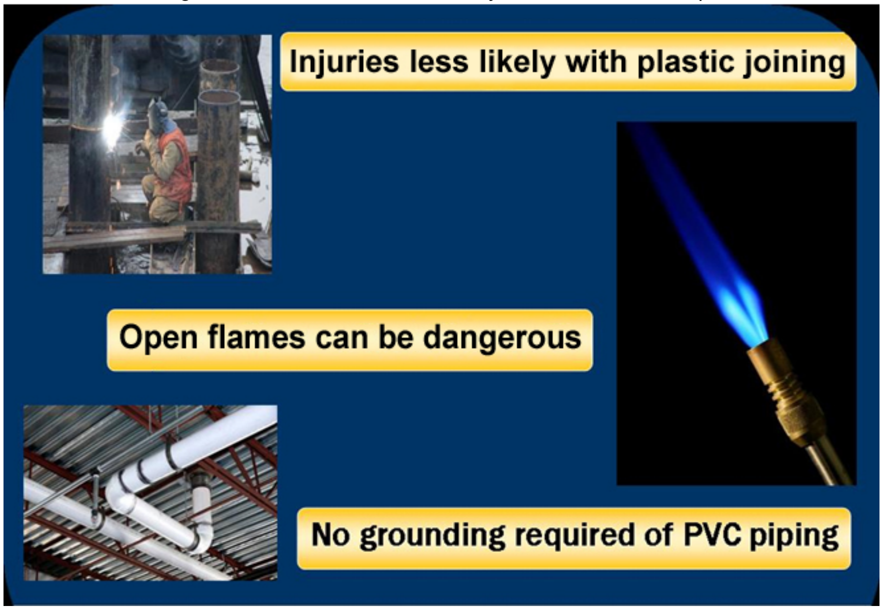
Figure 35. PVC Product Identifiers

Figure 36. PVC Plants in USA and Canada

Product Readily in Stock: There are over 7 dozen PVC pipe, valve, and fitting manufacturing plants in North America and thousands of stocking wholesalers. Needed product usually can be shipped or picked up in a matter of hours. Plus, most piping products are interchangeable from one manufacturer to another.

Reduced On-site Injuries: With no power tools, torches, or hot plates needed for installation, PVC poses less danger to plumbers and pipe fitters than other piping systems.

Figure 37. Less Chance of Injuries with PVC Pipe



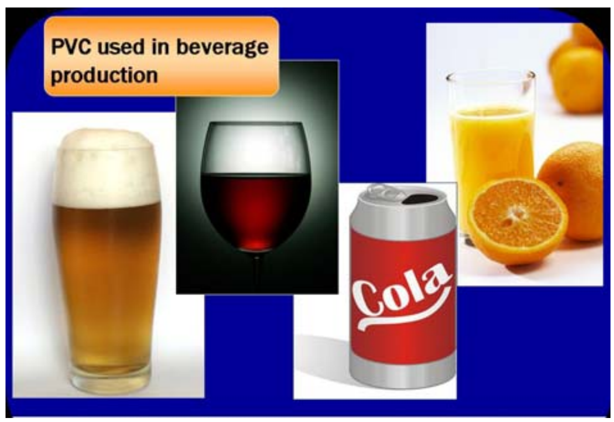
Environmentally Sound

Figure 38. Metal Piping with Insulation

Low Thermal Conductivity: PVC piping has low thermal conductance leading to less heat loss through the wall of the pipe. This feature may eliminate the need for pipe insulation and may reduce the energy needed to maintain fluid temperatures.

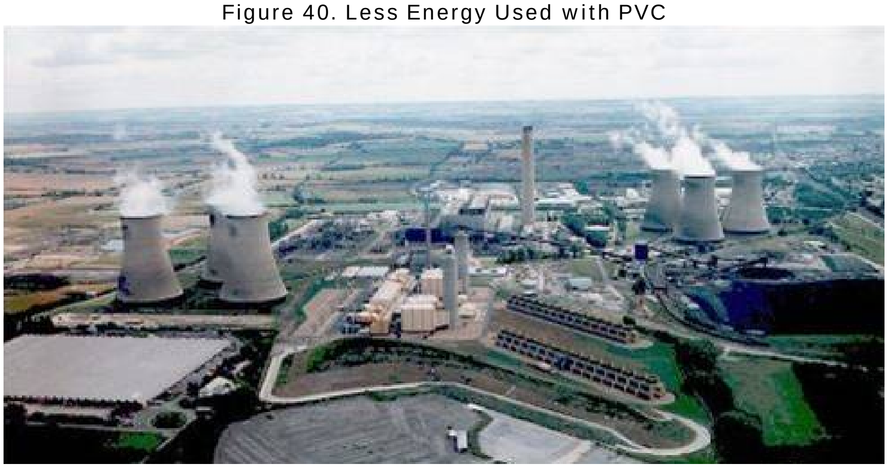
Non-toxic and Odorless: Most PVC compounds meet NSF and FDA requirements. This feature allows the use of PVC piping in many food, beverage, pharmaceutical, and high-purity water applications.

Figure 39. Non-Toxic and Odorless



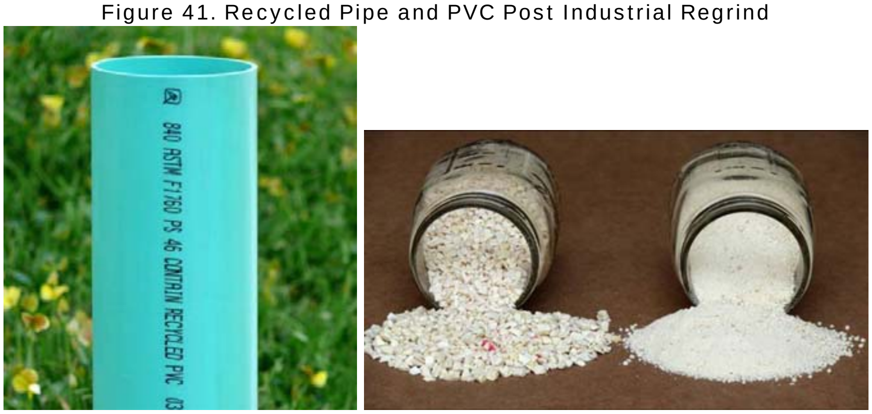
Energy Savings: Due to PVC's features of low thermal conductivity, favorable flow, lightweight, joint integrity, and excellent chemical and corrosion resistance, PVC is a leader in helping to reduce greenhouse gas emissions.

Figure 40. Less Energy Used with PVC



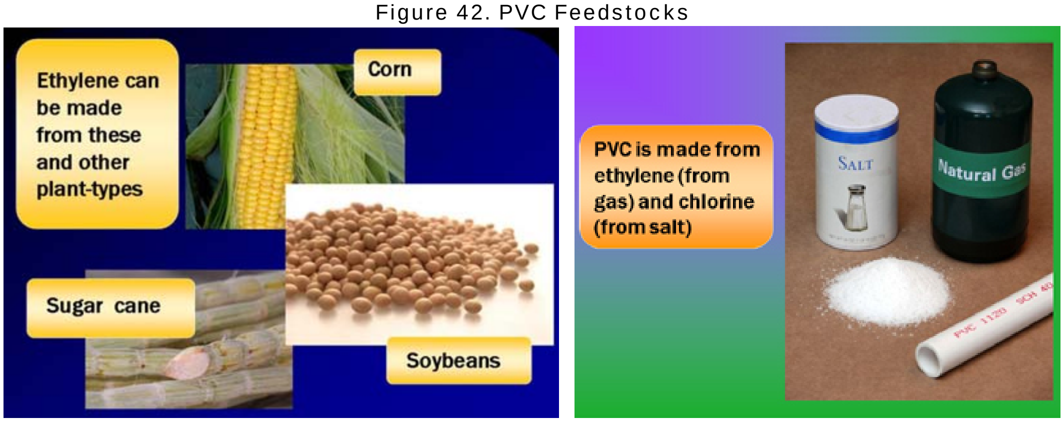
Fully Recyclable: In the production of PVC, pipe and fittings waste is virtually non-existent. Any off-spec and start-up materials are re-ground and recycled in the manufacturing process. Most post-consumer (product in use in the field) piping products can be fully recycled.

Figure 41. Recycled Pipe and PVC Post Industrial Regrind



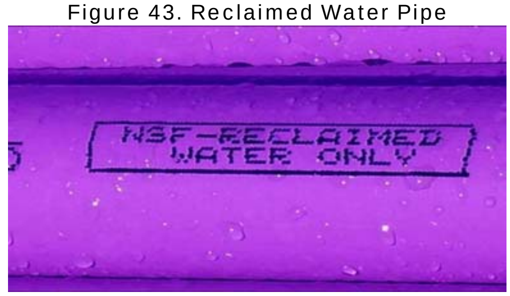
Sustainable Feedstocks: 57% of PVC material is made from salt (chlorine), one of the most common and available materials on earth. Fossil fuels are presently being used to provide the other component in making PVC. However with the advent of new technology and research, biofuels may be an economical and an environmentally sound alternative to replace fossil fuels in PVC feedstocks in the next 10 to 15 years.

Figure 42. PVC Feedstocks



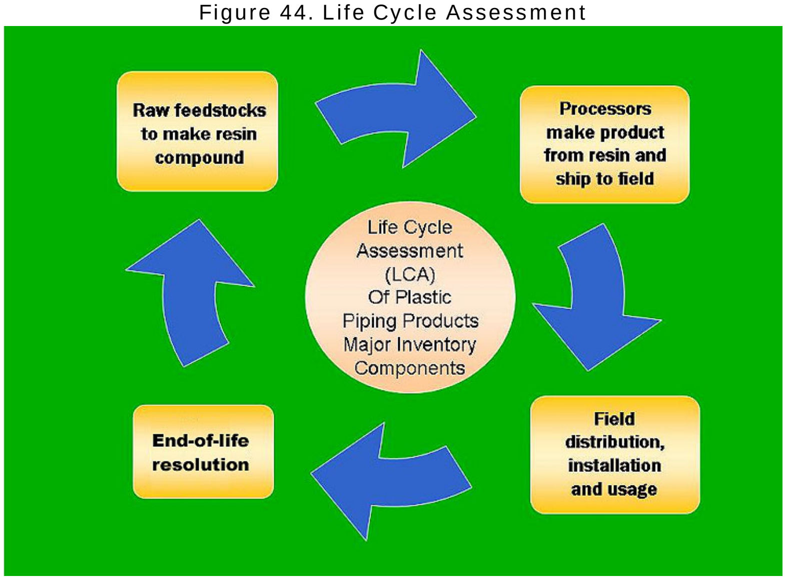
Environmental Applications: Many PVC piping products are used exclusively to prevent damage to humans and the environment. Double-contained piping systems, specially colored reclaimed water pipe, rain harvesting applications, land-fill piping, and subsurface irrigation are just a few of the PVC piping systems used for environmental purposes.

Figure 43. Reclaimed Water Pipe



Life Cycle Assessment (LCA): The PVC piping industry has actively supported scientific, independent party analysis called LCA to determine the environmental, energy, and economic impact that PVC piping has on the planet. Preliminary results indicate that PVC has a "greenness" that other piping materials do not have.

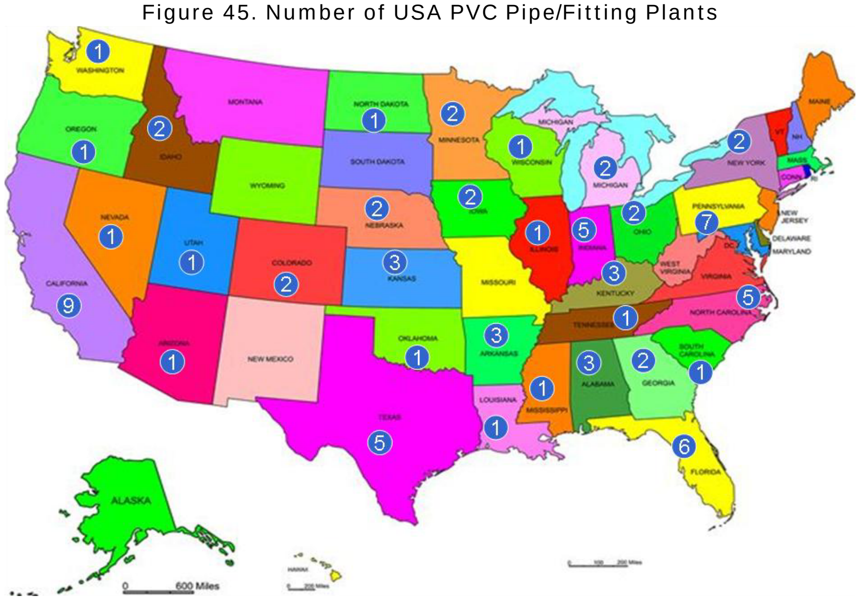
Figure 44. Life Cycle Assessment



Cost Effective

Low Material Costs: There are two major reasons for PVC's long-term competitive pricing. First, PVC's high strength to weight ratio allows for thinner pipe walls than most other materials. Secondly, the number of world PVC resin suppliers and the abundance of North American PVC pipe and fitting manufacturers ensure a competitive market place.

Figure 45. Number of USA PVC Pipe/Fitting Plants



Low Installation Costs: Lightweight, easy to use joining systems and lack of requiring additional corrosion protection and insulation materials give PVC a competitive installation advantage over other piping materials.

Figure 46. Estimated Time for Joining Piping Products

Estimated time for joining common piping products For Aboveground Applications					
Type Joint	Pipe Size and Man-hours per joint (hr)				
	1 in	2 in	4 in	6 in	8 in
Flanged (all)	0.15	0.30	0.80	1.32	1.72
Threaded (all)	0.08	0.18	0.80	NR	NR
Solder/braze (copper)	0.07	0.15	0.50	1.50	2.15
Solvent Cement (PVC)	0.07	0.15	0.25	0.66	0.86
For Belowground Applications					
Type Joint	Pipe Size and Man-hours per joint (hr)				
		4 in	8 in	12 in	18 in
Welded (metal)		0.80	1.72	2.81	3.30
Gasketed (PVC)		0.12	0.24	0.40	0.55

Source: Adapted from data of *Plastic Piping Systems*, author David Chasis, Industrial Press, New York, NY

Low Maintenance Costs: With its history of leak-resistant joint performance, immunity from most corrosive and chemical attack, and piping systems lasting for decades, PVC is unmatched in keeping maintenance costs low.

Figure 47. Metal Pipe Corrosion

Lower Overall Installed Piping Costs: There have been several third-party studies done to determine the costs of various piping materials in commercial and industrial applications. In most cases PVC piping had substantially lower installed costs than other piping systems.

Table 3. Cost Comparison of Installed Plastic vs. Metal Piping Systems

Estimates of 100-ft, 6-in Pipelines for Various Materials*

Materials	Piping Costs ($)	Ratio CS
PVC Sch. 80	**11,499**	**0.50**
CPVC Sch. 80	18,932	0.83
Carbon Steel Sch. 40	22,789	1.00
St. Steel 304L Sch. 40	45,835	2.01
Aluminum alloy 303 Sch. 40	48,134	2.11
St. Steel 316L Sch. 40	49,355	2.17
Copper	50,473	2.21
PVDF Sch. 80	63,945	2.81
Titanium Sch. 40	132,804	6.11
Alloy 20 Sch. 40	150,188	6.59
Zirconium Sch. 40	159,382	6.99

* Adapted from *Chemical Processing*, June 1999

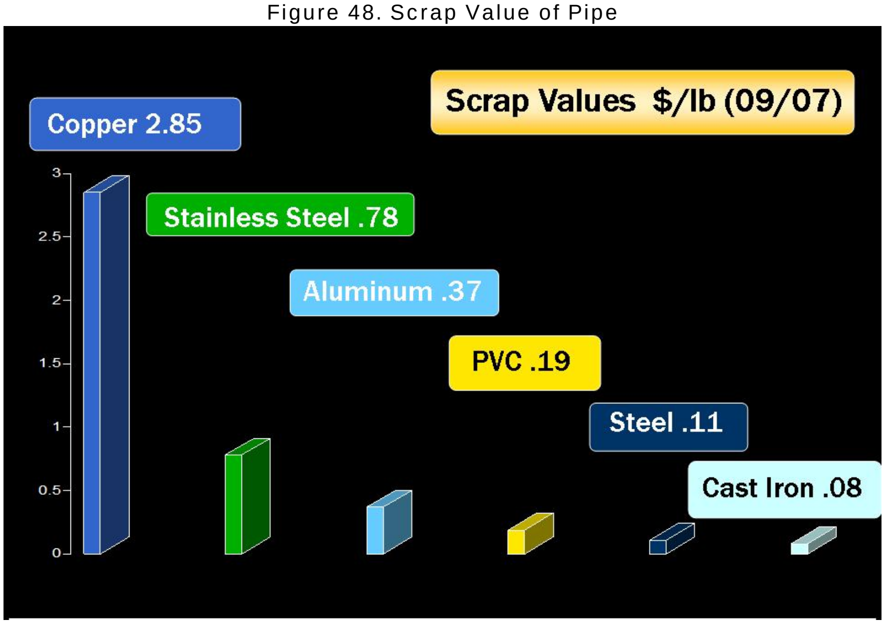
Table 4. Installed Cost for DWV and Storm Drainage Piping Installation

Item	Total Material Cost ($)	Total Labor (Hours)
Cast Iron Soil Pipe	121,218	2,737
PVC Plastic Pipe	19,537	2,003
Difference between PVC and Cast Iron	101,681	734
Percent Savings Using PVC Pipe	84%	27%

Notes:
1. Table 4 is adapted from a study done by JB Engineering and Code Consulting of Munster, Indiana in July, 2006 (values shown have been rounded to nearest whole number.
2. Piping materials and design is for a 12-story residential high-rise apartment.
3. Cast iron pipe is no-hub and PVC is Schedule 40 dual marked.
4. For a free copy of the JB Engineering 33 page report, visit the PPFA website.

Less On-site Theft: The high scrap value of non-plastic piping materials encourages on-site theft. In addition, there are few costly tools required on-site when installing PVC piping.

Figure 48. Scrap Value of Pipe



Source: Data obtained in October 2009 and edited by *Design Guide* editor, David Chasis

Less Insurance Costs: It stands to reason that with less on-site theft, the lack of torches, hot plates, heavy equipment, and acetylene containers, and less chance of reportable injuries, most insurance costs related to PVC piping installations will be less.

The bottom line…PVC piping is:

- **Durable**
- **Safe and Easy to Install**
- **Environmentally Sound**
- **Cost Effective**

Chapter

2

ENGINEERING DESIGN

A properly designed PVC piping system will normally outlive the life of any project in which it is installed.

With more than sixty years of history, PVC piping systems have performed successfully in dozens of applications. To design a successful PVC piping system, follow standard piping design practices and be aware of the various design nuances and material properties that are covered in this chapter of the *Design Guide.*

Design Piping Practices

General Design Piping Practices: When designing any piping system whether plastic or not, incorporate generally accepted engineering practices. These include the following:

- Selecting the proper material for the application
- Controlling pressure surges and velocities
- Identifying standards for piping components
- Selecting and proper sizing of pipe, valves, and fittings
- Proper pipe supports, anchors, and guides
- Proper underground design considerations
- Selecting the most cost effective system for required service life
- Following all applicable codes and standards
- Designing for thermally caused pipe movement
- Proper firestops

PVC Piping Design Practices: PVC piping has several unique engineering properties compared to non-plastic materials. To ensure an effective and long-lasting piping installation, the design engineer needs to be aware of these properties:

- Chemical resistance
- Pipe and system pressure ratings
- Temperature limits
- Temperature-Pressure relationship

- Expansion/Contraction
- Pipe support
- Firestops for PVC
- Other aboveground issues
- Underground piping design

Chemical Resistance

All plastics in general have excellent chemical resistance; however, there are certain chemical environments that affect the properties of plastics, including PVC in the following ways:

- Chemical attack: an environment that attacks the polymer chain
- Solvation: absorption of an organic solvent by PVC
- Plasticization: when a liquid, organic material reacts with PVC but is unable to dissolve it
- Environmental stress-cracking: a failure that occurs when tensile stresses combined with prolonged exposure to certain fluids generate localized surface cracks

Chemical Resistance Tables: Many manufacturers have tested hundreds of reagents to determine their affect on PVC piping products. Appendix C lists the chemical compatibility of hundreds of solutions with PVC piping products. The list is a guide for end-users and design engineers and is based on the best available information. If there is a critical application and there is any uncertainty of PVC handling the fluid, test PVC test strips in the fluid being considered. For a broad chemical resistance guide of PVC refer to Table 5.

Table 5. Chemical Resistance of PVC to Typical Broad Chemical Groups*

Chemicals—Inorganic	
Acids, dilute	Recommended
Acids, concentrated	Recommended
Acids, oxidizing	Recommended
Alkalis	Recommended
Acid gases	Recommended
Ammonia gases	Limited Use
Halogen gases	Limited Use
Salts	Recommended
Oxidizing salts	Recommended

Chemicals—Organic	
Acids	Recommended
Acid anhydrides	Recommended
Alcohols—glycols	Not Recommended
Esters/Ketones/Ethers	Not Recommended
Hydrocarbons—aliphatic	Limited Use
Hydrocarbons—aromatic	Not Recommended
Hydrocarbons—halogentated	Limited Use
Natural gas	Limited Use
Synthetic gas	Not Recommended
Oils	Limited Use

*Chemical resistance is provided as a guide only.

Pipe Operating Pressure

PVC piping pressure ratings are determined using material ratings by ASTM and PPI standards and requirements. Pipe pressure ratings are calculated using the following ISO equation:

$$PR = 2\,(HDS) \times \frac{t}{Dm}$$ where:

PR= Pressure rating, psi (Mpa)
t = Minimum wall thickness, in. (mm)
Dm = Mean diameter, in. (mm)
HDS = Hydrostatic design stress, psi (Mpa)

HDS = Hydrostatic design stress = HDB (hydrostatic design basis x design factor. For PVC the HDB = 4000 psi (Mpa) and the service or design factor for most PVC pipe is 0.5. Therefore the HDS for PVC pipe is 2000 psi.

Types of Pipe

Schedule Pipe: Schedule pipe is Iron Pipe Size (IPS) with an Outside Diameter (OD) and a wall thickness that matches the wall thickness of the same size and schedule steel pipe. Most PVC pipe is available in Schedules 40, 80, and 120. (The higher the Schedule number, the thicker the pipe wall for each size.) Scheduled pipe pressure ratings vary with each pipe diameter. Pipe pressure ratings decrease as pipe diameter increases for most Schedules. In the *Design Guide* most information and applications will focus on Schedules 40 and 80 PVC pipe.

Standard Dimension Ratio (SDR) Pipe: Standard dimension ratio (SDR) pipe is mostly based on the IPS-OD system. The SDR is the pipe OD divided by the wall thickness. For a given SDR, the pressure ratings and pipe stiffness values are constant for all pipe sizes. Non-standard dimension ratios (DR) can be computed for any pipe OD and wall thickness.

Pipe Markings: All PVC piping is well marked with ASTM standards, manufacturer's name and/or trademark, pipe size, the material, the mark of a certification organization where required by codes, and in particular cases the application such as reclaimed water or DWV. Fitting markings may vary slightly because of the limitation of space but in most cases include the manufacturer's name and/or trademark, pipe size, the material and the application symbol (DWV for example), and certification marks.

DWV Pipe Markings: PVC Schedule 40 DWV piping is marked in several different ways depending on the piping pressure ratings and pipe structure. (There is 3.25-inch OD pipe, but it is rarely used in commercial or industrial construction.) Listed below are PVC DWV markings and pipe descriptions:

DWV—cellular core: ASTM F 891, PVC pipe with a cellular core has the PVC-DWV label plus the additional marking "IPS SCHEDULE 40 SERIES COEX CELLULAR CORE PVC-DWV."

DWV—dual marked: ASTM D 1785 and ASTM D 2665 conformance allows for Schedule 40 PVC DWV solid wall pipe to be dual marked for both DWV and potable water pressure pipe. Dual marked PVC DWV piping can be triple marked for use as well casing with the addition of ASTM F 480. None of the other DWV pipes are pressure rated.

Other PVC Piping Systems

Other plastic piping systems have differing outside diameter dimensions and pressure ratings such as Cast Iron (CI) and Sewer & Drain. These products have DR ratings that are not used for most commercial and industrial applications.

Fittings

Pressure ratings of molded Schedule 40 and 80 fittings are affected by part size, wall thickness, part geometry, molding conditions, part design, and material. Most fitting manufacturers pressure rate their molded fittings similar to that of pipe under normal conditions as shown in Table 6. Some manufacturers recommend a maximum suggested design pressure of 60% of the equivalent sized pipe. Additional information on this subject can be found in Ron D. Bliesner's Irrigation Association article, "Designing, Operating, and Maintaining Piping Systems Using PVC Fittings." The pressure capabilities of fabricated fittings may vary with each fabricator. If there is a critical pressure application, check with the pipe and fitting manufacturer to ensure a properly designed system.

Temperature and Pressure Ratings

Thermoplastic piping materials increase in tensile strength as temperatures decrease, and decrease in tensile strength as temperatures increase. This characteristic must be considered when designing piping systems with PVC material. To determine the maximum pressure capability of each PVC piping product, temperature correction factors have been established. To determine the maximum suggested pipe operating pressure at a particular temperature, multiply the base pressure by the correction factor (see Table 6 and Table 7).

Table 6. Schedule 40 and 80 Pipe Pressure Ratings (psi at 73°F)

Nominal Pipe Size (in.)	PVC 40	PVC 80
½	600	850
¾	480	690
1	450	630
1 ¼	370	520
1 ½	330	470
2	280	400
2 ½	300	425
3	260	370
4	220	320
6	180	280
8	160	250
10	140	230
12	130	230

Note: Other pipe sizes are available. For pipe diameters and pressure ratings not listed, check with the manufacturer.

Source: "Plastic Piping Systems," author David Chasis, Industrial Press, New York, NY.

Table 7. Temperature Correction Factors for PVC Piping

Operating Temperature (°F)	Correction Factor
70	1.00
80	.88
90	.75
100	.62
110	.50
120	.40
130	.30
140	.22
140+	Not Recommended

Source: "Plastic Piping Systems," author David Chasis, Industrial Press, New York, NY.

Example: What is the pressure rating of 3" PVC 80 pipe @ 110°F?

Using Table 6 and Table 7: 370-psi x 0.50 = 185-psi

Operating Pressure of Valves, Unions, and Flanges: PVC piping system materials have a 150-psi maximum pressure capability for valves, union, and flanges. The reason for this is due to the mechanical connections involved (threads in valves and unions) and the nature of flat gaskets under pressure (flanges). However, several valve and union manufacturers have increased the maximum pressure capability of their products up to 235-psi (16 bar) in the 2-inch size range and below. Some flange gasket manufacturers offer designs with built in O-ring seals, allowing pressures well above the 150-psi on a standard flat gasket design. Similar to pipe, as the temperature increases, the pressure ratings of valves, unions, and flanges decrease. Typical valve, flange, and union pressure ratings shown in Table 8 may vary with each manufacturer. Consult manufacturer's published information if in doubt.

Table 8. Operating Pressure of Valves, Unions, and Flanges

Operating Temperature (°F)	Pressure Ratings (psi)
73–100	150
110	135
120	110
130	50
140	50
140+	Not Recommended

Source: Adapted from NIBCO, Inc. data

Operating Pressure of Direct Threaded Pipe: Direct threading of PVC piping is accomplished using proper threading equipment. However, do not thread pipe below the thickness of a Schedule 80 pipe wall. Threading vinyl pipe reduces operating pressures by 50%. If threaded PVC piping components must be used, increased working pressure could be obtained using special transition or adapter fittings. (See the Joining Methods section of the *Design Guide*.)

Friction Loss

As fluid flows through a piping system, it experiences head loss depending on fluid velocity, pipe wall smoothness and internal pipe surface area. Pipe, fitting and valve manufacturers using the Hazen-Williams formula, have calculated and have readily available friction loss and velocity data for all of their products. As mentioned, one of the features and benefits of PVC is having a C Factor (Flow Coefficient) of 150. This smooth bore rating results in less friction loss in PVC piping compared to most other non-plastic materials. And because PVC doesn't pit, rust, or corrode, it maintains this rating throughout the pipe life in most applications. Appendix D shows friction loss tables for PVC pipe and fittings.

Hydraulic Shock/Water Hammer

Hydraulic shock or water hammer is a momentary pressure rise resulting when the velocity of the liquid flow is abruptly changed. The longer the line and higher the change in liquid velocity, the greater the shock load from the surge. For the piping system to keep its integrity, the surge pressure plus the operating pressure in the piping system must not exceed the specified pressure rating or maximum suggested design pressure of the lowest rated component in the piping system.

The main factors that influence the severity of water hammer are:

- Liquid Velocity
- Length of Pipe Run
- Modulus of Elasticity of Piping Material
- Inside Diameter of Pipe
- Pipe Wall Thickness
- Valve and Pump Closing Times
- Entrapped Air

First, the speed a surge wave travels through the piping system must be calculated. Since the pressure wave travels at different speeds through each piping material, it is necessary to compute the speed of sound in the water as it is changed by the pipe material.

$$a = \frac{4600}{\left[1+\frac{k}{E}(D_R-2)\right]^{1/2}}$$

Where:

- $a =$ wave velocity, ft./sec.
- $k =$ Fluid bulk modulus, 300,000 psi for water at 73°F
- $E =$ Modulus of elasticity of pipe, 400,000 for PVC
- $D_R =$ Dimension ratio of pipe, OD/t

<u>Example</u>: What is the wave velocity for water with 2-inch DR 21 PVC pipe?

$$a = \frac{4600}{[1+.75(21-2)]^{½}} = 1177.9 \text{ ft./sec.}$$

The pressure surge in the water system can now be calculated using the change in flow rate or system velocity and the speed of the pressure wave. The following formula is used for this determination:

$$P = \frac{aV}{2.31\ g}$$

Where:

- $P =$ Pressure surge, psi.
- $V =$ Velocity change, ft./sec. = 12 ft./sec.
- $g =$ Acceleration of gravity, 32.2 ft./sec.

<u>Example</u>: The maximum pressure surge can be calculated:

$$P = \frac{1178 \times 12}{2.31 \times 32.2} = 190.0 \text{ psi}$$

This calculated surge pressure is added to the line pressure to realize the maximum pressure the system undergoes.

To lower or keep the maximum surge within reasonable limits, it is sometimes necessary to extend the velocity change time. It is common practice to increase, or slow, the valve closing time to exceed the critical close time (T_c) of a system.

$$T_C > \frac{2 \times L}{a}$$

Where:

- $T_c =$ Valve Closure Time, (sec.)
- $L =$ Length of pipe run, (ft.)
- $a =$ Sonic velocity of the pressure wave (1178 ft./sec.)

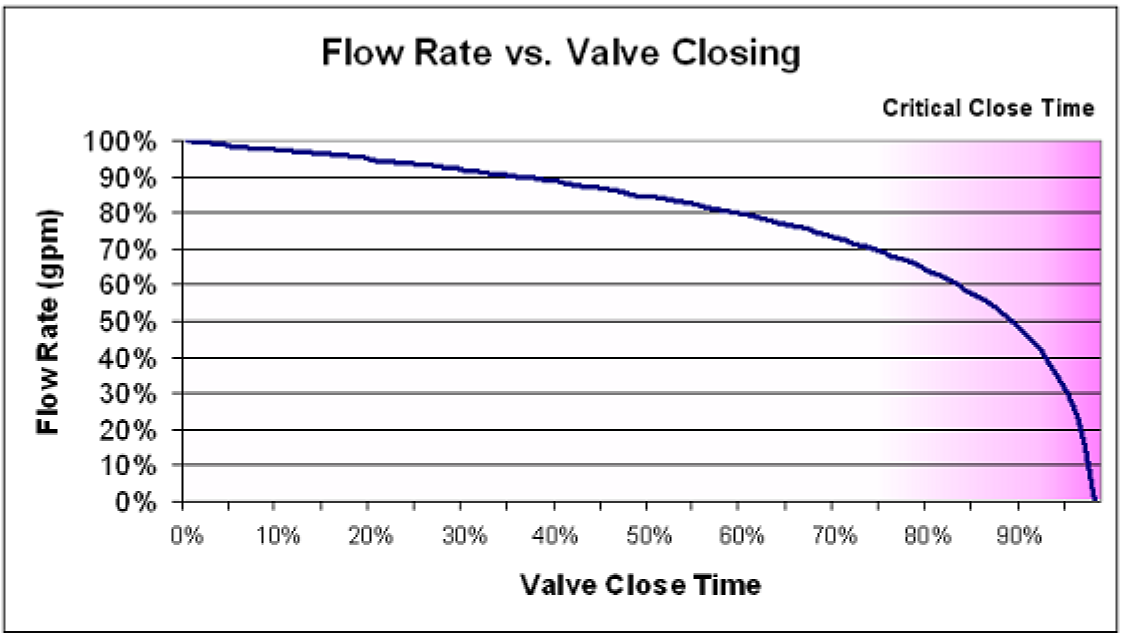
Example: What is the minimum valve closing time for 100-foot run of 2-inch DR 21 pipe?

$$T_C > \frac{2 \times 100}{1178} = 0.17 \text{ sec.}$$

Most solenoid-controlled diaphragm valves will close or open more rapidly the greater the difference between the upstream and the downstream pressure. This means that most of the flow (gallons per minute) is closed off in the last 25% of the valve operation. Conversely, the bulk of the flow comes on during the first 25% of opening.

These sudden, quick, and repeated changes in flow during system operation produce repeated cyclic pressure fluctuations. These are the fatigue-causing culprits that can weaken and damage piping systems, such as that for golf course irrigation applications.

Figure 49. Flow Rate vs. Valve Closing



Source: Adapted from LASCO Fittings Data

Avoiding Hydraulic Shock: The principal causes for surge or hydraulic shock are the closing and opening of a valve, the starting and stopping of a pump, and the movement of pockets of air accumulated in the pipeline. To reduce the chances of damaging surge from occurring, it is recommended that the following steps be considered when designing, installing, and operating a pipe line of PVC piping materials:

- The actual maximum operating pressure plus the surge pressure should not exceed the specified pressure rating or maximum suggested design pressure of the lowest rated component in the piping system.
- Fluid velocity < 5 ft/sec
- Actuated valves with specific closing times
- Do not use multiple-step fitting reductions. Keep multiple-step reductions less than 4 pipe sizes (ex. 12 x 6 tee).
- Start the pump with a partially closed valve in discharge line.
- Install a check valve near the pump discharge to keep the line full.

- Vent all air out of the system before start-up.
- Prevent air from accumulating while the line is operating
- Provide all necessary protective equipment for the system, such as pressure relief valves, surge arrestors, shock absorbers, and the like.

Aboveground Design

Thermal Expansion and Contraction

PVC compared to non-plastic piping has relatively higher coefficients of thermal expansion. For this reason, it is even more important to consider thermal elongation and contraction when designing PVC piping systems.

Table 9 lists the amount of movement of PVC piping per length of run. However to calculate the exact expansion/contraction of PVC piping, use the Constant factor of Y = 0.36 and the following formula:

$$\Delta L = \frac{y\,(T_1 - T_2)}{10} \times \frac{L}{100}$$

where

Δ = Expansion of pipe (in.)
y = Constant factor (in./10°F/100 ft
T^1 = Maximum Temperature (°F)
T_2 = Minimum temperature (°F)
L = Length of pipe run (ft)

Example: How much expansion will result in 300 ft of PVC pipe installed at 50°F and operating at 125°F?

$$\Delta L = 0.36 \times \frac{(125-50)}{10} \times \frac{300}{100} = 8.1 \text{ in.}$$

Table 9. PVC Pipe Thermal Expansion (in.)

Temp. Change ΔT (°F)	Length of Run (ft.)									
	10	20	30	40	50	60	70	80	90	100
30	0.11	0.22	0.32	0.43	0.54	0.65	0.76	0.86	0.97	1.08
40	0.14	0.29	0.43	0.58	0.72	0.86	1.01	1.15	1.30	1.44
50	0.18	0.36	0.54	0.72	0.90	1.08	1.26	1.40	1.62	1.80
60	0.22	0.43	0.65	0.85	1.08	1.30	1.51	1.73	1.94	2.16
70	0.25	0.50	0.76	1.01	1.26	1.51	1.76	2.02	2.27	2.52
80	0.29	0.58	0.86	1.15	1.44	1.73	2.02	2.30	2.59	3.24
90	0.32	0.65	0.97	1.30	1.62	1.94	2.27	2.59	2.92	3.24
100	0.36	0.72	1.03	1.44	1.80	2.16	2.52	2.88	3.24	3.60

Source: Adapted from NIBCO, Inc. data

Example:	Highest temperature expected:	120°F
	Lowest temperature expected:	50°F
	ΔT	70°F
	Length of run:	40 feet

Read down to ΔT 70°F row and then read across to 40 ft. run to 1.01 in. length change.

Managing Expansion and Contraction: Compressive and tensile forces, which result from thermal expansion and contraction, can be reduced or eliminated by providing piping offsets, expansion loops, or expansion joints. The preferred method of handling expansion/ contraction is to use offset and, or expansion loops. Expansion joints require little space but are limited in elongation length and can be a maintenance and repair issue. As a rule-of-thumb, if the total temperature change is greater than 30°F (17°C), compensation for thermal expansion should be considered.

Expansion Loops and Offsets:

Expansion Loop Formula:

$$\mathscr{L} = \sqrt{\frac{3\,ED\,(\Delta L)}{2S}}$$

where:

$\mathscr{L}$	=	Loop length (in.)
E	=	Modulus of elasticity at maximum temperature (psi)
S	=	Working stress at maximum temperature (psi)
D	=	Outside diameter of pipe (in.)
ΔL	=	Change in length due to change in temperature (in.)

Figure 50. Loop

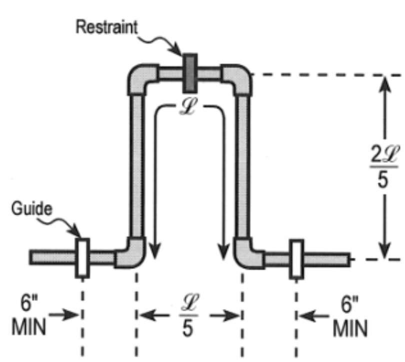
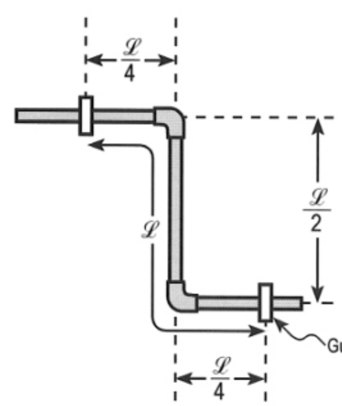


Figure 51. Offset



Example: What would the loop length be to compensate for 4" of expansion of 3" PVC Sch. 80 pipe with a minimum temperature of 110°F? (Outside diameter of 3" pipe = 3.5". E = 371,000, S = 1500)

$$\mathscr{L} = \sqrt{\frac{3\text{ ED }(\Delta L)}{2S}} = \sqrt{\frac{3 \cdot 4000{,}000 \cdot 3.5 \cdot 4}{2 \cdot 1{,}500}} = \sqrt{\frac{15{,}582{,}000}{3{,}000}} \approx 74.83 \text{ in.}$$

Thermal Stress and Longitudinal Force

Thermal Stress: If provisions are not made for expansion/contraction, th forces will be transmitted to the pipe, fittings, and joints. Expansion creates compı es and contraction creates tensile forces.

To calculate the induced stress of restrained PVC pipe use the formula:

$$St = EC\Delta T$$

where:

St = Stress (psi)

E = Modulus of elasticity (psi x 10^5)

C = Coefficient of thermal expansion (in/in/°F x 10^{-5})

ΔT = Temperature change between the installation temperature and max/min temperature, whichever produces the greatest differential (°F)

Example: What is the induced stress developed in 2" Schedule 80 PVC pipe with the pipe restricted at both ends? (Assume the temperature extremes are from 70°F to 100°F.)

$$St = EC\Delta T = (3.60 \text{ x } 105) \text{ x } 3.0 \text{ x } 105) \text{ x } (100 - 70) = 324 \text{ psi}$$

Longitudinal Force: To determine the magnitude of the longitudinal force of PVC pipe, multiply the stress by the cross-sectional area of the pipe. The formula is:

$F = St \times A$

where:

F = Force (lbs.)

St = Stress (psi)

A = Cross-sectional area (in^2) = $\pi/4 (OD^2 - ID^2)$

<u>Example</u>: With the stress as shown in the previous example (324 psi), calculate the amount of force developed in the 2" Schedule 80 PVC pipe.

cross-sectional area of 2" pipe = $3.1416/4\ (2.375^2 - 1.913^2) = 1.556\ in^2$

$F = St \times A = 324\ psi \times 1.556\ in^2 = 504\ lbs$

Support Spacing

The tensile and compressive strengths of PVC pipe are less than those of metal piping. Consequently, PVC requires additional pipe support. In addition, as temperature increases, tensile strength decreases requiring additional support. At very elevated temperatures, continuous support may be required. One other issue when considering pipe supports is to make sure corrections are made for liquids with a specific gravity higher than 1.0. Table 10 and Table 11 list the support spacing and specific gravity correction factors.

Table 10. Support Spacing of PVC 40 and 80 Pipe

Nominal Pipe Diameter (in.)	PVC 40			PVC 80		
	60°F	100°F	140°F	60°F	100°F	140°F
½	4½	4	2½	5	4½	2½
¾	5	4	2½	5½	4½	2½
1	5½	4½	2½	6	5	3
1¼	5½	5	3	6	5	3
1½	6	5	3	6½	5½	3½
2	6	5	3	7	6	3½
2½	6½	5½	3½	7½	6½	4
3	7	6	3½	8	7	4
4	7½	6½	4	9	7½	4½
6	8½	7½	4½	10	9	5
8	9	8	4½	11	9½	5½
10	12½	11½	11	13	12	11½
12	14	13	12	15	14	13

Note: Listings show spacing (ft) between supports. Pipe is normally in 20-ft lengths. Use continuous support for spacing less than three feet.

Source: Adapted from NIBCO, Inc. data

Table 11. Support Spacing Corrections with S.G. Greater than 1.0

Specific Gravity	Correction Factor
1.0	1.00
1.1	0.98
1.2	0.96
1.4	0.93
1.6	0.90
2.0	0.85
2.5	0.80

Note: Above data are for un-insulated piping. For insulated piping, reduce spans to 70% of values shown.

Source: Adapted from NIBCO, Inc. data

Pipe Hangers

Use hangers that have a large bearing area to spread the load over the largest practical area. The basic rules for PVC pipe hanger design pipe are:

- Avoid point contact or concentrated bearing loads
- Avoid abrasive contact
- Use protective shields to spread the loads over large areas
- Do not have the pipe support heavy valves or specialty fittings
- Do not use hangers that "squeeze" the pipe
- Compatible to PVC, especially those hangers having plasticized rubber inserts

On high-rise buildings, it is suggested to install a pipe support at each floor unless site conditions deem otherwise (check with project design engineer if in doubt). Figure 52 and Figure 53 are suggested hanger and support illustrations for PVC piping.

Figure 52. Typical Pipe Hangers

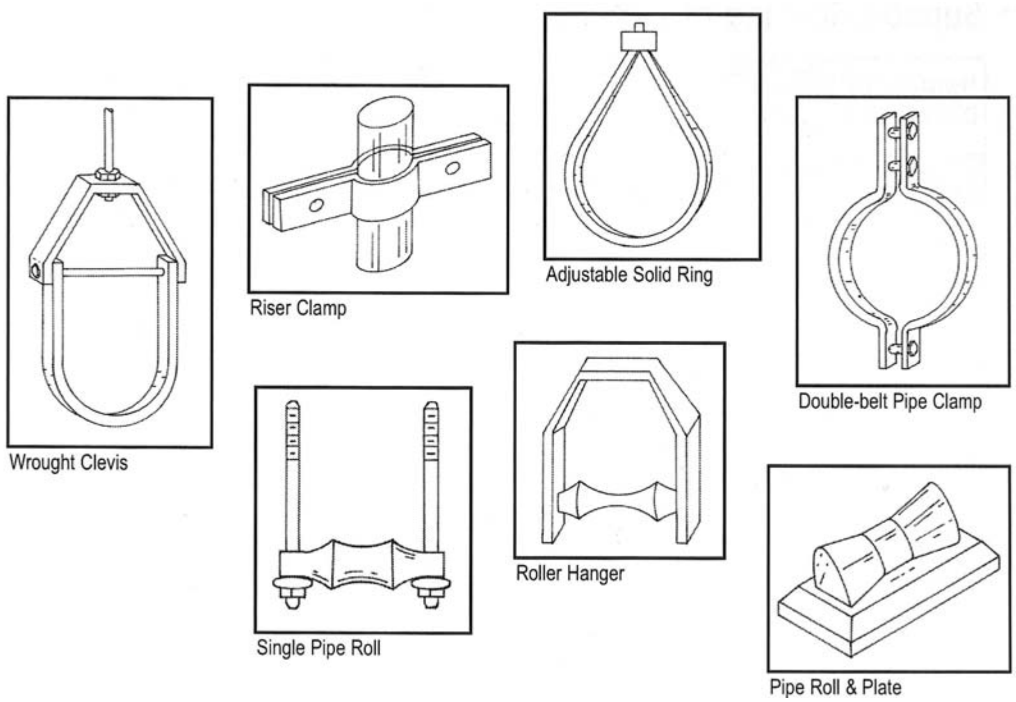
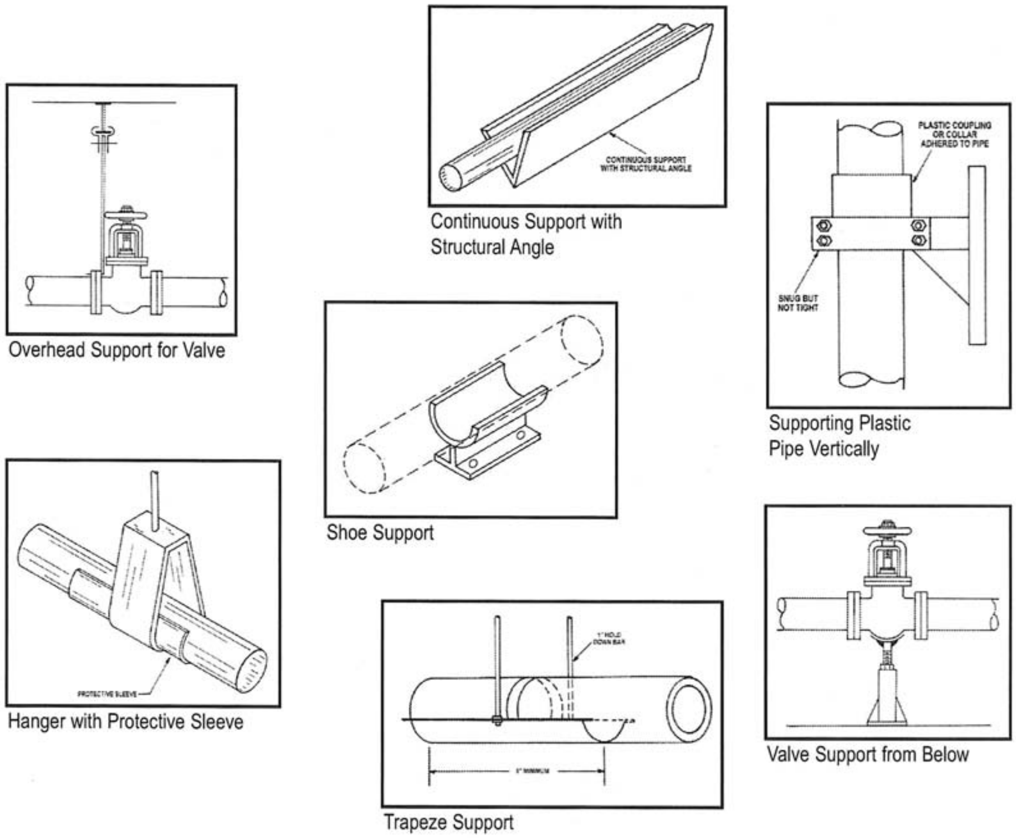


Figure 53. Pipe and Valve Supports



Anchors and Guides

Anchors direct movement of pipe within a defined reference frame. At the anchoring point, there is no axial or transverse movement. Guides allow axial movement of pipe but prevent transverse movement. Use guides and anchors whenever expansion joints are utilized and on long runs and directional changes in pipe. Figure 54 and Figure 55 are illustrations showing anchors, guides and anchor-guide design diagram.

Figure 54. Anchoring

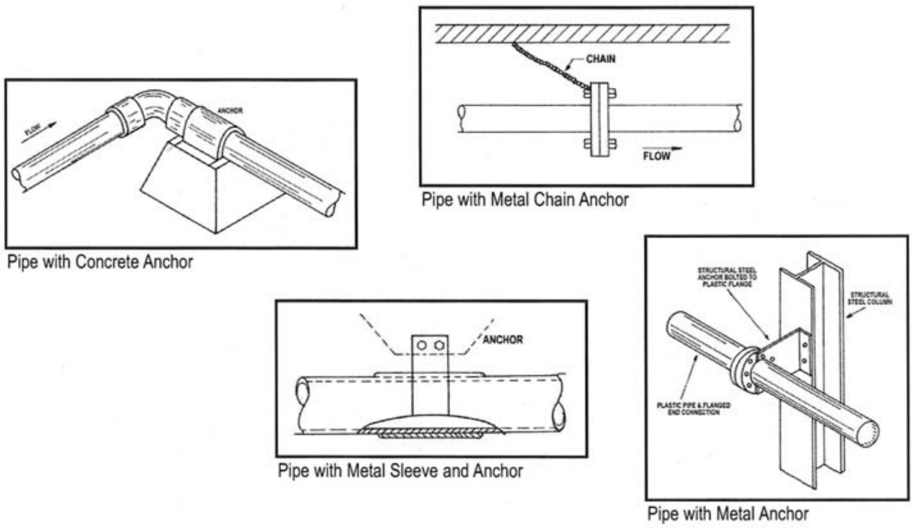
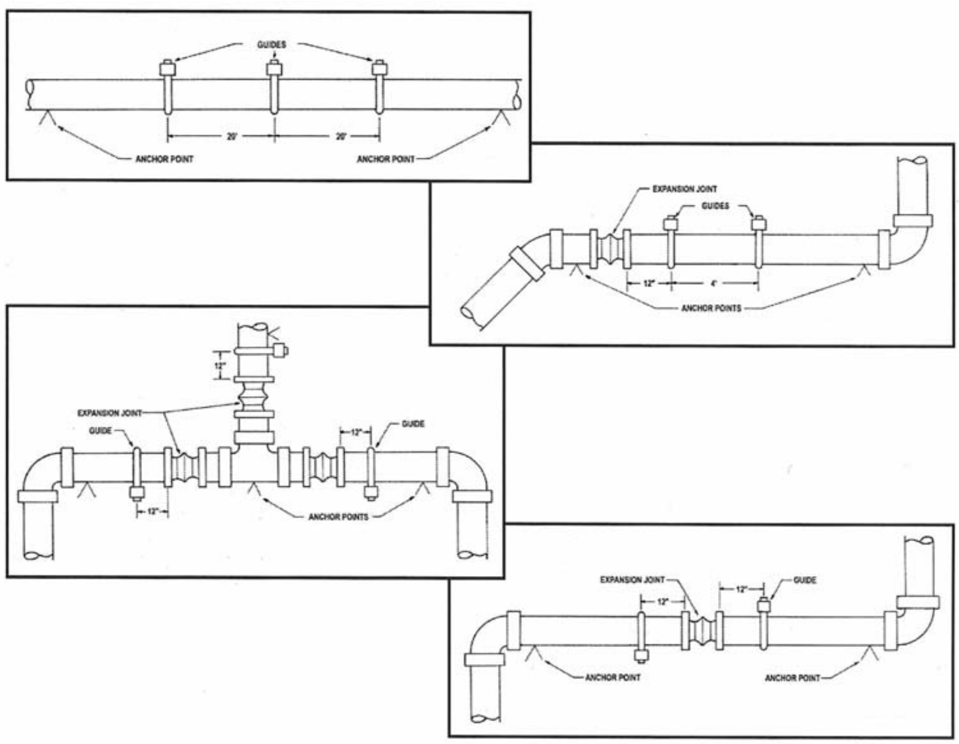


Figure 55. Anchoring and Guide Design Diagrams



Piping Insulation

PVC is a low conductive material. In most cases, minimum or no insulation is required of PVC piping systems. For example, compared to steel, PVC has over 250 times the insulating capacity. To calculate heat loss or gains through any piping material, use the following equation:

$$Q = \frac{K\, t\, A \bullet \Delta T}{x}$$

where:

Q = Heat gain or loss (Btu)

K = Thermal conductivity of the pipe (Btu-in./ft^2-HR-°F)

ΔT = Temperature difference of inside and outside pipe walls (°F)

A = Surface area (ft^2)

x = Wall thickness (in.)

t = Time (hrs)

Example: What is the heat loss over 1 hour of a 1-foot long section of 2" PVC Schedule 80 pipe with a temperature difference of 80°F?

K = 1.2 Btu-in./ft^2-hr-°F (for PVC)

D = 2.375 in. for 2" pipe

$A = \pi DL$ = (3.141) (2.375 in.) (1ft/12in.) (1 ft) = 0.621 ft^2

X = 0.218 in.

$$Q = \frac{K\, t\, A \times \Delta T}{x} = \frac{1.2 \times 1 \times 0.621 \times 80}{0.218} = 273.47 \text{ Btu}$$

Fire Resistive Design

One of the reasons PVC piping has been used extensively in residential, commercial, and industrial applications for decades is that it has inherent fire resistant properties and does not support combustion. Because PVC piping represents a very small portion of materials in buildings by weight, no evidence of a need for special tests or requirements other than those that are specified in building codes has been found.

Plenums

Most PVC piping is within walls or pipe chases; it is protected from fires that originate in occupied spaces. For unducted return air plenum areas, all building and mechanical codes require a Flame Spread value of 25 or less and a Smoke Developed value of 50 or less when tested in accordance with ASTM E84. PVC piping does not meet these minimum requirements for use without external protection; however, various pipe insulation manufacturers have tested their products in accordance with ASTM E84 and have met 25/50 FS/SD limits.

Fire Resistance Ratings

As buildings became larger, provisions were added to the codes to contain any fire within a limited area and to prevent it from spreading vertically or horizontally. This was accomplished by establishing requirements that certain wall, floor, and floor-ceiling assemblies have fire resistance ratings of one to four hours. The rating of a barrier is established by subjecting a sample assembly to the ASTM E 119 fire conditions of one to four hours. Plumbing codes reinforce the fire and building code provisions by requiring that all piping penetrations be made in such a manner as to maintain the integrity of the fire rating of building walls, floors, and ceilings. To prevent fire movement, fire stops are designed and installed using ASTM E 814 testing methods. For detailed information on this subject the publication *Plastic Piping in Fire Resistive Construction* (a comprehensive guide for selecting and installing plastic piping fire-rated barriers and fire stops) is available free and can be downloaded from the PPFA site (www.pphahome.org).

Other Aboveground Design Considerations

Cold Environments

PVC piping can handle temperatures below freezing if the system liquid does not freeze; however, the pipe flexibility and the impact resistance decrease. This may cause the pipe to become brittle. Protect the piping from impact if this condition can occur. To prevent liquid freezing in piping, electric heat tracing may be used and applied directly on the pipe (within the insulation if applicable). The heat tracing must not exceed the temperature-pressure system design. It is always good practice to check with the pipe manufacturers for their recommendations.

Compressed Air/Gases

DO NOT CONVEY COMPRESSED AIR OR GASES OR PRESSURE TEST PVC PIPING SYSTEMS, OR ANY PORTION THEREOF, WITH COMPRESSED AIR OR GASES. FAILURE TO FOLLOW THIS WARNING COULD LEAD TO LIFE THREATENING INJURIES AND SEVERE PROPERTY DAMAGE.

Outdoor Environments

PVC piping products are formulated for protection against the harmful effect of ultraviolet rays from the sun. However, long periods of exposure to direct sunlight can discolor the surface of the piping slightly reducing impact resistance. To prevent this phenomenon, PVC compatible opaque protection, paint, and/or other coverings can be applied. If using a paint, make certain it is an acrylic or water-based and not oil-based. A light color paint would be preferable to minimize heat absorption. If uncertain on what covering to use, consult the pipe manufacturer.

Air Admittance Valve

An air admittance valve (AAV) is a product that simplifies drainage and waste venting in commercial and residential applications by replacing or supplementing traditional vertical stacks. It is a one-way valve designed to allow air to enter the plumbing drainage systems when negative pressures develop in the piping system. The device closes by gravity and seals the vent terminal at zero differential pressure and under positive internal pressures. The purpose of the valve is to provide a way of allowing air to enter the plumbing drainage system without the use of a vent extended to open air and to prevent sewer gases from escaping into a building. Check with local codes to determine if AAVs are allowed.

Noise in DWV Piping

Good plumbing practices routinely employ the following techniques to reduce the noise in PVC piping systems:

- Be selective in plumbing wall stack location and avoid critical areas where possible.
- Use a plumbing "wall" of adequate thickness to properly accommodate the plumbing system without restriction.
- Support pipe properly and make sure it is not installed under strain and that it is not in contact with the wall material. Be sure to allow adequate clearances between piping and holes cut in framing members.
- Use long-radius fittings to reduce turbulence.
- Wrap stacks and piping in critical wall spaces with sound deadening material, or pack the wall with insulating materials.
- Isolate the piping system from the building structure using vibration damping materials, such as fiberglass or rock wool, in areas where noise would be objectionable.

Static Electricity

PVC piping is relatively non-conductive—an advantage particularly in electrical or electronic applications. In other applications this property could present issues by allowing electrostatic charges to be generated and accumulated.

Static electricity or electrostatic charge is normally generated by the separation and insulation of like bodies. This is likely to occur in the transport of dry bulk solids, powders, and slurries. To prevent charges from accumulating, all equipment and personnel should be grounded and measures should be taken to dissipate charge by increasing the conductivity of the piping system. This can be accomplished in three ways:

1. Coating the pipe surface with a solvent-free conductive metallic powder coating then grounding the pipe.

2. Wrapping conductive wire around the pipe for the entire pipe run and then running it to ground.

3. Increasing the relative atmospheric humidity with a thin film of moisture on the pipe will improve conductivity. This temporary measure can be made more permanent by treating the pipeline surface with a PVC compatible hygroscopic soap.

Underground Design

Due to the benefits of durability, safe and easy to use, environmentally soundness, and cost effectiveness, well over 75% of PVC piping is used for underground applications. This *Design Guide* will highlight some of the design criteria for using PVC pipe in underground applications. For a more thorough design and installation of underground PVC piping, the *Handbook of PVC Pipe* published by the Uni-Bell PVC Pipe Association is a recommended resource. Uni-Bell's website is www.uni-bell.org.

Similar to all other buried piping systems, good installation practices should be as follows:

- Grade all trench bottoms free of stone and pockets and for continuous, uniform support fill holes or depressions with clean, well-tamped material.
- Do not set pipe on bricks, concrete, or wood blocks.
- Install pipe on proper grade with full, continuous support.
- Backfill along sides of pipe with selected fill, free of stones, clods, or frozen lumps.
- Tamp backfill carefully to protect pipe alignment; then backfill on top of pipe with selected fill free of rock, stone, cement, and other hard-abrasive materials to a depth of 12 inches.
- The trench can then be backfilled in a conventional manner.
- Avoid burying mechanical connections if possible especially in high traffic areas.

As mentioned earlier, PVC piping is a non-conductor of electricity. Therefore, when burying plastic pipe, consider using a conductive product such as a metal wire in or above the trench to definitively locate the piping by using a metal detector device.

Keep in mind that PVC pipe in most instances is considered a flexible pipe rather than a rigid piping product. Flexible pipe is able to bend slightly without breaking and uses the pipe wall and buried medium to sustain external loads. When installed properly, PVC pipe develops support from the surrounding soil. Pipe deflection or compression depends on any one or a combination of three factors:

- Pipe stiffness
- Soil stiffness (soil density along the sides of the pipe)
- Load on the pipe (earth, static, and live)

For more complete engineering and design information on PVC pipe stiffness, soil stiffness, and pipe loading, go to Uni-Bell's website: www.unibell.org.

Pipe Stiffness

Pipe stiffness is the force in psi divided by the vertical deflection in inches. An arbitrary data point of 5% deflection is used as a comparison of pipe stiffness values in flexible piping. Each pressure piping material has a different pipe stiffness value that is based on the material's flexural modulus. For any given SDR, the pipe stiffness remains constant for all sizes.

Soil Stiffness

Soil stiffness is the soil's ability to resist compaction. Spangler's formula is used to determine the "E" values or deflection of buried flexible pipe in terms of soil stiffness independent of pipe size. The "E" value is also referred to as the modulus of soil reactions. The soil backfill type and amount of compaction directly affect these values.

Pipe Loading

Earth loads may be calculated using Marston's load formula. Static loads are calculated using Boussinesq's Equation. Live or dynamic loads are also calculated using Boussinesq's Equation, by multiplying the superimposed load (W) by 1½. There are existing tables available from pipe manufacturers for various piping materials listing soil conditions, soil compaction, pipe stiffness values, maximum height of cover recommendations, and other useful data to design underground PVC piping.

Trench Design

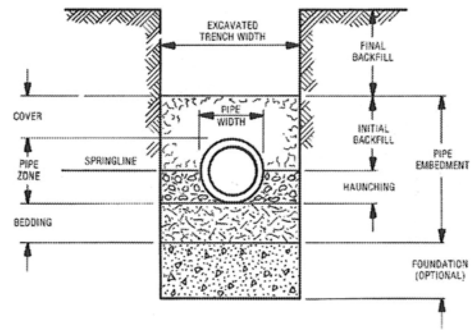
Trenches should be of adequate width to allow the proper bedding and back-filling of PVC pipe, while being as narrow as practical. A trench width of two or three times the piping diameter is a good rule of thumb in determining the trench width. Following is Table 12 listing minimum trench widths for various pipe sizes and Figure 56 listing trench terminology.

Table 12. Minimum Trench Widths

Nom. Pipe Sizes (Diameter in.)	Number of Pipe Diameters	Trench Width (in.)
4	4.3	18
6	2.9	18
8	2.9	24
10	2.5	26
12	2.4	30
15	2.0	30
18	1.8	32
21	1.6	34
24	1.5	36
27	1.5	40
30	1.4	42
33	1.4	46
36	1.4	50
40	1.4	56
48	1.3	62

Source: Uni-Bell Pipe Assoc.

Figure 56. Trench Terminology



Source: Uni-Bell Pipe Assoc.

Minimum Cover for Pipe

The following minimum guidelines may be used when burying PVC pipe:

- Locate pipe below the frost line.
- Use a minimum cover of 18 in. or one pipe diameter (whichever is greater) when there is no overland traffic.
- Use a minimum cover of 36 in. or one pipe diameter (whichever is greater) when truck traffic may be expected.
- Use a minimum cover of 60 in. when heavy truck or locomotive traffic is possible.

Risers

PVC pipe has excellent weathering resistance especially if coated with a latex paint or other covering; however, the vertical piping should not be brought above grade under the following conditions without making particular provisions:

- If pipe is expected to provide structural strength such as supporting an above-grade heavy metal valve—the valve should be independently supported.
- If pipe is subject to external damage—this can be rectified by sleeving the pipe with an independently and rigidly supported metal barrier.
- If pipe is subjected to high temperature environments—the situation might be remedied by insulation.

Chapter

3

JOINING METHODS

PVC piping systems have many joining methods that have stood the test of time and proven in most cases to have superior joint integrity when compared to other piping materials.

This section will cover several different joining methods; however, solvent cementing, the most common method for joining PVC piping, will be discussed in the greatest detail. To guarantee a trouble free piping system two major factors are needed: an experienced installation crew and completely following the manufacturer's instructions.

General Piping Practices

There are some distinctive differences between plastic and non-plastic joining and installation techniques; yet, always use good piping practices similar to other piping materials. For example:

- Always have a slow operating valve at the pump discharge if water hammer is a possibility.
- Provide for proper air relief and vacuum break at high points.
- Follow specific manufacturer's installation and safety manual instructions.
- Train installers if handling PVC piping material for the first time.
- Use appropriate and well maintained piping joining tools and accessories.
- Piping should be installed as stress-free as possible, especially at fitting and valve areas.
- Eliminate air from the piping system before testing and start-up.
- Design for thermally caused pipe movement.

Joining Methods

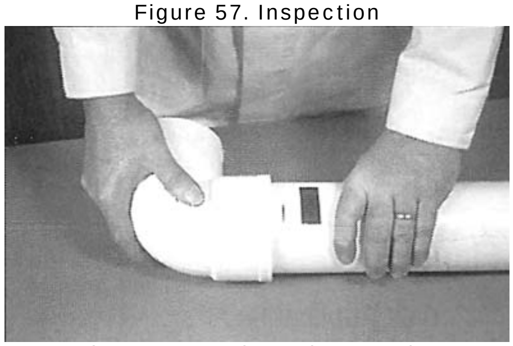
Before joining any PVC piping system, always make certain of the following:

- Products chosen are appropriate for the design.
- Products to be joined are inspected to ensure that no cracks (normal fitting molding “knit” lines are acceptable), gouges, warping, or other imperfections are present.
- The fitting socket and outside pipe diameter fit as specified by the manufacturer.
- All pipe is cut squarely, deburred, and beveled.
- All piping products are thoroughly cleaned before joining.
- Piping products to be joined are kept at similar temperatures when solvent cementing.
- You are knowledgeable of the manufacturer’s products and installation procedures.
- Ensure all tools are in good condition.

Inspection

Before joining the pipe, inspect the pipe surface for deep gouges and cracks. If suspect areas are found, cut out the damaged section at least 12 inches beyond the ends of the gouge or crack. Also, make certain the component socket and outside pipe diameter fit correctly.

Figure 57. Inspection

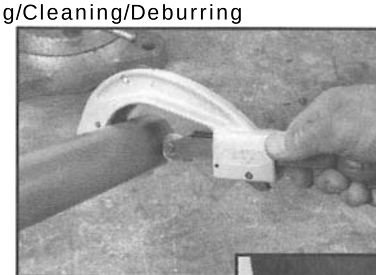


Check pipe and fittings for proper fit.

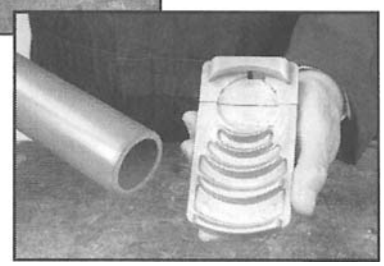
Cutting/Cleaning/Deburring

Cut, deburr, and bevel PVC pipe with specially-designed tools. Using a clean, dry cloth, remove any dirt, grease, and/or water from joining surfaces. If the cloth is unsuccessful at removing surface dirt, follow the manufacturer's recommendations on cleaners or other acceptable methods. Do not use mechanical sanding tools to clean or bevel pipe.

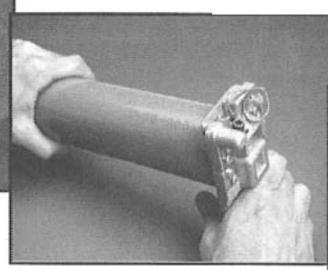
Figure 58. Cutting/Cleaning/Deburring

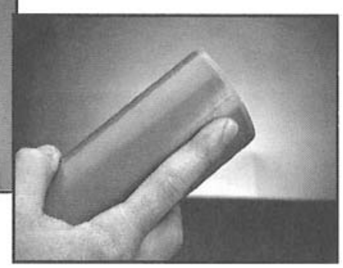


Plastic Pipe Cutter for Square Cut

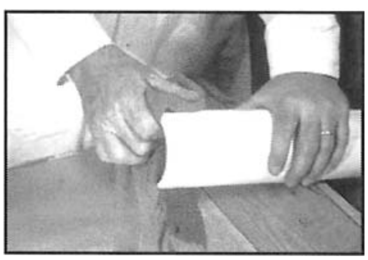


Pipe Beveller





Remove all burrs on inside and outside of pipe.



Remove dirt, grease and moisture using a clean, dry rag.

Solvent Cementing

The preferred joining system for most PVC installations is solvent cementing. The ease of joining, durability and integrity of the joint, and low labor cost of this joining method make PVC one of the most preferred piping systems in the world.

Advantages

- Joint is as strong or stronger than the pipe or fitting
- Monolithic—no foreign substance contacting fluid being handled
- No special costly tools required
- No open flames, torches, or hot plates
- Less likelihood for on-site burn, cut, or impact injuries
- Extremely cost-effective
- Fewer training hours for installers to learn techniques
- No need for electric power in many cases

Concerns

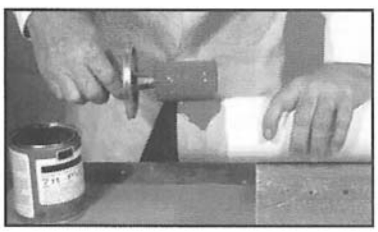
- Once joined, connections are permanent
- Time required before testing
- May require ventilated environment
- Leaks, though rare, may require replacement or back welding
- Special precautions may be needed to join in poor weather conditions

Joining Method

Using ASTM standard D 2855, the method of joining PVC piping is shown in Figure 59 as follows:

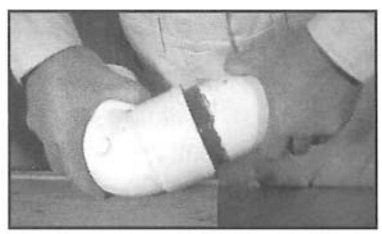
Figure 59. Solvent Cementing

Using the correct applicator, aggressively work primer into fitting socket & pipe OD until surface is softened. Apply second coating of primer in fitting socket.



Before the primer is dried, apply cement aggressively to the pipe OD and fitting socket.

Apply a second even layer of cement to pipe OD.



Without delay and while cement is wet, push pipe into fitting, twisting a quarter-turn until pipe bottoms out.

After assembly, joint should have a solid ring or bead of cement around joint interface. If voids are present, the joint may be suspect.

Hold pipe & fitting together for about 15-30 seconds to avoid push out.

Using a rag, remove excess cement from pipe & fitting.

Joint Movement Times: The cement begins to "set" within just a few seconds to a few minutes after its application. Be careful not to move or disturb the joint during this set time. Below is a guide for moving newly installed PVC piping.

Cementing Cure Times: Always follow the manufacturer's instructions for a successful installation of PVC solvent-cemented piping systems. Listed below are typical guidelines for installers to follow when moving or testing PVC solvent-cemented piping (cure times may vary—check with manufacturer before testing).

Table 13. Joint Moving Set Times

Pipe Size (inches)	Hot Weather 90° to 150° F	Mild Weather 50° to 90°F	Cold Weather 10° to 50°F
¼ - 1¼	12 Min.	20 Min.	30 Min.
1½ - 2½	30 Min.	45 Min.	1 Hr.
3 - 4	45 Min.	1 Hr.	1½ Hrs.
6 - 8	1 Hr.	1½ Hrs.	2½ Hrs.
10 - 12	2 Hrs.	3 Hrs.	5 Hrs.

Source: Adapted from NIBCO, Inc.

Ten Percent Pressure Testing Times (typical guideline): Hydrostatic (water) testing of PVC welded joints could be accomplished at 10% of the largest pipe diameter's operating pressure (temperature-corrected) working pressure according to the times shown in Table 14.

Table 14. 10% Pressure Testing Cure Times

Pipe Size (inches)	Hot Weather 90° to 150°F	Mild Weather 50° to 90°F	Cold Weather 10° to 50°F
¼ - 1 ¼	1 Hr.	1 Hr. & 15 Min.	1 Hr. & 45 Min.
1 ½ - 2 ½	1½ Hr.	1 Hr. & 45 Min.	3 Hrs.
3 - 4	2 Hrs. & 45 Min.	3½ Hrs.	6 Hrs.
6 - 8	3½ Hrs.	4 Hrs.	12 Hrs.
10 - 12	6 Hrs.	8 Hrs.	72 Hrs.

Source: Adapted from NIBCO, Inc.

One Hundred Percent Pressure Testing Times (typical guideline): PVC solvent-welded joints should be tested for no more than 15 minutes at 100% of the largest pipe diameter's operating pressure (temperature-corrected) and working pressure. (Values below are for systems of 180 psi or less).

Table 15. 100% Pressure Testing Cure Times

Pipe Size (inches)	Hot Weather 90°to 150°F	Mild Weather 50° to 90°F	Cold Weather 10° to 50°F
¼ - 1¼	4 Hrs.	5 Hrs.	7 Hr
1½ - 2½	6 Hrs.	8 Hrs.	10 Hrs.
3 - 4	8 Hrs.	18 Hrs.	24 Hrs.
6 - 8	12 Hrs	24 Hrs	48 Hrs.
10 - 12	18 Hrs.	36 Hrs.	3 - 12 Days

Note: Job site conditions such as humidity, altitude, and other factors can effect the cure times. The listed cure times are guidelines only. It is best practice to use the cement manufacturer's recommendations for cure times before testing.

Source: Adapted from NIBCO, Inc.

Special Conditions for Cementing

Hot Weather Cementing: Quicker solvent evaporation during hot weather and/or high winds needs to be taken into account to have a successful installation. Hot weather causes the primed piping surfaces to dry out more rapidly. To overcome these concerns, the installation crew needs to reduce the elapsed time from preparing the joint to the joint installation. Listed below are suggestions to ensure proper joining at high temperatures:

- Increase the size of the joining crew and organize the team to achieve speed without compromising manufacturer's instructions.
- Construct a makeshift windscreen around the joining site and the crew.
- Shade the piping products and cement and primer containers from the sun before installing to eliminate heat absorption.
- Using adequate lighting, the joining may be done at night or early morning.
- Prefab components under controlled conditions if feasible.
- Use a cement applicator that is a minimum of ½ the pipe diameter size.

Cold Weather Cementing: Solvent in the cement and primer will not evaporate as readily when temperatures are below 40°F and cements become heavier, and may even gel. A stiff bristle brush can be used to better work the primer solvents into the pipe surfaces. Since the joints take longer to bond and cure in cold temperatures, be sure to hold together the newly cemented joint longer to prevent breaking the bond. Listed below are suggestions to help insure a proper installation at lower temperatures:

- Store piping materials and cement and primer in a temperature controlled area until ready for use.
- Keep moisture away from the joining site using overhead protection.
- Prefabricate as much of the system as possible in a safely heated work area (no open flames).
- Protect joints made outside with a portable shelter. The shelter should remain in place until the joint is set.

Cement and Primer Usage

The usage estimates listed in the table below should be used as a guide; actual usage depends on many factors especially installation conditions.

Table 16. Number of Cemented Joints per Container Size

Pipe Size	Pint	Quart	Gallon
½	130	260	1040
¾	80	160	640
1	70	140	560
1 ¼	50	100	400
1 ½	35	70	280
2	20	40	160
2 ½	17	34	136
3	15	30	120
4	10	20	80
6	NR	8	32
8	NR	3	12
10	NR	NR	10
12	NR	NR	6

Source: Adapted from NIBCO, Inc.

Cementing Dissimilar Plastics

As previously stated, only ABS, CPVC, and PVC piping can be joined using solvent cementing. There are rare circumstances where there may be a need to *transitionally* join a PVC system with either an ABS or CPVC piping system using solvent cementing techniques. This method has been and can be used successfully following the piping and cement manufacturer's directions. ASTM D 3138 standard specifies the use of only one single transition joint needed to connect an ABS and PVC piping system. The standard is intended for joints between ABS and PVC materials in low pressure applications only (25 psi or less).

One-step Cementing

Just recently, several PVC piping system manufacturers have supported a one-step solvent cementing procedure where priming the pipe is not necessary. This cementing method is typically recommended only for DWV applications with up to a 4-inch diameter. The major advantages of this joining method are that it reduces the amount of volatile organic compounds (VOCs), reduces the cost of joining products, and reduces potential damage from unintended primer spillage. Check with the piping and fitting manufacturer and your local building codes for acceptance of this type of joining system.

Key Points of Safety and Use

- Use approved eye protection when doing any job.
- Pipe, fittings, and cement should be exposed to the same temperature for at least one hour prior to cementing.
- Use only appropriate sized *natural bristle* brushes with a width of one-half of the pipe diameter, approved daubers, and/or rollers to apply cement/primer.
- Some pipe system joints may be prepared without a primer. Check the manufacturer's instructions and local codes.
- When joining in unusual conditions—temperatures below 40°F or above 90°F—carefully follow the cement manufacturer's instructions.
- Use the appropriate cement for the piping material, wall thickness, and local codes.
- Always thoroughly shake cement and primer containers before use.
- Observe the "use prior to" date on cement containers.
- Discard cements if they become gelled, lumpy, and/or stringy.
- Apply cement in open or well-ventilated environments and avoid prolonged breathing of solvent vapors. In some cases, personal protective equipment may be required.
- Keep cements, primers, and curing work pieces away from all sources of ignition, heat, sparks, and open flame. Store cement cans tightly closed and out of areas of extreme heat or cold. The solvents in cement and primers are highly flammable.
- Avoid skin contact with primers, cleaners, and cements. Wear proper gloves impervious to and unaffected by the solvents.
- Appropriate joint-drying time should elapse before moving or testing the cemented pipe system (see manufacturer's guidelines or ASTM recommendations).
- Don't be stingy using cement and primer—use the proper amount.
- When cementing ball valves, carefully cement the pipe into the valve with the ball open at a 45° angle. Leave valve open until cure time has elapsed.
- Do not take shortcuts; follow manufacturer's instructions completely.
- For safe handling of solvent cements and primers, refer to ASTM Standard F402 or PPFA's bulletin *Safe Handling of Solvent Cements and Primers.*
- Always work safe!

⚠ WARNING

WHEN JOINING PVC PIPING SYSTEM COMPONENTS USING SOLVENT CEMENT, THE SAFE HANDLING PROVISIONS OF ASTM F402 MUST BE FOLLOWED, INCLUDING BUT NOT LIMITED TO USING APPROVED GLOVES AND EYE PROTECTION AND WORKING IN A WELL-VENTILATED ENVIRONMENT. FAILURE TO FOLLOW THIS WARNING COULD LEAD TO LIFE THREATENING INJURIES.

Flanging

When flanging PVC systems, similar flanging practices are used as with most other materials. For PVC systems to be successful, the attached flanged hubs must be properly cemented to the pipe as described in the solvent cementing section of the *Design Guide*.

Advantages

- Can join dissimilar piping materials
- Can disassemble sections for inspection and maintenance
- Can fix leaks easily
- Can prefabricate a system for field installation
- Can test the system immediately if cemented flange hub is fully cured

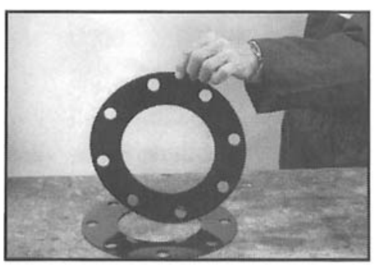
Concerns

- High initial cost
- Dissimilar material (gaskets) may contact fluid
- Not dimensionally compact
- Limited to 150 psi working pressure

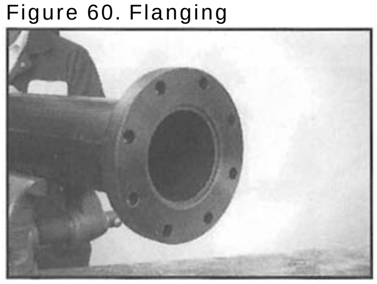
Joining Method

To properly flange PVC piping, see the following instructions shown in Figure 60.

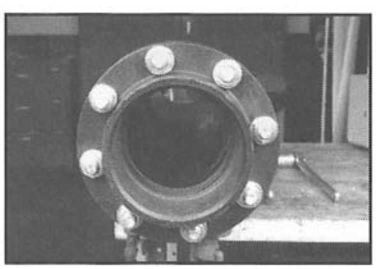
Figure 60. Flanging



Use soft, full-face gaskets compatible with handled liquid and thermoplastic material.



Install the flange making sure the pipe is bottomed-out to the flange stop. Use lubricated bolts and flat washers.



Pull down all bolts gradually to a uniform tightness. Maintain flange surfaces parallel within 1/16-in. during tightening.

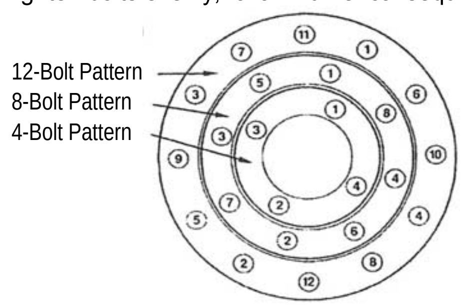
Tighten bolts by pulling down on the nuts diametrically opposite each other with a torque wrench at manufacturers' bolt torque values.

Key Points

- Make certain the system pressure does not exceed the working pressure of the flange—normally 150 psi.
- Use a torque wrench and follow manufacturers' bolting pattern and torque requirements when tightening nuts/bolts.
- Heavy flat washers should be used under both bolt heads and nuts on flanges to be joined. (Check with manufacturer for proper size washers.)
- Use lubricated bolts (lubricant to be material-compatible).
- Do not use ring gaskets; use chemically compatible full-face gaskets with a 55-80 durometer hardness.
- Avoid joining PVC flanges to metal flanges with an excessively raised inner lip.
- Do not direct bury flanged connections.
- Maintain flange surfaces parallel within 1/16-in. during tightening.

Figure 61. Flange Bolt Tightening Pattern

(Tighten bolts evenly; follow numerical sequence)



Threading

Direct threading of PVC pipe must only be used for Schedule 80 or 120. For critical applications use threaded PVC joints only if necessary. If threading is required, consider using transition unions or threaded fitting adapters.

Advantages

- Can disassemble
- Can fix leaks easily
- Can join dissimilar materials
- Can prefabricate a system for field installation
- Can test the system immediately

Concerns

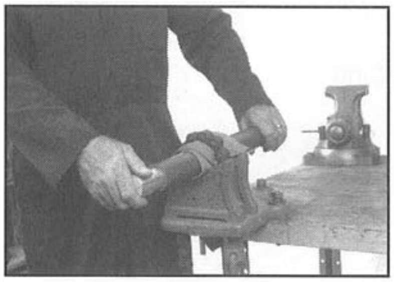
- Requires more expertise assembling sizes larger than 2-in. diameter
- Reduces the working pressure of the system 50%
- Threads are the weakest part of the piping system

- Special threading tools are required
- Thicker pipe (Schedule 80 or 120) is required
- Thread sealants must be compatible to PVC

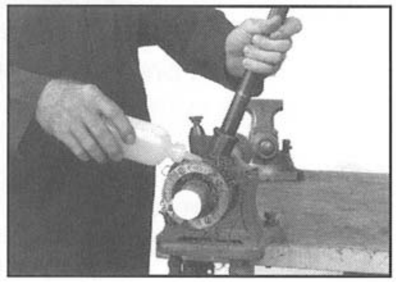
Joining Method

To properly thread PVC pipe see following instructions as shown in Figure 62.

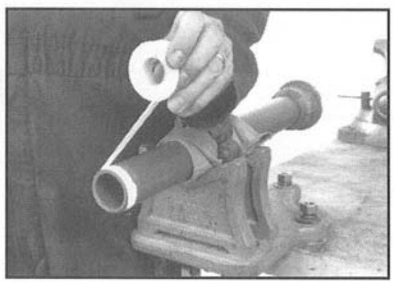
Figure 62. Threading



Insert plug into pipe end to prevent distortion of pipe walls.



Turn threading dies slowly, keeping speed constant. Use an approved thread-cutting lubricant.



After threading pipe, use Teflon tape or approved sealer/lubricant (ft. instructions).

Screw fittings onto pipe and tighten with strap wrench. Avoid excessive torque. One to two threads past hand-tight is adequate.

Key Points

- Use only schedule 80 pipe or thicker.
- Threading dies must be clean and sharp.
- Use strap wrenches or other non-metal tightening device.
- Threaded pipe will reduce working pressure of the system 50%.
- Do not subject threaded joints to repeated or severe strain.
- Use Teflon tape or manufacturer's approved thread sealant.
- Do not thread male metal piping into plastic female connections.

Other Joining Systems

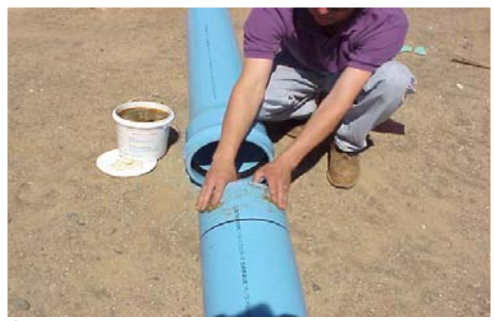
The *Design Guide* has listed the most common aboveground joining methods for PVC piping systems. There are several other PVC joining methods for specifically designed applications that are briefly covered.

Gasketed-Bell and Spigot

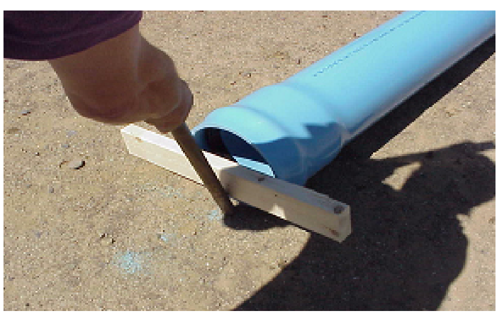
A popular method for joining underground PVC piping is with a gasketed bell and spigot joint. There are thousands of miles of successfully installed piping using this easy, safe, and cost-effective method of joining. This joining method requires no fancy or expensive tools, and in most cases, the gasket is permanently installed in the bell at the factory. One of the advantages of this joining system versus solvent cementing is that the system can be tested immediately after being joined.

Figure 63. Gasketed Joint Assembly

Step A. Clean the bell making certain the beveled spigot end and the gasket grove are aligned and free from dirt.



Step B. Apply lubricant to beveled spigot only. Lubricant used must be approved for potable water service and recommended by pipe manufacturer.



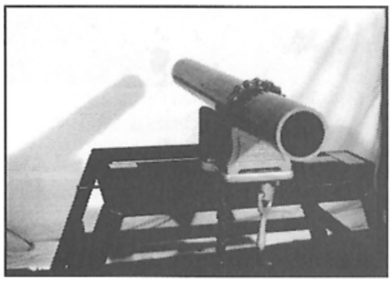
Step C. Assembly of small diameter pipe may be accomplished using only manual force. The block and bar method of assembly is recommended for larger diameter piping requiring a greater insertion force.

Step D. Push lubricated end past the gasket into the bell until reference mark is even with the bell lip. Over-insertion of spigot end past the reference mark may create a stress condition that could result in a joint failure or leakage.

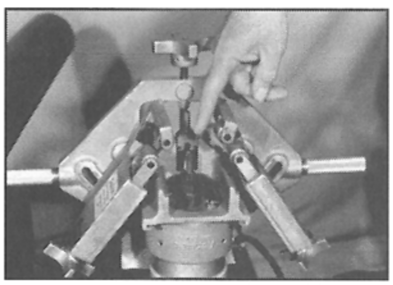
Mechanical Radius Cut/Rolled-Grooved with Metal Gasketed Coupler

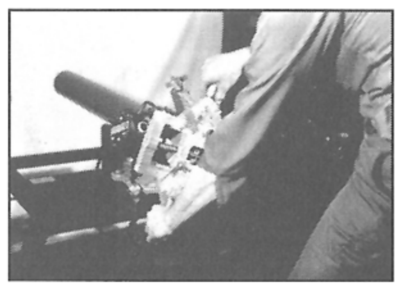
This system is similar in many ways to a flanged system in that it can be prefabricated and is easy to assemble and disassemble. These systems require rather expensive and sophisticated tools to "notch" the pipe (many times the grooves are made at the factory). Grooving (cut-grooving in particular) will reduce the working pressure of the pipe, and due to the pipe tolerances at pipe diameters above 8 inches, it may be difficult at times to fabricate a groove with acceptable tolerances. Joining instructions for cut and roll grooving of PVC pipe is shown in Figure 64 and Figure 65.

Figure 64. Mechanical Radius Cut-Groove with Metal Gasketed Coupler



Attach pipe to vise after cutting & beveling pipe end.





Use approved pipe tool to cut-groove pipe end.

Finished Cut-groove Pipe End

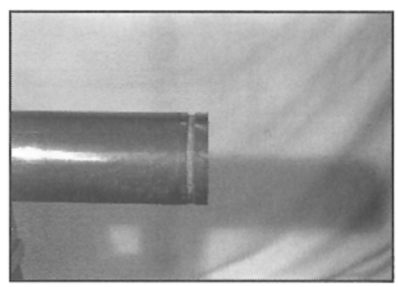
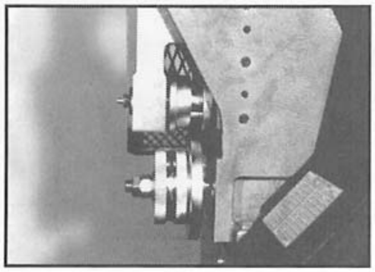
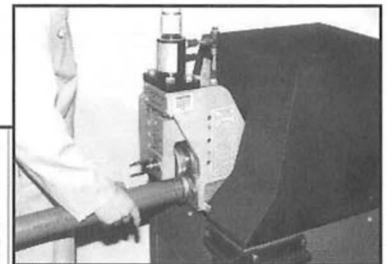
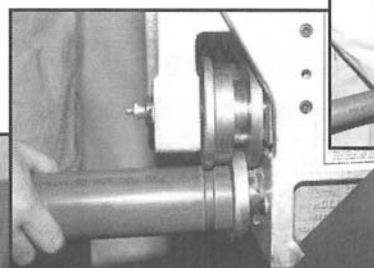


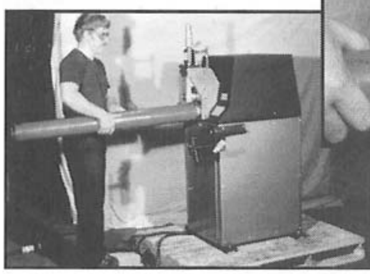
Figure 65. Mechanical Roll-Groove with Metal Gasketed Coupler



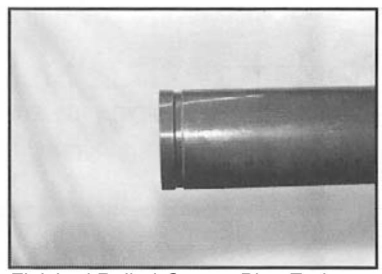
Use approved pipe tool roll-groove pipe end.





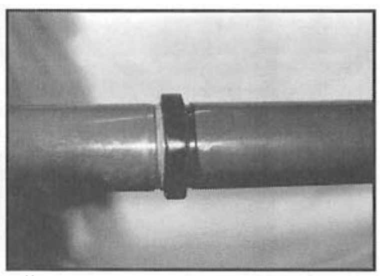


Roll-grooving of Pipe End

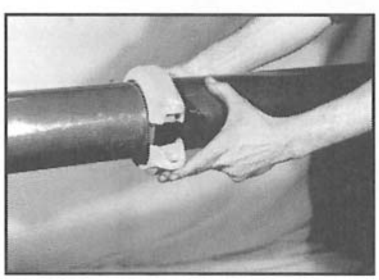


Finished Rolled-Groove Pipe End

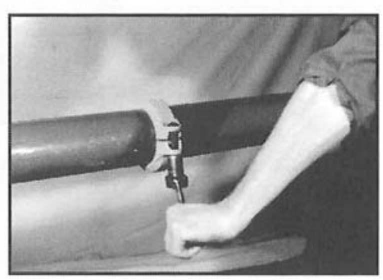
Ring Gasket to Fit in Grooved Pipe End



Affix gasket to pipe.



Place compression coupling over gasket.

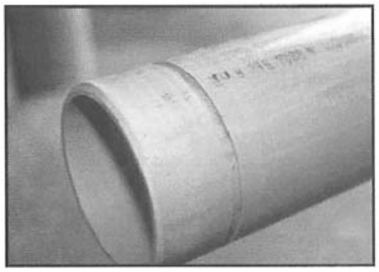


Tighten compression bolt to desired torque.

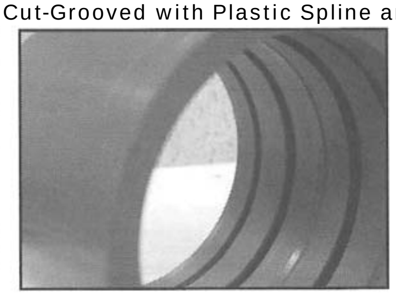
Mechanical Cut-Groove with Plastic Spline and Coupler

Similar to the cut/rolled system with a metal gasket coupler however, the coupling for this system is PVC, which aids in preventing corrosion and chemical attack. There are no expensive tools required for this joining method. Most of the applications for this system are in mines where acidic waters need to be pumped from mining locations to other sites and in emergency situations where flooding occurs. Figure 66 shows the proper joining method for this piping system.

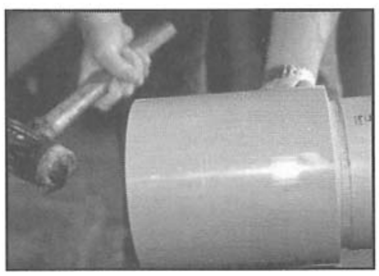
Figure 66. Mechanical Cut-Grooved with Plastic Spline and Coupler



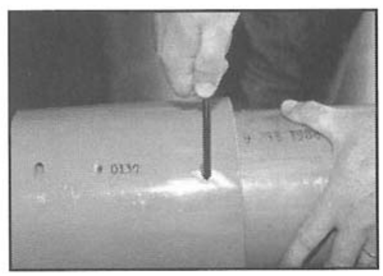
Pipe is manufactured with a groove on the pipe OD.



Coupling is machined with an internal groove for the spline, an internal groove for the O-Ring, and a pipe stop.



Insert coupling onto pipe end using a rubber mallet to bottom out.



Insert nylon spline into the overlapping grooves.

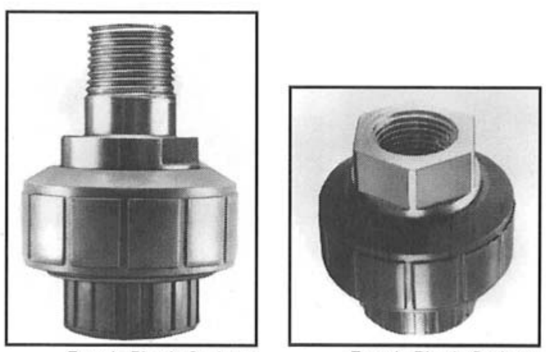
Transition Joints

Elastomeric couplings with compression clamps: Couplings and/or transition fittings are available for joining cast-iron soil pipe to PVC. These specialty fittings are needed due to the dissimilar outside diameter of these piping materials. For joining steel pipe to PVC (both made to Schedule 40 dimensions), the standard Cast Iron Soil Piping Institute (CISPI) hubless coupling is satisfactory. Plastic adapter fittings are also made that provide a contour with a raised ridge to provide a better gripping area for the elastomeric coupling.

Figure 67. Cast Iron and PVC Transition Using Elastomeric Coupling and Clamps

Threaded adapters: Threaded adapters are used to join a component with standard tapered pipe thread to PVC pipe. The PVC portion may be either spigot or socket, and the threaded portion may be either external or internal NPT threads. PTFE tape or compatible sealant is used to lubricate and seal the treaded joint. For metal threaded connections to PVC, metal/PVC adapters are available and will assist greatly in preventing splitting or leaking of the threaded joints.

Figure 68. Transition Fittings



Female Plastic Socket x Male Metal Thread

Female Plastic Socket x Female Metal Thread

Cast Iron soil pipe hub adapters: Cast iron hub to PVC spigot transition joints using oakum and lead wool as a sealant in DWV applications are becoming less used and may be completely replaced by a type of compression gasket. For more information on this transition fitting, consult with the fitting and/or pipe manufacturer.

Heat Fusion

PVC can be and is heat fused in very controlled environments where temperature and pressure have to be carefully monitored. Many fabricated large diameter fittings and other fabrications are made using this joining method. Recently, one pipe manufacturer has developed and is marketing a PVC field-joined heat fusion system mostly used for underground and slip-lining applications. It is too early to determine if this system will be a major factor in future PVC underground (or aboveground for that matter) applications.

Chapter

4

INSTALLATION

PVC piping installation, due to the product's lightweight, durability, ease of joining, absence of expensive and potentially dangerous joining tools, and minimal or no on-site theft, makes PVC one of most environmentally and economically sound piping systems in use today.

Installation practices for PVC piping, except for joining methods, differ very little from those of installing other piping systems. There are some slight differences however, and novice installers should contact an experienced plastic piping representative to educate the installing crew in proper joining techniques. In large critical projects, it may be advisable to certify the competency of each pipe fitter or hire the services of an experienced installation supervisor.

Work Crew

The size of the work crew is shown in Table 17 depends on the following:

- Crew's experience
- Pipe diameter and length of piping system
- Installation weather conditions
- Construction schedule
- Type of joining method
- Local labor requirements

Table 17. Recommended Crew Size for PVC Pipe Installation

Pipe Diameter (in.)	No. of installers (minimum)
½ - 2	1
2½ - 3	2
4 - 8	3
10 and above	4

Source: "Plastic Piping Systems," author David Chasis, Industrial Press, New York, NY.

Storage and Handling

PVC piping is tough and resilient, and does not require special treatment; however, like other piping materials, common sense and due care should be used when storing and handling PVC piping products.

Storage

Where possible, pipe should be stored inside. If impossible, store the pipe on dry level ground free from sharp objects. If various wall thicknesses of pipe are stored together, the pipe with the thickest walls should be on the bottom. If storing the pipe in pallets, the pallet cross-members should be stacked on one another not more than two pallets high. If the pipe is stored in racks, it should be continuously supported along its length or at a minimum of supports every three feet. To lessen the effects of the sun and help prevent heat build-up, the pipe should be in a shaded area with proper ventilation.

Figure 69. Pipe Storage

Summary of points to remember when storing PVC pipe are as follows:

- For prolonged outside storage, put pipe and fittings under an opaque, light-colored tarpaulin or in a well ventilated shed. This will minimize warpage and possible surface discoloration.
- Some pipe manufacturers ship pallets of pipe with an opaque wrap. Leave the wrap on until ready to use.
- Palleted pipe may be multi-stacked with the wooden frame for each pallet abutting the pallet above.

- Pipe rack storage should be free from sharp metallic burrs and edges and away from heat sources such as radiator steam pipes. Pipe racks should have appropriate support to prevent pipe from sagging.
- Belled pipe, if stored for extended periods, should have alternate rows of bells inverted so the loading on the bell is minimized.

Handling

When receiving the pipe, do a thorough inspection to make sure no damage occurred during transportation. Pipe received in a closed trailer should be inspected as the trailer is opened. Take extra time to ensure that the pipe has not been damaged by other materials that might have been stacked on top of the piping.

PVC pipe is lighter in weight than metal pipe, and handlers may be tempted to throw the pipe around carelessly. This should be avoided. The pipe should never be dragged or pushed from a truck bed. Removing pallets of pipe should be done with a properly sized forklift one pallet at a time. The pipe should never be lifted or moved by inserting the forks of a forklift into the pipe ends. Loose pipes require special handling to prevent damage. Avoid contact with sharp objects that could gouge the pipe. Keep in mind that PVC pipe becomes more brittle as the temperature decreases. Therefore, take extra care when handling the pipe below 50°F.

Summary of points to remember are as follows:

- Do not carelessly drop pipe from truck when unloading.
- Use a load distributor when moving small OD pipe.
- Protect piping from impact abuse, especially in cold weather.
- Use soft pads on truck bottoms that have metal edges.
- Use 3- or 4-inch wide nylon or rope slings for pipe lifting.
- Discard piping that has been run over by vehicles.

Aboveground Installation

The major considerations in installing PVC piping versus other non-plastic piping are as follows:

- Expansion/Contraction
- Support spacing
- Outdoor weathering
- Avoidance of compressed air and gases
- Impact protection
- High heat areas
- Air admittance valves
- Fire stops
- Recyclability

Expansion/Contraction

PVC piping systems expand and contract with temperature changes more than metallic piping systems. However due to the fact that plastic systems are less rigid than metal systems, PVC will absorb repeated flexing and develop less force than metal piping when exposed to temperature changes.

In cases involving extreme temperature ranges, long, straight pipe runs, and in installations where pipe is restrained so that it can move only in one direction, special provisions may be required. A primary concern is the connection between a long straight and a fixed-in-place fitting. Generally, when installing PVC piping systems with long runs of pipe and temperature change of 30°F or more, allowance must be made for thermal movement. The temperature during installation must also be considered and accounted for during design.

PVC has the capacity to absorb some stresses that may be placed on the system, but without proper planning, pipe expansion/contraction can create problems. Provision for thermal movement must be included in the system design. Often, changes in direction that occur naturally in the piping system may be used for handling the thermal piping travel. If this is impossible, expansion loops, offsets, or piston-type expansion joints will be needed.

In DWV systems, special consideration should be given between a long, straight branch line and a stack fitting. Because the stack is comparatively rigid and is held in place by the floor penetrations, provision for the branch line expansion must be made so that excessive force is not exerted on the stack wye or tee branch. Unlike tees and wyes, 45- and 90-degree elbows can absorb more stress and are used in offsets or at changes in directions.

A professional piping design engineer should review and sign-off on all piping plans to ensure a well designed piping system by calculating the estimated amount of thermal expansion and contraction for a particular project. Once the amount of expansion and contraction is determined, the installer can compensate for this phenomenon by using the following methods:

- Expansion loop
- Offset
- Change in direction
- Piston type expansion joint
- Bellows and/or rubber expansion joints

Figure 70. Expansion Loop

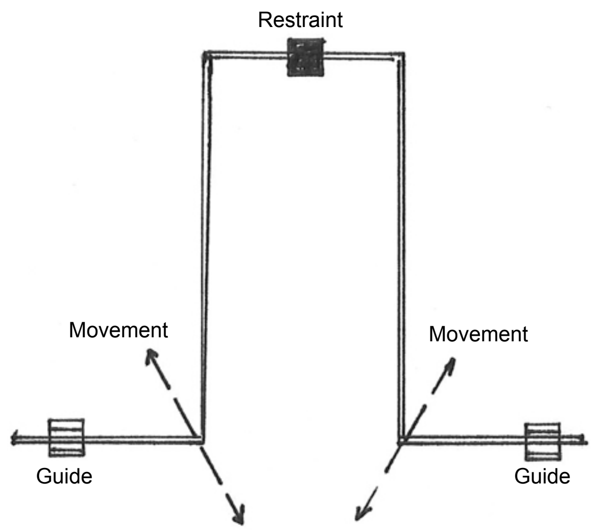


Figure 71. Offset

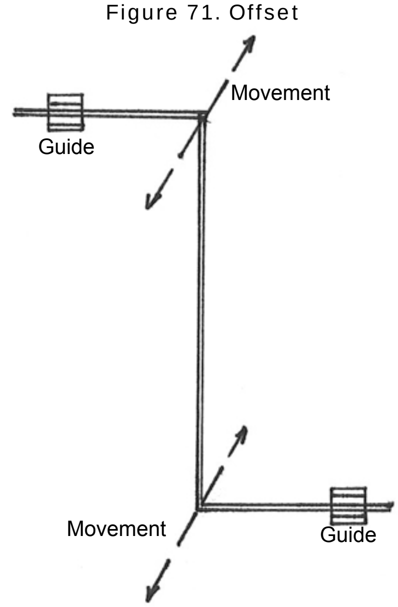


Figure 72. Change in Direction

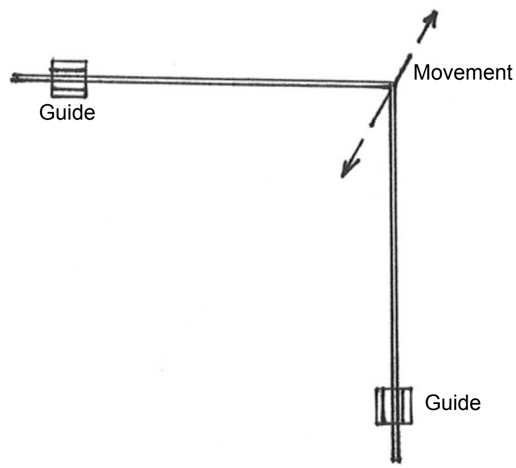


Figure 73. PVC Flanged Piston-Type Expansion Joint

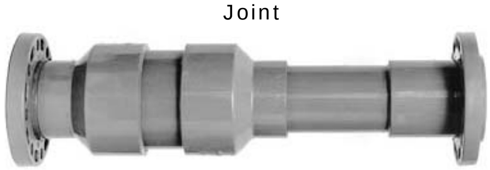
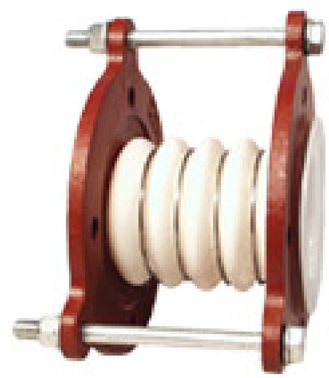


Figure 74. Bellows Expansion Joint



For vertical stacks in DWV or storm drainage systems in above-grade multi-story applications, compensation for expansion/contraction or building settling is recommended. This can be accomplished by installing a horizontal offset or expansion joint at a minimum of every other floor.

Secure aboveground vertical DWV or storm-drainage piping at sufficiently close intervals to maintain proper alignment and to support the weight of the piping and its contents. Support the stack at its base, and if over two stories in height, support the stack at its base and at each floor with approved riser clamps. Anchor the stacks so that movement is directed to the offset or expansion joint. Expansion joints should be installed in the neutral position. Compensation for thermal movements is usually not required for venting systems.

When installing the expansion loop, no rigid or restraining supports should be placed within the leg lengths of the loop. The loop should be installed as closely as possible to the mid-point between anchors. Piping support guides should restrict lateral movement and direct axial movement into the loop. The loops, offsets, and change of direction should be constructed of solvent-cemented joints only. If multiple loops are necessary, space accordingly.

Support Spacing

As in all piping systems, adequate support for aboveground installations is very important. Support spacing is a function of the pipe size, operating temperatures, the location of heavy valves or fittings, and the mechanical properties of the pipe material. When selecting the proper metal hanger, choose those that do not compress, distort, cut, or abrade the PVC piping.

Generally, all piping should be supported with an approved hanger at intervals sufficiently close to maintain correct pipe alignment and to prevent excessive sagging or grade reversal. Pipe should also be supported at all branch ends and at all changes of direction. Listed below are other important support issues.

- Concentrated loads should be supported directly to eliminate high stress concentrations.
- In piping systems where large fluctuations of expansion and contraction can occur, hangers must be placed as not to restrict the thermal movement.
- Hangers should provide as much bearing surface as possible and be free of sharp edges or burrs.
- Do not place PVC piping systems next to steam or other high temperature pipe lines or heat emitting products.
- Support spacing for horizontal PVC piping systems is determined by the maximum operating temperature the system will encounter.
- Hangers should not restrict axial movement.
- To determine support for vertical lines, it is recommended that an engineer design the support system based on the vertical load involved.

Outdoor Weathering

Although PVC piping has compound additives that minimize attack from the sun's rays, almost all pipe manufacturers recommend that PVC piping exposed to long periods of outdoor use be protected. Studies show that the effect of ultraviolet aging of PVC pipe causes a reduction in the impact strength, but the modulus of elasticity and tensile strength are virtually unaffected. The fact that these properties are unaffected signifies that structural integrity and pressure capacity of PVC pipe remain unchanged. UV degradation does not continue after installation when exposure to UV radiation is terminated.

Usually, the most cost effective method of "environmental proofing" the piping system is to apply a thin shield such as paint, coating, or wrapping to the pipe exterior. If using paint, use a water-based light-color paint. Of course, burial provides complete protection.

Compressed Air/Gases

DO NOT CONVEY COMPRESSED AIR OR GASES OR PRESSURE TEST PVC PIPING SYSTEMS, OR ANY PORTION THEREOF, WITH COMPRESSED AIR OR GASES. FAILURE TO FOLLOW THIS WARNING COULD LEAD TO LIFE THREATENING INJURIES AND SEVERE PROPERTY DAMAGE.

Impact Protection

In aboveground PVC piping applications that experience high vehicle traffic such as fork lifts or dollies, protect the piping from accidental impact by using a metal cover or the use of a more impact resistance piping material transitioned to the PVC at safer impact areas.

High Heat Environments

PVC can handle most applications not exceeding 140°F. However, if there are other piping systems or mechanical equipment that can exceed 140°F (steam lines or hot water heaters for example) and contact PVC, there needs to be protection of the PVC piping using insulation or a more heat resistant piping material to transition from the heat source to the PVC pipe.

Air Admittance Valve (AAV)

AAVs are available for DWV systems in sizes that fit vents from 1¼ inches to 4 inches. Most manufacturers have very detailed instructions on how to install their products. The following are key guidelines for successful AAV installations:

- When installed on single fixtures or branches, AAVs should be located a minimum of 4 inches above the weir of the fixture trap.
- Valve should be located to allow adequate air to enter the valve.
- Valve should be installed in the vertical upright position. The maximum offset from the vertical position should not exceed 15 degrees.
- Stack type AAVs are acceptable only in engineered drainage systems.
- When a horizontal branch connects to a stack more than four branch intervals from the top of the stack, a relief vent should be provided.
- A minimum of one vent should extend outdoors to the open air for every building plumbing drainage system.
- Valve should be installed after the drainage system rough-in test.
- Valve should not be used as a vent terminal for any sump vent.
- Valve should not be used to vent a special waste or chemical waste system.
- Valve should not be located in a supply or return plenum.
- The maximum height of drainage stack being vented by a stack type AAV should be six branch intervals.
- Protection of the AAV with insulation material is recommended if exposed to extreme temperatures.
- AAV should only be used in low pressure DWV systems.

Figure 75. An Installed Air Admittance Valve

Fire Stops

Building codes specify the fire ratings required in the building structure. All penetrations must be fire stopped using approved methods. PVC piping meets all applicable building code requirements and fire ratings when installed properly. It is recommended that piping installers become familiar with fire-stop techniques, systems, and materials, and how to properly select and install them so that the project meets the requirements of the building codes. The PPFA publication, *Plastic Piping in Fire Resistive Construction*, lists in its Design Compendium 450 designs for plastic piping showing various manufacturers, type of penetration medium, ASTM tests results, pipe diameter, and E814 test ratings. In Appendix E there are listings of over a dozen PVC fire-stop design installations tests.

Aboveground Installation Summary of Key Points

- Have a knowledgeable crew handling and joining PVC piping.
- Handle and store the piping products properly.
- Be aware of expansion and contraction considerations.
- Use proper support spacing and hangers.
- Keep hangers and anchors close to elbows.
- Use anchors and guides when necessary.
- Properly support plastic valves.
- Do not test or transmit compressed air or gases in PVC pipe.
- Eliminate all air from the piping system.
- Protect pipe from being damaged by moving vehicles.

Underground Installation

The majority of all PVC piping is used in underground applications due to its durability, installation ease and safety, environmentally soundness, and cost-effectiveness. A recent independent research study confirms that PVC has the lowest break rate of any installed water main material in use. Cast iron piping has a break rate 50 times that of PVC while ductile iron has a break rate more than 10 times that of PVC. The AWWA Research Foundation performed a study using highly specialized computer modeling to estimate the life of various underground piping materials and found that PVC piping was rated a minimum of 100 years while concrete and ductile iron piping were rated at 85 and 60 years respectively. Most of the *Design Guide* is focused on aboveground applications for commercial and industrial use. For a more detailed study of PVC underground installation techniques, refer to Uni-Bell's *Handbook of PVC Pipe* or Uni-Bell's website: www.uni-bell.org.

Trench Preparation/Depth/Cover

The individual project will determine the proper line and grade for the trench; however, several points to keep in mind for trenching and burial procedures are as follows:

- The width of the pipe zone should be as narrow as practical but have adequate room to join the pipe in the trench if required, be able to snake the pipe to compensate for expansion and contraction and to provide the necessary fill and compaction. See Table 12 in the Engineer Design section for suggested trench widths.
- Use trench supports to protect workers when necessary
- The trench bottom should be smooth and provide continuous uniform support. If smooth bottom trenches are difficult to construct naturally, foundation bedding should be installed as required by an engineer.
- Trench depth is determined by the pipe's service requirements but in any event the pipe should always be installed 6 to 12 inches below the frost line.
- Based on standards of the American Association of State Highway and Transportation Officials (AASHTO), for live loads of Highway H20, use a minimum cover of 12 inches or one pipe diameter, whichever is greater providing a minimum soil stiffness of E = 1000. For the same soil stiffness value for heavy truck or train traffic (live loading-Railway E80), use a minimum cover of 36 inches or one pipe diameter, whichever is greater.
- If the pipe is buried too deeply, it may not be cost or loading effective.

Bedding and Backfilling

Sub-soil conditions vary widely from place to place; however, the pipe backfill should always be stable, provide protection for the pipe, and be free of any large sharp rocks or other objects. Other points to keep in mind are:

- The pipe should be surrounded with an aggregate material that is easily worked around the sides of the pipe. Backfilling should be performed in layers of 6 inches with each layer being sufficiently compacted to 85 to 95%.

- The use of a mechanical tamper is recommended for compacting sand and gravel backfill, which contain a significant amount of fine-grained material. If a tamper is not available, use manual compacting.
- Don't tamp the initial backfill layer until all joints are visually inspected and the piping is left to settle and normalize dimensionally.
- The trench must be completely filled. The backfill should be in uniform layers to prevent unfilled spaces or voids.
- Make certain large rocks, stones, frozen clods, or other debris be removed from the backfill.
- Heavy tampers or rolling equipment should only be used to consolidate only the final backfill.

Pipe Placing and Snaking

The piping system should be placed in the trench using ropes and skids, slings on a backhoe bucket or by hand. Throwing or dropping the pipe into the trench could cause damage. Be especially careful of handling pipe in cold weather as the material becomes less impact resistant.

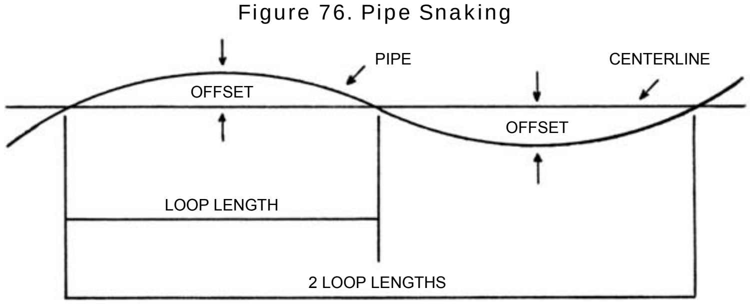
After the PVC pipe has been joined using solvent cementing, it is recommended to snake the pipe in the trench. When snaking the pipe, be careful not to apply any undue stress that will disturb the uncured joint. Snaking allows for any anticipated thermal movement that will take place in the newly joined pipeline. Table 18 and Figure 76 show suggested offset loops for buried PVC pipe.

Table 18. Loop Offset (in.) for Contraction

	Maximum Temperature Variation, °F (°C), Between Time of Joined Pipe and Final Use									
Loop Length (ft)	**10 (5.6)**	**20 (11.1)**	**30 (16.7)**	**40 (22.2)**	**50 (27.8)**	**60 (33.4)**	**70 (38.9)**	**80 (44.5)**	**90 (50.0)**	**100 (55.6)**
20	3	4	5	5	6	6	7	7	8	8
50	7	9	11	13	14	16	17	18	19	20
100	13	18	22	26	29	32	35	37	40	42

Source: Adapted from NIBCO, Inc. data

Figure 76. Pipe Snaking



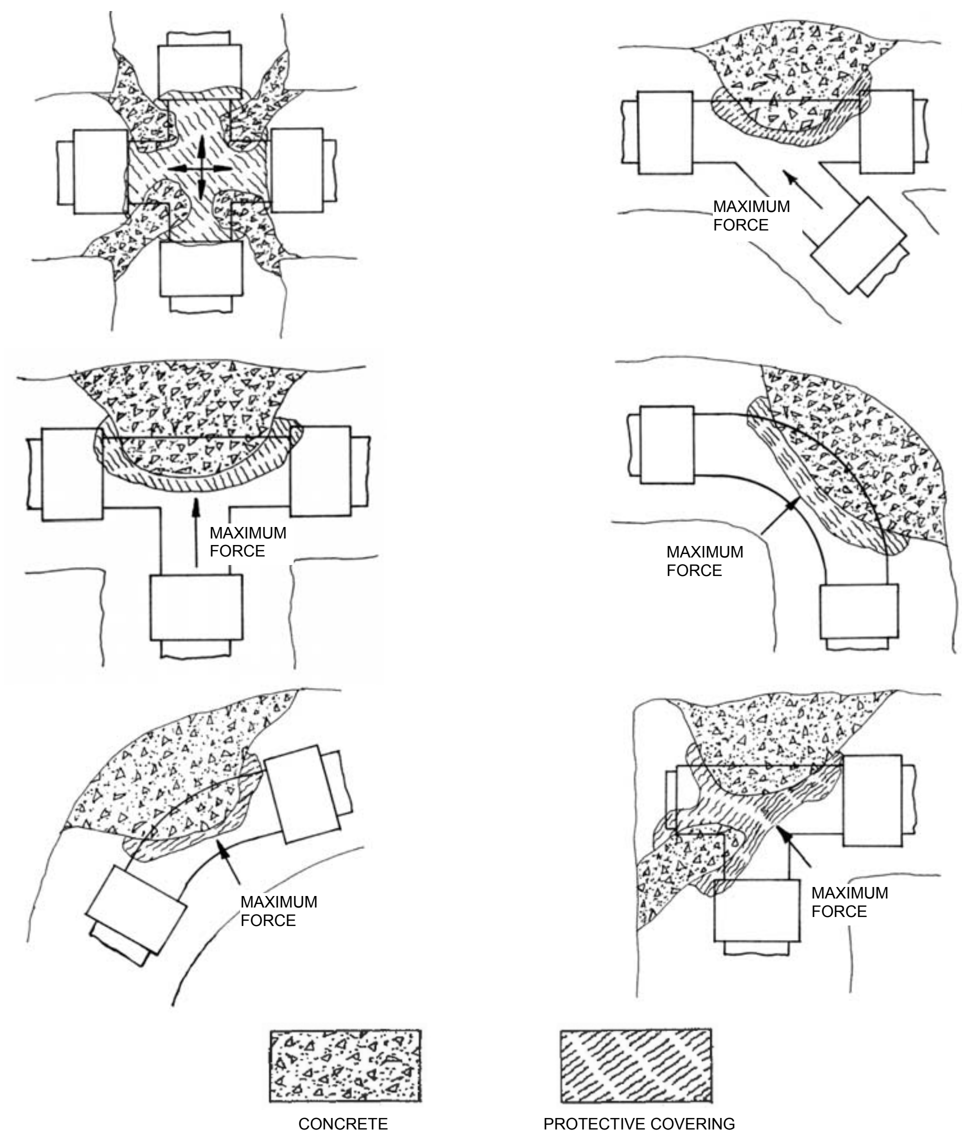
Source: Adapted from NIBCO, Inc. data

When laying long runs of piping at elevated temperatures, it is advisable to begin working from a fixed point such as the entry or exit of a building and work away from that point, testing and backfilling. This procedure should allow the piping to assume soil temperature progressively as work continues.

Thrust Blocking

PVC gasket-bell and spigot pipe in buried piping systems have to contend with thrust forces occurring at any point in the piping system where the directional or cross-sectional area of the waterway changes. These forces can be handled by means of concrete thrust blocks or encasements. This is accomplished by pouring concrete into appropriately sized forms at each point the thrust forces will develop. The concrete must be placed between the fitting and the undisturbed native soil at the side of the trench. Do not use pre-formed cement blocks for thrust blocking. Solvent-cemented buried piping does not require thrust blocking. See Figure 77 for various types of poured concrete thrust blocking.

Figure 77. Various Types of Poured Concrete Thrust Blocking



System Testing

Once the piping system has been assembled and initially backfilled, the system must be tested for leaks as shown in the Testing section of the *Design Guide*. Be certain the pipe is sufficiently backfilled to prevent movement during testing. Once the test is passed, the system can be covered.

Pipe Relocation

It is good practice to precisely map out the underground piping system after finishing the project. Since PVC is basically non-conductive, laying a conductive wire over the pipe or in the trench before final backfilling will facilitate accurately locating the pipe in the future.

Underground Installations Summary of Key Points

- Use as narrow a trench as possible and use trench support to protect workers when necessary.
- Do not direct bury mechanical connected piping (threaded, flanged, or grooved).
- Make certain the trench depth is a minimum of 12 inches below the frost line.
- Snake all small diameter pipe in trenches.
- Soil surrounding pipe and backfill should be free of any rocks or sharp objects.
- Be sure that solvent-welded joints are dry before handling or creating other pipe movement.
- If thrust blocking is required, use only poured-in-place concrete into undisturbed soil. Do not use wood or precast concrete blocks.
- Record precisely or lay conductive wire to be able to accurately locate underground pipe.

WARNING: IMPROPER INSTALLATION OR MISUSE OF TAPPING TOOLS MAY CAUSE RUPTURES IN PVC PIPING SYSTEMS UNDER HIGH PRESSURE WHICH COULD LEAD TO LIFE THREATENING INJURIES AND SEVERE PROPERTY DAMAGE.

Chapter

5

Testing and Repair

All piping systems should be tested to ensure a leak-free and long lasting installation. The caveat with PVC testing and repair is to explicitly follow manufacturer's instructions taking no shortcuts.

Testing PVC piping systems is similar to testing other piping systems except that the testing medium in virtually all cases is water and NOT COMPRESSED AIR OR GASES. Once a PVC system has been certified acceptable, future maintenance and repair will be rare due to the piping materials durability and joint integrity.

Water Testing

Site water pressure testing is required for most piping systems. In most cases, the piping system is tested to withstand the design working pressure, plus a safety margin. (In many applications the safety margin is 150% of the working pressure.) PVC piping should be HYDROSTATIC (water) TESTED only. Testing with air or gas can result in catastrophic failures causing property damage and life threatening human injuries.

One exception to the prohibition against air testing PVC piping systems involves sanitary drainage systems with ordinary trap seal pull testing. This testing method is performed after the DWV system is completed and air tested with all of its traps filled with liquid water, and the trap seals are then tested with pressure or vacuum in the normal operational pressure range of the system, typically between one to two inches of water column. Precautions must be taken to ensure the traps do not freeze before or during the testing.

When testing, the installers should properly restrain the piping system at all bends, changes of direction, and the end of pipe runs. Also, concealed joints should remain uncovered until the required testing is performed and approved. If a solvent welded joint system is involved, follow the cure time listed in this *Design Guide*'s solvent cemented joining section before fully testing.

Testing Procedure

1. Field inspect the installed piping system for evidence of mechanical abuse or suspect joints.
2. Divide the system into convenient test sections not to exceed 1,000 feet in length.
3. Slowly fill the pipe section with water at a velocity of one fps or less making certain any entrapped air is vented from the system high points.
4. Do not pressurize at this stage. leave the tested section for a least one hour to allow equilibrium temperature to be achieved.
5. Check the system for leaks, and if clear, make sure to remove any remaining air in the system before increasing the pressure up to 50 psi (for pressurized piping systems). For DWV piping systems hydrostatic testing, pressures of 10 feet of head of water is normal.
6. Leave the tested section pressurized for ten minutes. If the pressure gage shows a decline, inspect for leaks. If no leaks occur, gradually increase the pressure to 1½ the normal working pressure.
7. Leave the tested section pressurized for a period not to exceed one hour. During this time, the pressure should not change.

Summary of Key Points

- Test all piping systems before putting them into service.
- Do not test PVC pipe with compressed air or gas.
- Before testing the system, make sure the air is removed from the pipe.
- When testing a solvent-welded system, ensure the solvent-welded joints are fully cured.
- In dual-containment piping systems, test both the carrier and containment pipe. In some cases, the containment pipe many be air tested up to a maximum of 5 psi. (Check with the manufacturer.)
- Minimize surge pressures when filling the system to be tested.
- The test pressure should be no more that 1½ times the designed maximum system operating pressure, or at the rating of the lowest rated system component (whichever is lower).
- Test underground piping systems before completely backfilling, leaving all joints exposed during testing.
- If testing at high pressures, only the personnel required for the test should be at the test site.
- Testing personnel should be properly equipped with protective eyewear, clothing, and other safety items.

DO NOT CONVEY COMPRESSED AIR OR GASES OR PRESSURE TEST PVC PIPING SYSTEMS, OR ANY PART THEREOF, WITH COMPRESSED AIR OR GASES. FAILURE TO FOLLOW THIS WARNING COULD LEAD TO LIFE-THREATENING INJURIES AND SEVERE PROPERTY DAMAGE.

Repair

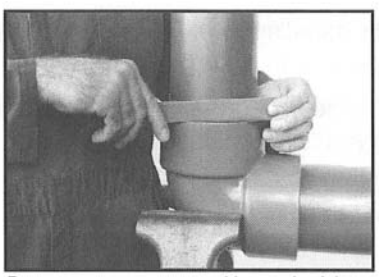
A PVC piping system properly installed in an approved application requires no repairs. In fact, as mentioned earlier in the *Design Guide*, the durability of PVC is one of the major reasons for its popularity and use. However, installation environments change and human error occurs which can cause the need to repair any piping system.

Mechanically joined piping systems using threading and flanging techniques are repaired similarly to non-plastic piping systems. However, in solvent-welded joining systems, there is a unique repair method for minute leaks called back or fillet welding.

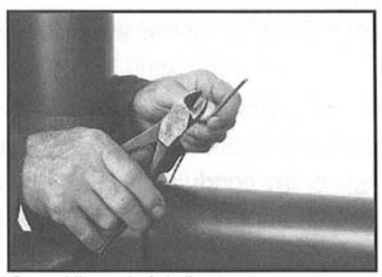
Back Welding (fillet welding)

If small leaks do occur in cemented piping systems, back welding may be of use. If the leaking joint provides a steady and heavy stream of fluid, do not back weld but rather cut out and replace the joint. Welding of PVC uses PVC welding rod and hot gas (air or nitrogen) to make a surface weld. The plastic weld, unlike metal, is not as strong as the parent material. For this reason fillet welding as a repair technique is recommended for very minor leaks in low pressure piping systems only. Before repairing a leaking joint make certain the joint to be welded is completely dry. Only skilled plastic welders should repair joint leaks. Adhesive-type repair kits are also available, (Check with pipe and/or fitting manufacturers.) Instructions for back welding are as follows.

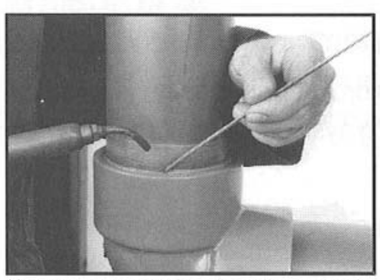
Figure 78. Repairing Plastic Piping Systems



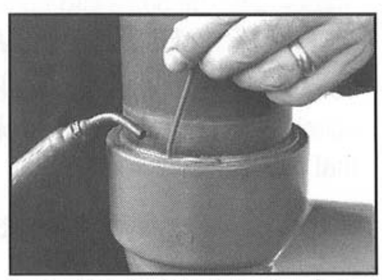
Remove excess cement residue at pipe joint and make sure the joint is moisture-free.



Cut welding rod of similar piping material at 45° angle.



Using an appropriate hot-air welding gun and maintaining uniform heat and pressure on the rod, weld a root bead into the prepared area.



Apply additional weld beads; number of beads depends on pipe size.

Table 19 lists the welding rod diameter and number of welding passes per pipe size.

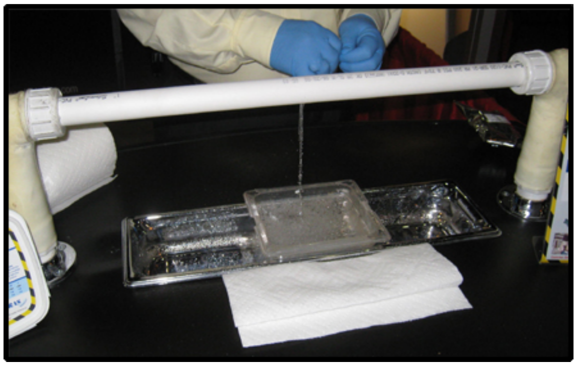
Table 19. Welding Rod Diameter and Number of Passes

Pipe Size (in.)	Rod Diameter (in.)	No. of Passes
½ - ¾	3/32	3
1 - 2	1/8	3
2½ - 4	3/16	3
6 - 8	3/16	5
10 - 12	3/16	5

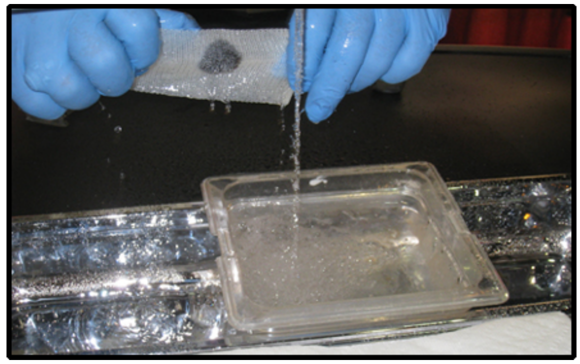
Source: Adapted from IPEX, Inc.

Pipe Repair Kits

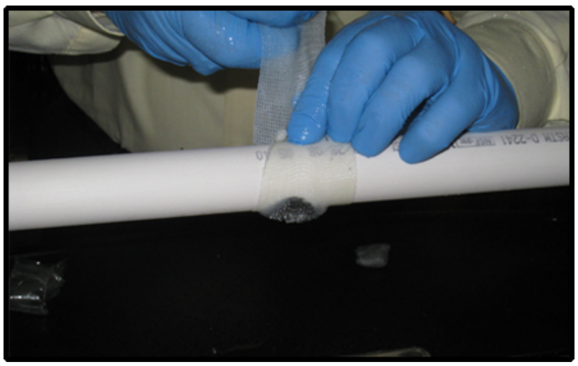
There are a few manufacturers that offer field repair kits for plastic and non-plastic piping. These kits normally include a hand-moldable epoxy "plug," urethane rich knitted fiberglass water-activated tape and gloves. No special tools are required. Most of the repair kits are certified to ANSI/NSF 61. Depending on the installation weather conditions, the tack free time is 3 to 5 minutes while the cure time for testing the repair is usually a minimum of 30 minutes. Contact repair kit and piping manufacturer to ensure material compatibility and possible temperature or pressure limitations. Figure 79 demonstrates the repair of a leaking PVC pipe.



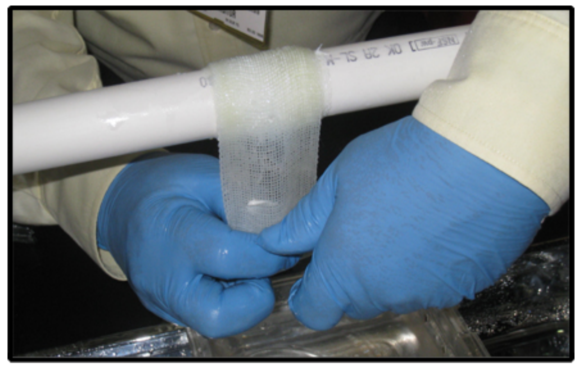
Steady leak from PVC pipe



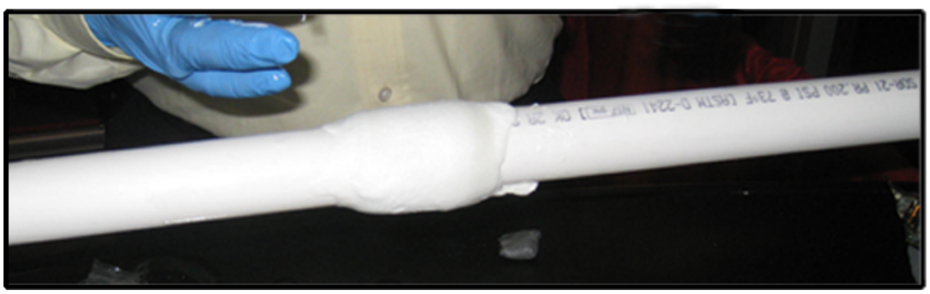
Water activating urethane FRP tape
wrapped around the epoxy plug



Wrapping plug with several layers of FRP
Notice the leak has stopped.



Final wrapping of repair
Notice the use of latex gloves during installation.



The finished product repair requires curing before testing.

Figure 79. Pipe Repair

Underground Joint Repair

If you take into account the cost of materials and labor costs, usually the installer is better off cutting out the defective joint and replacing it with new piping materials especially for underground piping. However, there are gasketed repair couplings available that have been successfully used to repair damaged piping sections. The advantage of these couplings is that no solvent cement is used in the installation allowing immediate testing of the system after the repair has been made.

Figure 80. Compression Coupling

Pipe Thawing

PVC piping is used for water distribution piping within buildings and for water service lines. These two areas of application are somewhat different so that when freezing occurs, they can be treated in the following ways.

Building Distribution Piping: When freezing occurs within the wall or in the crawl space, thawing should be done as soon as possible since complete freezing may cause the pipe to rupture.

Several methods of thawing may be used depending on the accessibility of the pipe and the availability of the devices. PVC piping should be limited to 140°F and the pipe temperature can be judged by grasping it firmly with the bare hand. For most people, 140°F is the maximum acceptable hand contact temperature. Do not pour boiling water on the pipe! Do not use an open flame heating source!

The following methods of applying heat have been used successfully:

1. Expose the piping in the area the freeze has occurred as much as possible and direct a small fan into that area to circulate warmer air from the occupied space into the wall cavity, in which the pipe is frozen.

2. If the frozen section of pipe is accessible, wrap it with a cloth saturated with hot water. As the cloth cools, remove it; dip it in hot water again and rewrap.

3. If the frozen section of pipe is fully or partially accessible, blow heated air directly on the area where freeze occurred utilizing a low capacity heater/blower such as a hair dryer.

It may be possible to use other means of heating, provided the temperature of the plastic piping at any point does not exceed those mentioned above. It should be noted that PVC has much lower thermal conductivity than metals, and therefore the rate of heat transfer from the exterior surface to the ice inside the pipe will be low. Thus, slightly more time is required to thaw the ice in the pipe. The technique described below can be used for distribution piping under most conditions.

Water Service Lines: If there is an outside underground water meter, this should be checked first because it may be the point at which freezing has occurred. If there is reason to believe that the meter is frozen, call the Utility Department for assistance.

Buried pipe should always be installed well below the frost line. However, if a buried line freezes and the condition is localized, the pipe can be exposed and then thawed with hot water. If the exact location of the ice plug cannot be established and the line terminates in a basement or crawl space, it may be possible to cut the line there and feed a small diameter tube into the pipe. By pouring or pumping warm or hot water into the small tube, it is possible to melt the ice plug.

The ice plug can also be melted with a resistance-heating element inserted into the pipe. Take a 3/8" or 1/2" diameter rod-type DC resistance heating element and fasten it securely to an electrician's steel fish tape. CAUTION: Follow the heater manufacturer's instructions to eliminate the possibility of electrical shock. Feed the element into the service line until the element hits the ice plug. The heating element will melt through the ice plug as it is moved forward. Continue to penetrate the ice plug until flow is established. If penetration is stopped, pull the element back. Do not leave the heater element in the pipe.

Other techniques for thawing can be devised, but the most economical method is prevention. Thermostatically controlled heat tapes may be useful for permanent protection in certain areas if insulation does not provide adequate protection.

Chapter

6

APPLICATIONS

Plastics are the leader in pipe usage in North America with PVC having approximately two-thirds of the total plastic piping market. Why? Because it is durable, easy and safe to use, environmentally sound, and cost-effective.

The most voluminous applications of PVC piping is for underground use in such markets as mains and distribution for potable water, sewer, drainage, irrigation, reclaimed/gray water, and swimming pools. The *Design Guide* will touch on these applications but mainly aboveground PVC commercial and industrial applications will be discussed.

Commercial Applications

PVC piping can be and has been used in most commercial projects such as:

Airports	Office Buildings
Apartments	Prison/Jails
Banks	Research Centers
Condominiums	Restaurants
Health Care Facilities	Resorts/Spas
Hotels/Motels	Retail Shops/Centers
Hospitals	Schools
Landfills	Sports Arenas
Marinas	Warehouses

The lack of training and education of the engineering and construction community, as well as some local code restrictions, have caused PVC piping systems to be underused in many construction projects, especially in aboveground applications. Hopefully, the *Design Guide* will assist engineers and installers to be more knowledgeable and comfortable with designing future projects with one of the most popular piping materials in the world—PVC.

Plumbing and Mechanical Piping Systems

PVC piping systems are listed in all major building plumbing and mechanical codes and standards in North America and abroad. Listed below in Table 20 are organizations that are involved with PVC piping standards.

Table 20. Standard Organizations for PVC Piping

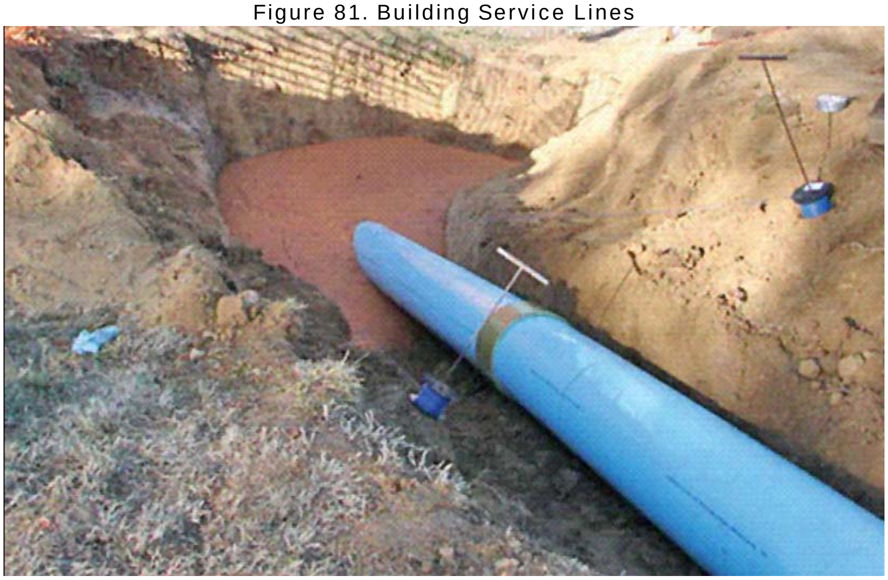
Abbrev	Standard Organization
AASHTO	American Association of State Highway and Transportation Officials
ANSI	American National Standards Institute
ASAE	American Society of Agriculture Engineers
ASTM	ASTM International
AWWA	American Water Works Association
BNQ	Bureau de Normalisation du Quebec
BOCA	Building Officials and Code Administrators
CSA	CSA International
DHUD	Department of Housing and Urban Development
DOD	Department of Defense (Military Standards)
FS	Federal Specifications
HUD	Housing and Urban Development
IAPMO	International Association of Plumbing and Mechanical Officials
ICBO	International Conference of Building Officials
ISO	International Standards Organization
NAPHCC	National Association of Plumbing, Heating, Cooling Contractors
NFGS	Naval Guide Specifications (Department of the Navy)
NFPA	National Fire Protection Association
NSF	NSF International
SBCCI	Southern Building Code Congress International
UL	Underwriters Laboratories
USACE	Department of the Army
USDA	U.S. Department of Agriculture

PVC piping is specified in plumbing or mechanical building codes for the following applications.

Pressure Systems

Building service lines: These PVC piping systems consist of cold potable water lines including water main and service lines to the building water meter and booster pump (if required). PVC is usually the preferred material in these applications.

Figure 81. Building Service Lines



Site utility systems: These rugged PVC piping systems comprise temporary de-watering lines, slip-lining of existing failing non-plastic piping systems, temporary drinking water lines, and temporary irrigation lines.

Figure 82. Site Utility Systems

Reclaimed and gray water systems: Purple colored or stripped PVC piping is used for non-potable water applications handling reclaimed and gray water. These piping systems are becoming more vital in green-build building systems as non-potable water may be reused for irrigation or other non-potable services. The purple colored PVC piping makes it almost impossible for a plumber to mistakenly mix potable with non-potable water.

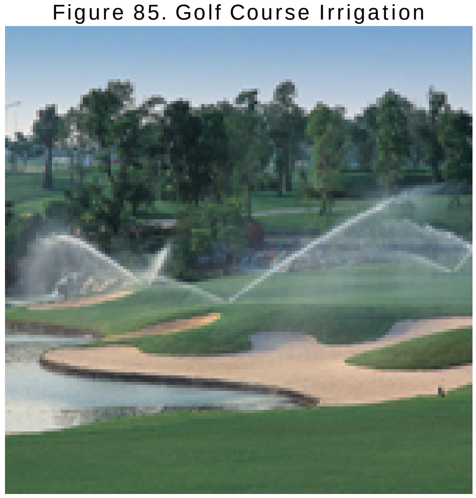
Figure 83. Reclaimed and Gray Water Systems

Pool, spa, and fountains: Many commercial structures incorporate swimming pools, spas, and fountains to enhance a property's value to existing and potential tenants in apartments, condos, and resort areas. PVC pressure piping is used throughout these applications.

Figure 84. Pool, Spa and Fountains

Turf irrigation: PVC pressure piping systems are used in most commercial landscaping projects where large areas of precise irrigation are required.

Figure 85. Golf Course Irrigation



Condenser water: Commercial air-conditioning systems use water-cooled or evaporative condensers—a device that transfers unwanted heat out of a refrigeration system to either air or water that absorbs the heat and transfers it to a disposal site. PVC makes an excellent condenser water piping material.

Figure 86. Outdoor Condenser Return Lines

Chilled water: A chilled water air conditioning system has no refrigerant in the unit itself. The refrigerant is contained in a chiller, which is located remotely. The chiller cools water, which is piped to the air conditioner to cool the space. PVC chilled water piping can easily handle the lower temperature water with unmatched durability. Most chilled water systems are closed-loop and often contain bactericides or chemical treatment compounds. Make sure these additives are compatible with the PVC piping system.

Figure 87. Chilled Water Lines

Water tower intake and outtake: Not only is PVC piping used for water intake and outtake lines to water towers but also in many instances in roof-top water tanks, the actual spray header and nozzles are made of PVC components.

Figure 88. Cooling Tower Pumping System

Non-pressure Systems

Venting: To protect against fixture trap siphonage, back-pressure, and air circulation, PVC— both cellular-core and solid-wall piping—is a natural for vent piping.

Figure 89. Drainage, Waste, and Vent Piping at a Commercial Job Site

Sanitary drainage: PVC piping from 1¼ to 12-inch diameter is available for commercial building sanitary drainage systems.

Figure 90. Sanitary Drainage

Building sewer: PVC sewer pipe sizes are available to handle the largest amount of drained fixture units in any commercial complex.

Figure 91. Building Sewer

Indirect wastes: Indirect wastes from applications other than standard sanitary wastes include but are not limited to the following:

- Food and beverage handling establishments
- Bar and fountain sink traps
- Sterilizers
- Drip or drainage outlets

PVC is acceptable in handling almost all of these indirect waste lines.

Figure 92. Piping for Restaurant Grease Traps

Storm/Roof drainage: Rainwater piping within the interior of a building is easily transmitted to designated sewers or rain harvesting systems using PVC piping systems.

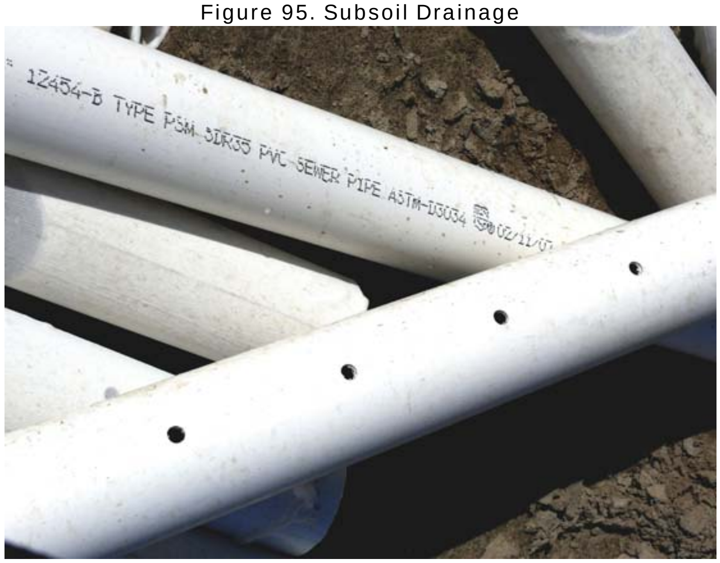
Figure 93. Storm/Roof Drainage

Condensate drain: In air-condition systems when air is cooled, water is removed from the air. The condensate that results is captured in a drain pan under the cooling coil and is discharged to a designated drainage system. The minimum pipe size for this application is ¾ inch and can increase in diameter depending on the refrigeration tonnage. PVC piping has been used for decades in this drainage application.

Figure 94. Rooftop Piping with Condensate Drain

Subsoil drainage: Subsoil drains placed around the perimeter of buildings with spaces below grade are 3-inch minimum in diameter perforated pipe. PVC perforated piping is a stocked item and has ideal durability for underground use.

Figure 95. Subsoil Drainage



Rain harvesting: Rainwater harvesting is the gathering, or accumulating and storing, of rainwater. In the past, rainwater harvesting has been used in arid and semi-arid areas providing drinking water, water for livestock, and water for irrigation, as well as a way to replenish ground water levels. Many buildings being designed today incorporate some type of rain harvesting whenever possible. PVC piping is a natural for these systems.

Figure 96. Manifold Piping Connecting Rain Harvesting Barrels

Industrial Applications

PVC piping and air handling products are ubiquitous and have been and are used successfully in dozens of industrial applications. The following applications are a partial listing of some of the more popular markets for PVC.

Air Pollution Control

Process piping and ducting applications to include:

- Cooling and washing tower
- Absorption tower
- Sulfuric acid mist elimination
- Waste liquor
- Waste lye
- Neutralization
- Calcium sulfate
- Cleaning agent
- Absorbed liquid thickener

Figure 97. Air Handling System

Amusement and Theme Parks

Process piping applications to include:

- Water rides
- Fountains
- Water supply
- Waste water treatment

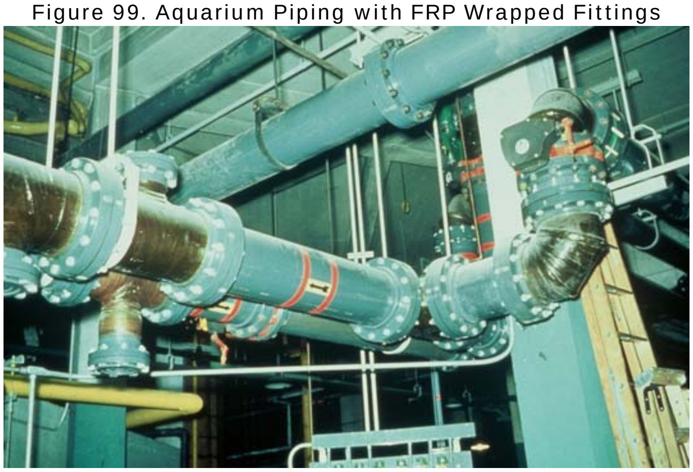
Figure 98. Water Slide Park

Aquariums

Process piping to include:

- Fresh water
- Salt water
- Aeration

Figure 99. Aquarium Piping with FRP Wrapped Fittings



Chemical Process

Process piping and ducting to include all chemically compatible flows at temperatures 140°F and below and working pressures usually below 150-psi. Also included:

- Waste and water treatment
- Air pollution control
- Double containment piping systems

Figure 100. Process Piping

Desalinization

Process piping to include:

- Seawater intake and outlet
- Fresh water
- Reverse osmosis
- Electro-dialysis

Figure 101. Desalinization Piping

Electronics and Semiconductors

Process piping and ducting to include:

- Deionized water
- Etching solutions
- Plating solutions
- High purity water
- Water and waste treatment
- Air pollution control
- Double containment

Figure 102. Electronics and Semiconductors

Environmental Protection

Process piping to include:

- Methane release
- Reclaimed water
- Rain harvesting
- Double containment
- Acid accumulation
- Odor control
- Zebra mussel control
- Landfill leachate

Figure 103. Odor Control Piping at Landfill

Fish Hatcheries and Farms

Process piping to include:

- Fresh water
- Salt water
- Feed
- Circulation

Figure 104. Fish Farm Piping Systems

Food and Beverage

Process piping to include:

- Brine
- Vinegar
- Auxiliary water
- Chemical bleaching
- Citrus acid
- Corn syrup
- Acidic juices
- Hot sauce
- Beer, wine, and sodas

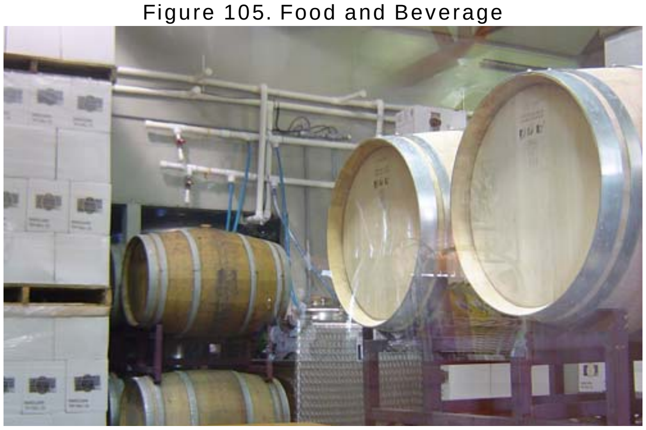


Figure 105. Food and Beverage

Marine

Process piping to include:

- Fresh water
- Salt water
- Refrigeration

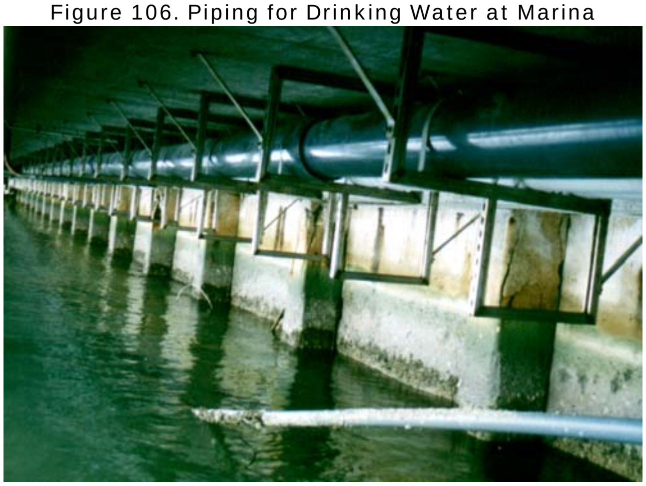


Figure 106. Piping for Drinking Water at Marina

Mining

Process piping to include:

- Slurries
- Leaching
- Acids
- Chemical mineral extraction
- Decant
- Tailings
- Impoundment
- Water supply

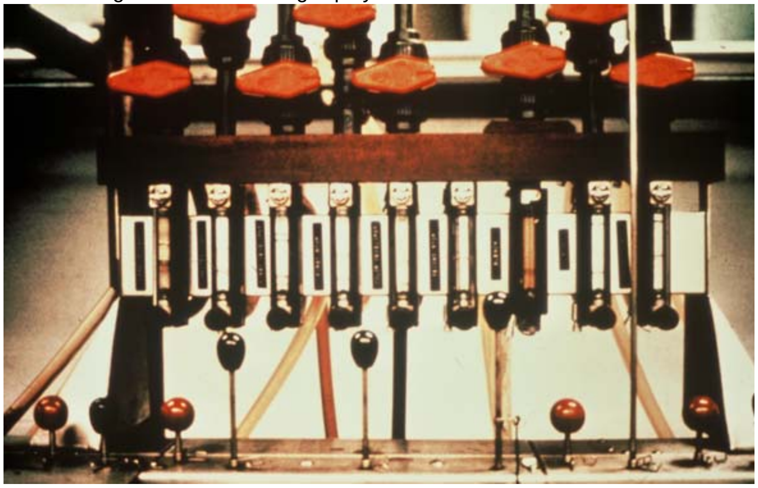
Figure 107. Mining

Photography

Process piping to include:

- Reservoirs
- Film rollers
- Developers
- Stabilizers
- Bleaching
- Dielectric shield
- Waste and water treatment

Figure 108. Photography Chemical Manifold Lines

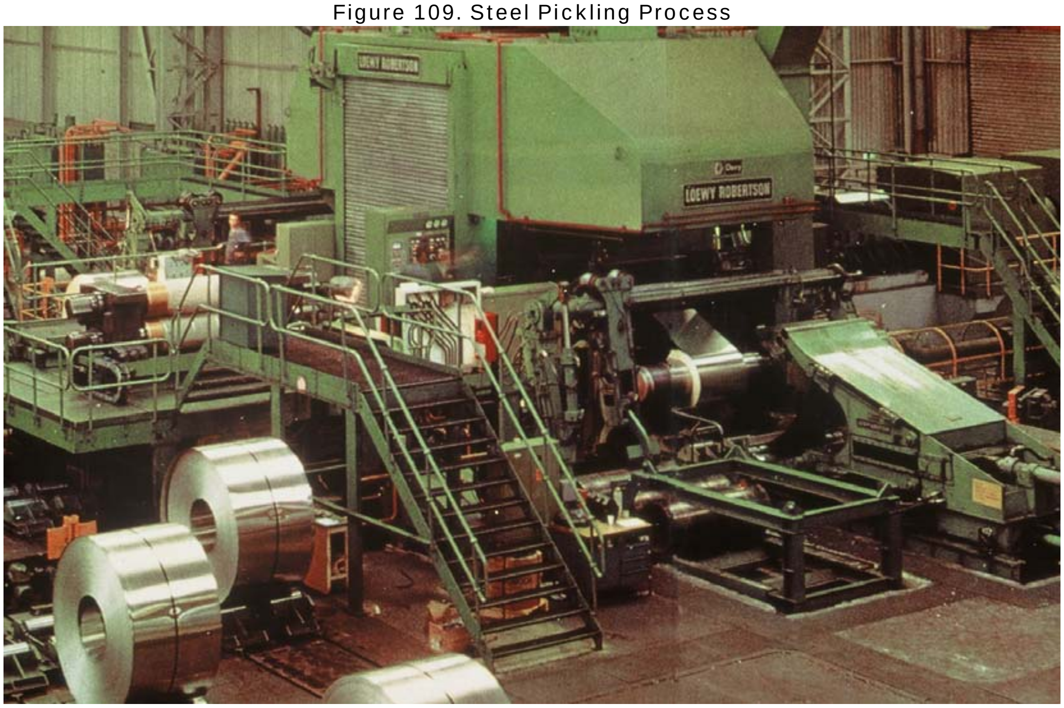


Steel Processing

Process piping and ducting to include:

- Coke
- Galvanizing
- Pickling
- Tin
- Wire drawing
- Waste and water treatment
- Air pollution control
- Double containment

Figure 109. Steel Pickling Process



Surface Finishing (Plating)

Process piping and ducting to include:

- Transfer feed
- Rinse
- Light and heavy metal salt plating solutions
- Galvanizing
- Waste and water treatment
- Air pollution control
- Double containment

Figure 110. Plating of Faucets

Swimming Pools (Municipal and School)

Process piping to include:

- Filtration
- Backwash
- Main drain
- Chlorine
- Inflow
- Outflow

Figure 111. Municipal Swimming Pool Filtration System

Waste and Water Treatment Plants

Process piping to include:

- Chemical feed
- Batch treatment
- Neutralization
- Filter press
- Diatomaceous earth cleaning
- Waste water
- Neutralized water
- Clean water

Figure 112. Bleach Process Piping

For additional commercial and/or industrial applications, contact the PPFA.

Chapter

7

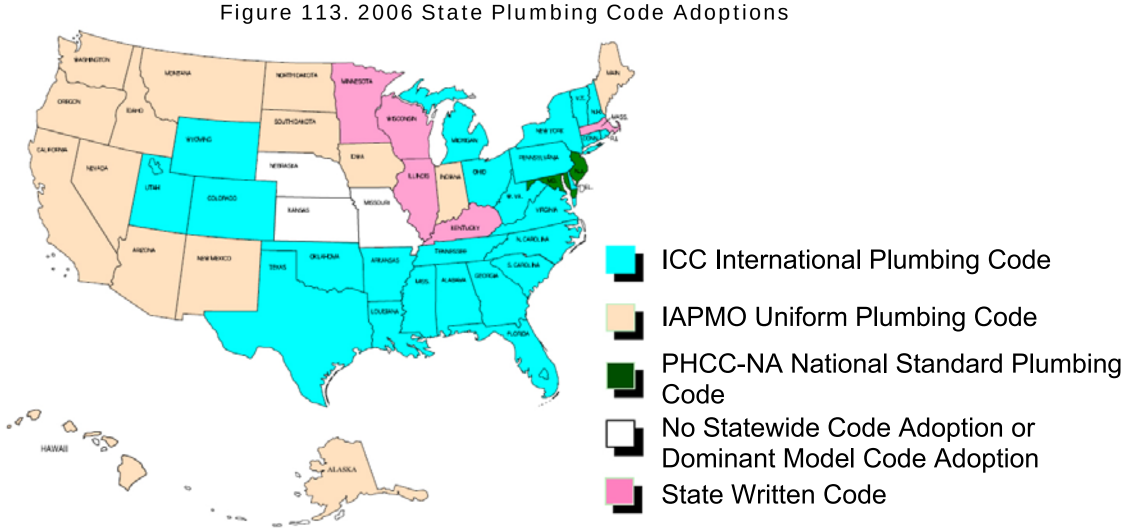
Building Codes, Standards, and Sample Specifications

The under utilization of PVC piping in commercial and industrial applications is changing as specifying engineers and installers realize the economic and environmental benefits PVC offer their clients.

Building Codes

Most plumbing codes around the world recognize and include PVC piping where applicable in residential and commercial construction. In the United States there are several plumbing codes adopted by states as shown in Figure 113. Most of the codes share much in common including those of the Canadian Standards Association; however, it is the responsibility of the design engineer and installer to ensure that all piping systems are in accordance with local codes.

Figure 113. 2006 State Plumbing Code Adoptions



This *Design Guide* is, in part, a tool to facilitate the learning experience for engineers, installers, and building code officials for them to fully understand where and how PVC may be used in commercial and industrial applications. The following section will offer sample engineering specifications and applicable standards for many of the applications mentioned in Chapter 6 of the *Design Guide*.

Standards

There are dozens of standards required for PVC piping systems referenced in the various plumbing codes. In Table 21, a listing of the pertinent standards for PVC is shown. These standards are constantly reviewed and may be updated as more data is known and made available of the industry's manufacturers' products and research. The latest revision of each standard applies.

Table 21. Mandatory Referenced Plumbing Standards for PVC Pipe

Standard No.	Standard Title	Application
ASME B31.1	Power piping	Piping
ASME B31.9	Building services pressure piping	Piping
ASTM D1784	Rigid PVC compounds	Piping
ASTM D 1785	PVC Sch. 40, 80, and 120	Piping
ASTM D 2241	PVC pressure-rated pipe	Piping
ASTM D 2464	PVC threaded fittings Sch. 80	Piping
ASTM D 2466	PVC Sch. 40 fittings	Piping
ASTM D 2467	PVC Sch. 80 fittings	Piping
ASTM D 2564	PVC solvent cements	Joints
ASTM D 2665	PVC DWV pipe and fittings	Piping
ASTM D 2672	Solvent Cementing IPS pipe	Joints
ASTM D 2729	PVC sewer pipe and fittings	Piping
ASTM D 2855	Making PVC solvent cemented joints	Joints
ASTM D 3034	PSM PVC sewer pipe and fittings	Piping
ASTM D 3138	Transition joint-PVC to ABS	Joints
ASTMD 3139	Elastomeric seals-pressure	Joints
ASTM D 3212	Elastomeric seals-DWV	Joints
ASTM D 3138	Cement for transition ABS/PVC	joints
ASTM D 3139	Use of flexible elastomeric seals-pressure	Joints
ASTM D 3212	Use of flexible elastomeric seals-drainage	Joints

Standard No.	Standard Title	Application
ASTM E 84	Surface burning characteristics	Misc.
ASTM E 814	Fire tests of fire stops	Misc.
ASTM F 402	Safe handling of cements and primers	Joints
ASTM F 477	Elastomeric seals	Joints
ASTM 480	Well casing pipe and couplings	Piping
ASTM F 480	PVC well casing pipe and couplings	Piping
ASTM F 656	Primers for PVC pipe and fittings	Joints
ASTM F 789	PS-46 and PS-115 PVC gravity sewer pipe	Piping
ASTM F 794	PVC gravity sewer pipe/controlled ID	Piping
ASTM F 891	PVC coextruded pipe w/ cellular core	Piping
ASTM F 913	Elastomeric seals for joining pipe	Joints
ASTM F 949	PVC corrugated sewer pipe w/smooth ID	Piping
ASTM F 1803	PVC gravity pipe and fittings	Piping
ASTM F 1866	PVC drainage and DWV fabricated fittings	Piping
ASTM F 1970	PVC special engineered fittings and valves	Piping
AWWA C900	PVC pressure pipe 4 in. thru 12 in.	Piping
AWWA C907	PVC pressure fittings 4 in. thru 8 in.	Piping
CSA B 137.2	PVC molded gasketed fittings	Piping
CSA B 137.3	Rigid PVC pressure pipe	Piping
CSA B 181.2	PVC DWV pipe and fittings	Piping
CSA B 182.2	PVC sewer pipe and fittings	Piping
CSA B 182.4	PVC profile sewer pipe and fittings	Piping
CSA B 137.2	PVC molded gasketed fittings	Piping
NFPA 255	Test method of surface burning	Misc.
NSF 14	Plastic piping components	Piping
NSF 61	Drinking water system components	Misc.
UL 723 / ASTM E 84	Test of flammability	Misc.

Sample Specifications General

Pipe

The sample specifications will cover those products listed in the applications section for aboveground use and will include the following PVC IPS diameter piping systems:

- Schedule 80
- Schedule 40 solid wall
- Schedule 40 DWV cellular core
- SDR Pressure Rated
- Reclaimed water

The listed specifications are for plain or bell-end pipe to be joined by solvent cementing methods. For belowground, use Schedule 40 solid wall, and SDR piping is available for gasketed-bell and spigot joining. Other PVC belowground piping is available but not covered in the specifications; this includes AWWA, perforated drain, PIP irrigation, gravity sewer, and well casing.

Other PVC piping products that may be used aboveground but not covered in these specifications are clear, double-containment, and high purity.

Fittings

Fittings for aboveground piping products are IPS diameter suitable for Schedule 80, Schedule 40 and DWV. DWV fittings are designed for drainage, wasting, and venting applications with limited working pressure ratings. PVC Schedule 40 and 80 fittings are pressure rated by most manufacturers to the similar working pressure as the pipe under normal conditions. Some fitting manufacturers recommend a maximum design pressure of 60% of the equivalent sized pipe. The pressure capabilities of fabricated fittings may very with each fabricator. If there is critical pressure application, it is prudent to check with the pipe and fitting manufacturer to ensure a properly designed system.

Valves

Ball, check, butterfly, globe, gate, diaphragm, relief, and many other PVC valves are available for use with pressure piping systems of PVC Schedule 40, 80, and SDR (IPS). Most of these products meet ASTM and NSF standards and are available in various elastomeric diaphragms, o-rings, seals, and gaskets depending on the fluid being handled.

PVC Schedule 80 Piping Systems Specification

Applications

To be used in all pressurized commercial and industrial process piping where applicable. These applications would include industrial processes, condenser water, chilled water, and double-containment.

Scope

This specification covers PVC Schedule 80 pipe, fittings, and valves in IPS size where temperatures do not exceed 140°F. The pipe, fittings, and valves shall meet or exceed all applicable ASTM and NSF standards.

Materials and Products

Pipe shall be manufactured from virgin rigid PVC compound and shall comply with the material requirements of ASTM D 1784, have a cell classification of 12454, and be in accordance to the requirements of NSF 61 for use in potable water. The piping system components should conform to NSF Standard 14 and the following ASTM standards:

- Pipe ASTM D 1785 / CSA B 137.3
- Fittings-socket ASTM D 2467
- Fittings-threaded ASTM D 2464
- Valves ASTM F 1970
- Solvent cement ASTM D 2564
- Primer ASTM F 656

Markings

PVC 80 pipe is marked as prescribed in ASTM D 1785 and NSF 14. The marking includes the following: Manufacturer, Nominal Pipe Size, IPS PVC, and the Schedule and Pressure Rating @ 73°F (23°C), ASTM D 1785, NSF 14, and NSF 61 Potable.

Installation

Installation shall comply with the piping component manufacturer's latest installation instructions and conform to all local plumbing, building, and fire code requirements. Solvent cement joints shall be made in a two-step process using approved primer and cement. Installers shall strictly follow manufacturer's joining instructions. Only use compatible materials coming in contact with PVC piping such as fire stopping, rubber pipe supports, thread sealants, or other possible aggressive chemical agents. Systems shall be hydrostatically tested after installation to 1½ times the system working pressure. Do not test with compressed air or gas.

PVC Schedule 40 Pressure Piping Systems Specification

Applications

To be used in pressure and non-pressure piping systems where applicable. These applications would include sanitary drainage, roof/storm drainage, vents, site utility systems, condensate drain, pool/spa/fountain, cold water distribution, rain harvesting, condenser water, chilled water, and double-containment.

Scope

This specification covers PVC Schedule pipe, fittings, and valves in IPS size where temperatures do not exceed 140°F. Pipe may be dual-marked as Schedule 40 and DWV. The pipe, fittings, and valves shall meet or exceed all applicable ASTM and NSF standards.

Materials and Products

Pipe shall be manufactured from virgin rigid PVC compound and shall comply with the material requirements of ASTM D 1784, have a cell classification of 12454, and be in accordance to the requirements of NSF 61 for use in potable water. The piping system components should conform to NSF Standard 14 and the following ASTM standards:

- Pipe — ASTM D 1785 / CSA B 137.3
- Fittings-socket — ASTM D 2466
- Valves — ASTM F 1970
- Solvent cement — ASTM D 2564
- Primer — ASTM F 656

Markings

PVC 40 pipe is marked as prescribed in ASTM D 1785 and NSF 14. The marking includes the following: Manufacturer, Nominal Pipe Size, IPS PVC, and the Schedule and Pressure Rating @ 73°F (23°C), ASTM D 1785, NSF 14, and NSF 61 Potable.

Installation

Installation shall comply with the piping component manufacturer's latest installation instructions and conform to all local plumbing, building, and fire code requirements. Solvent cement joints shall be made in a two-step process using approved primer and cement. Installers shall strictly follow manufacturer's joining instructions. Only use compatible materials coming in contact with PVC piping such as fire stopping, rubber pipe supports, thread sealants, or other possible aggressive chemical agents. Systems shall be hydrostatically tested after installation to 1½ times the system working pressure in pressure piping systems and less in DWV applications. Do not test with compressed air or gas.

PVC Schedule 40 Dual Marked Pipe and PVC DWV Fittings

Applications

To be used in non-pressure piping systems where applicable. These applications would include sanitary drainage, roof/storm drainage, and vents.

Scope

This specification covers PVC Schedule 40 Pipe and DWV fittings in IPS size where temperatures do not exceed 140°F. The pipe and fittings shall meet or exceed all applicable ASTM and NSF standards.

Materials and Products

Pipe and fittings shall be manufactured from virgin rigid PVC compound with a Cell Class of 12454 PVC as identified in ASTM D 1784 for pipe and ASTM D 2665 for fittings. Both pipe and fittings shall be manufactured in accordance to the requirement of NSF 61 for use in potable water. The pipe and fittings should conform to NSF Standard 14 and the following ASTM standards:

- Pipe ASTM D 1784 / CSA B 137.3
- Fittings ASTM D 2665 / CSA B 181.2
- Solvent Cement ASTM D 2564
- Primer ASTM F 656

Markings

If PVC DWV pipe is dual marked as prescribed in ASTM D 1784 (Sch. 40) and ASTM D 2665 (DWV), the markings are as follows: Manufacturer, Nominal Pipe Size, IPS PVC, and the Schedule and Pressure Rating @ 73° F (23°C) ASTM D 1784 and ASTM D 2665 PVC-DWV, PVC Schedule 40, NSF 14, and NSF 61 Potable. (Note: This piping product could be triple marked if used for well casing per ASTM F 480.)

Installation

Installation shall comply with the piping component manufacturer's latest installation instructions and conform to all local plumbing, building, and fire code requirements. Solvent cement joints shall be made in a two-step process using approved primer and cement. In particular applications (4-inch diameter size and below) a one-step cementing process can be used with manufacturer and local code approval. Installers shall strictly follow manufacturer's joining instructions. Only use compatible materials coming in contact with PVC piping such as fire stopping, rubber pipe supports, thread sealants, or other possible aggressive chemical agents. Systems shall be hydrostatically tested after installation to less than 5 psi. Do not test with compressed air or gas.

PVC Cellular Core Pipe and DWV Fittings

Applications

To be used in non-pressure piping systems where applicable. These applications would include sanitary drainage, roof/storm drainage, and vents.

Scope

This specification covers PVC Schedule pipe, fittings, and valves in IPS size where temperatures do not exceed 140°F. The pipe, fittings, and valves shall meet or exceed all applicable ASTM and NSF standards.

Materials and Products

Pipe shall be manufactured from virgin rigid PVC compound with a Cell Class of 11432 as identified in ASTM D 4396 and fittings shall be manufactured from virgin rigid PVC compounds with a Cell Class of 12454 as identified in ASTM D 1784. The piping system components should conform to NSF Standard 14 and the following ASTM standards:

- Pipe ASTM F 891
- Fittings-DWV ASTM D 2665 / CSA B 181.2
- Solvent cement ASTM D 2564
- Primer ASTM F 656

Markings

PVC Cellular Core Pipe is marked as prescribed in ASTM F 891. The marking is as follows: Manufacturer, Nominal Pipe Size, IPS PVC-DWV, ASTM F 891, and NSF 14.

Installation

Installation shall comply with the piping component manufacturer's latest installation instructions and conform to all local plumbing, building, and fire code requirements. Solvent cement joints shall be made in a two-step process using approved primer and cement. In particular applications, a one-step cementing process (4-inch diameter and below) can be used with manufacturer and local code approval. Installers shall strictly follow manufacturer's joining instructions. Only use compatible materials coming in contact with PVC piping such as fire stopping, rubber pipe supports, thread sealants, or other possible aggressive chemical agents. Systems shall be hydrostatically tested after installation to less than 10 psi. Do not test with compressed air or gas.

PVC SDR Pressure Piping Systems

Applications

To be used in pressure piping systems where applicable. These applications would include site utility systems, pool/spa/fountain, cold water distribution, water mains, rain harvesting, condenser water, and chilled water.

Scope

This specification covers PVC SDR pipe, fittings, and valves in IPS size where temperatures do not exceed 140°F. The pipe, fittings, and valves shall meet or exceed all applicable ASTM and NSF standards.

Materials and Products

Rigid PVC compound used in the manufacture of piping systems shall comply with the material requirement of ASTM D 1784, have a cell classification of 12454 and be in accordance to the requirements of NSF 61 for use in potable water. The piping system components should conform to NSF Standard 14 and the following ASTM standards:

- Pipe ASTM D 2241 / CSA B 137.3
- Fittings-socket ASTM D 2466
- Valves ASTM F 1970
- Solvent cement ASTM D 2564
- Primer ASTM F 656

Markings

PVC SDR/PR pipe is marked as prescribed in ASTM D 2241 as follows: Manufacturer, Nominal Pipe Size, IPS PVC, SDR #, and/or the pressure rating in psi for water @ 73°F (23° C), ASTM D2241, and NSF 61 Potable.

Installation

Installation shall comply with the piping component manufacturer's latest installation instructions and conform to all local plumbing, building, and fire code requirements. Solvent cement joints shall be made in a two-step process using approved primer and cement. Installers shall strictly follow the manufacturer's joining instructions. Only use compatible materials coming in contact with PVC piping such as fire stopping, rubber pipe supports, thread sealants, or other possible aggressive chemical agents. Systems shall be hydrostatically tested after installation to 1½ times the system working pressure in pressure piping systems. Do not test with compressed air or gas.

PVC Reclaimed Water Piping Systems

Applications

To be used in reclaimed water projects for pressure applications.

Scope

The specification covers PVC Scheduled 40 and SDR pressure rated plain-end pipe and pipe where temperatures do not exceed 140°F. Piping shall meet all applicable ASTM and NSF standards.

Materials and Products

Pipe shall be manufactured from virgin rigid PVC compound and shall comply with the material requirements of ASTM D 1784, have a cell classification of 12454, and be in accordance to the requirements of NSF 61 for use in potable water. All reclaimed piping should be purple in color or with three parallel purple stripes the length of the pipe. The piping should conform to NSF Standard 14 and the following ASTM Standards:

- PVC 40 Pipe ASTM D 1785 / CSA B 137.3
- PVC SDR Pipe ASTM D 2241
- Fittings ASTM D 2466
- Cement ASTM D 2564
- Primer ASTM F 656

Markings

PVC Reclaimed Water Pipe is marked as prescribed by the ASTM standard of pressure or schedule of the pipe being specified and marked accordingly except will be purple in color and the warning: "Reclaimed Water-Do not Drink" affixed on two sides of the pipe exterior no less than every five feet.

Installation

Installation shall comply with the selected piping system manufacturer's latest installation instructions and conform to all local plumbing and building code requirements.

Other PVC Piping System Products

PVC is unmatched with other plastic piping materials when it comes to the breath of complementary products. Besides the standard pressure and DWV piping systems, there are dozens of other products as shown. For more information on these and other products, contact the PPFA.

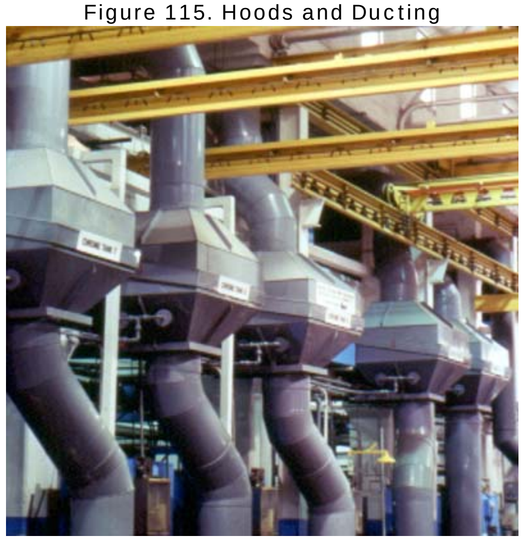
Accessory Equipment

Figure 114. Accessories

Primer/Cement/Applicators/Pipe Cutters/Deburrers/Welders and Rod/Strap Wrenches/ Threaders and Dies/Bolts, Nuts and Gaskets/Vises

Ducting Systems

Figure 115. Hoods and Ducting



Duct/Fans/Hoods/Blowers/Scrubbers/Scrubber Packing/Dampeners

Fabrications

Figure 116. Fabricated Fitting

Manifolds/Double-Containment/Large-Diameter Fittings/Pump and Filter Units/Work Stations/Round and Rectangular Ducting/Nuts and Bolts

Filters and Strainers

Figure 117. Strainers

Bag-Filters/Cartridge-Filters/Wye-Strainers/Basket-Strainers

Flow Monitoring Devices

Figure 118. Flow Meters

Vortex Sensors/Rotor Sensors/Gage Guards/Sight Glasses

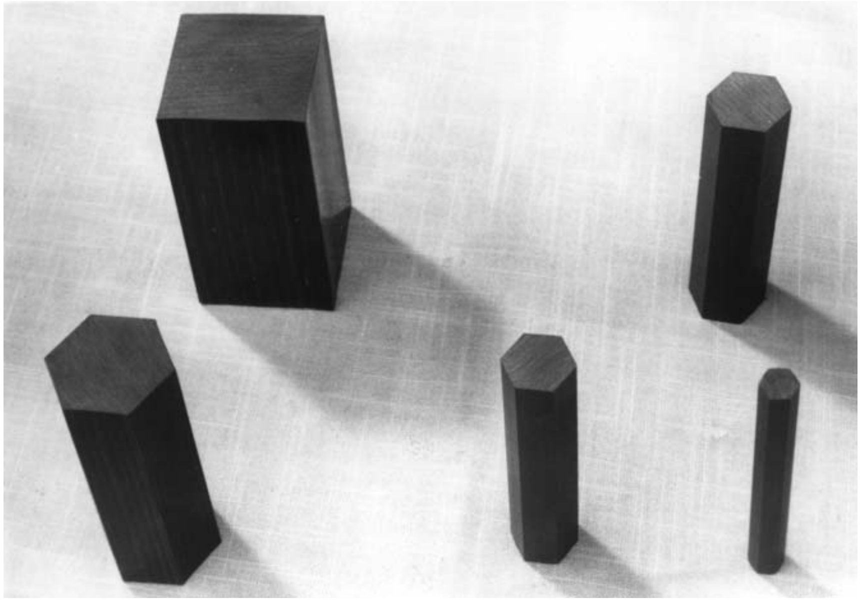
Pumps

Figure 119. Pumps

Barrel-Drum/Diaphragm/Flexible Liner/Horizontal Centrifugal/Magnetic Drive/
Metering/Peristaltic/Submersible/Vertical Centrifugal

Sheet and Rod and Profiles

Figure 120. Rods and Profiles



Normally 4 X 8 ft. sheets with various thicknesses/Rod and Profiles

Special Piping and Fitting Systems

Figure 121. High Purity Water Systems

Clear/Double-Containment/Perforated/Well-Casing/Reclaimed/Low Extractable/Piston-type Expansion Joints/Van-Stone Flanges/Underground Sprinkler Swing Joints

Tanks and Tank Accessories

Figure 122. Tank-Filter-Pump Station

Fabricated Tanks/Tank Adaptors/Vacuum Breakers

Valves

Figure 123. Valves

Angle/Ball/Butterfly/Check/Diaphragm/Float/Gate/Globe/Goose-Neck/Laboratory/Multiport/Needle/Pressure Relief/Pressure Regulator/Solenoid

Chapter

8

PVC PIPING AND THE ENVIRONMENT

Most scientific studies show that PVC piping systems are unmatched in providing economic and energy savings as well as being environmentally sound.

With many articles promoting sustainable and green building construction, it's timely to reflect on how PVC piping systems fit into the goal of providing more eco-friendly residential, commercial, and industrial construction projects. This section of the *Design Guide* will attempt to address and point out how PVC compares with other piping materials in making a light footprint on the planet's environment plus dispel many unfounded myths.

Resin

PVC resin is made (by weight) from 43% ethylene (a derivative of a fossil fuel based feedstock) and 57% from chlorine. PVC production uses less energy, generates fewer emissions, and requires fewer natural resources than many other piping materials. And since salt (where chlorine is derived) is a relatively inexpensive material and one of the most abundant resources on earth, PVC is more sustainable and price competitive compared to other piping materials.

Fossil Fuels

Depending on the region of the world, ethylene is made from oil, gas, or coal feedstocks, which offer a rather large selection of existing natural resources. In addition, a growing number of on-stream ethylene plants instead of using fossil fuels as its feedstock are using *bio-feedstocks* such as sugar cane to produce ethylene, one of PVC's major ingredients. If this process method proves to be economically and environmentally sound, the reduction of the dependence on fossil fuels to produce PVC can soon be a reality. Only plastic piping materials can be produced from bio-feedstocks.

Chlorine

Chlorine is one of the most abundant elements in the world, is a major ingredient in building materials, packaging, and pharmaceuticals, and arguably, has saved more lives in its use of disinfecting water for drinking purposes than any other world health initiative—ever! Chlorine is derived from an inexhaustible source—ocean water. In some instances, the salt is taken out of the water using electro-dialysis desalinization, which extracts chlorine with the resulting unsalted water being processed for potable water.

Durability

There is no projected end life for many PVC installations. Some of the first PVC piping that was installed in Germany is still operational after almost 75 years. It is practically inert in most above and underground environments. PVC piping is immune to corrosion, scaling, rusting, and pitting and is very resistant to abrasion, as well as bacteria, fungi, and chemical attack. Independent studies have shown that PVC municipal piping systems are performance rated at a minimum of 100 years usage while concrete and ductile iron piping were rated at 85 and 60 years respectively. Longer durability means fewer leaks, better water conservation, and less cost.

Easy and Safe to Install

Due to its light weight, standard 20 foot lengths, simple method of joining, lack of expensive tools, no hot plates or open flames needed, no corrosive protection needed, lack or minimum insulation requirements, variety of joining methods, ease of product identification, and ease of fabrication, PVC piping is most likely the easiest and safest piping material to install. This benefit ensures less likelihood of reportable on-site accidents, less chance of property damage, more easily trained installer crews, and faster project completion rates compared to other piping materials.

Cost Effectiveness

Higher costs means less investment in new or remodeled construction, higher unemployment rates, higher inflation rates, and other undesirable factors affecting the growth and prosperity of all people and communities. It seems no matter what category of costs you consider, PVC comes up on top. Product, labor, installed, maintenance, insurance, theft, and shipping costs are almost always less using PVC compared to any other non-plastic piping systems.

Economic Benefits of Polyvinyl Chloride Piping Systems

According to a study sponsored by the Vinyl Institute and the American Chemistry Council, the use of PVC, when compared to other piping materials, has a total estimated economic savings well over $9 billion. These savings include material costs, installation costs, and those costs that are due to more frequent replacement, maintenance and repair requirements than are required for PVC piping systems. In other words, to substitute aluminum, cast iron, concrete, copper, ductile iron, or other piping materials for PVC results in substantial cost premiums. For more information on this study and PVC products in general go to the website of the Vinyl Institute and the Chlorine Chemistry Division of the American Chemistry Council.

Recyclable

PVC is totally recyclable, but because most PVC piping systems are still in use, not much PVC pipe has been required to be recycled. PVC is a thermoplastic, which means that the material can be constantly heated and reformed making it ideal for recycling. Therefore, any processing scraps developed in production start-up, shutdown, and quality control testing samples are routinely reground and introduced back into the production process. There is less than 1% scrap non-recycled materials in most PVC piping plants. Presently, end-of-life use or post consumer PVC piping is being sent to land fills or incineration with a relatively small amount being recycled. This form of disposing PVC pipe after use will change in the future as a result of aggressive industry plans to recycle as much PVC, in all forms, for reuse as possible. With PVC's lightweight, durability, chemical resistance, ease of manufacturing, and cost effectiveness, many millions of pounds of PVC will be recycled into useful products in the years to come.

Joint Integrity

PVC piping can be joined in several different ways—flanging, threading, compression couplings, bell and gasket, heat fusion, and solvent cementing to name a few. The two most popular joining methods are solvent cementing and gasketed-bell and spigot. When properly installed, these two joining systems have working pressures equal to or greater than the pipe or fitting. And, the piping joint integrity is unbeatable. One other reason for PVC's record of exceptional performance is that there are fewer joints than with other non-plastic piping due to its standard 20-foot pipe lengths. And fewer joints means fewer leaks.

Plasticizers

To make PVC material flexible and pliable (such as tubing and packaging) plasticizers known as phthalates are added to the final compound. This resin additive is being vilified by many environmentalists as a very harmful chemical compound although there are many studies that dispute their claims. Unfortunately, all PVC material gets tossed into the fray with other headline news. This issue, however, is not relevant to rigid PVC piping since it is UNPLASTICIZED and has been for over five decades. In some places of the globe, the acronym UPVC is listed for pipe and stands for "unplasticized" PVC. Again, rigid PVC piping does not contain phthalates or any other plasticizers!

Vinyl Chloride Monomer (VCM)

In the early 1970's, there were reports that VCM, an intermediate material in the vinyl production chain, was present in excessive quantities in a few manufacturing facilities. The vinyl industry acted quickly in cooperation with OSHA and the EPA completely re-engineering vinyl production facilities, which has resulted in reducing VCM emissions by over 99%. For the last several decades, PVC resin and product processing plants have some of the best employee safety and health results of any manufacturing industry.

Hydrogen Chloride Gas Emissions

When vinyl (PVC) is burned, hydrogen chloride gas is emitted. Yet, when wood and other building materials burn, lethal carbon monoxide is emitted. With any residential, industrial, or commercial structure you name, there are much more harmful fumes given off by other construction materials than by PVC. Why? Because PVC piping represents less than 2% by weight of most buildings.

Dioxins

Dioxins are compounds that are suspected of being human carcinogens. Several uninformed anti-progressive proponents argue that PVC is the major polluter of the environment with dioxins. Nothing could be further from the truth. The largest contributors of dioxin discharge, according to EPA findings, are forest fires, wood burning fireplaces, coal-fired utilities, metal smelting, diesel trucks, sewage sludge, and burning of trash. Studies estimate that the entire PVC industry produces about 13 grams of dioxin a year (that's less than a half ounce). Another irrefutable fact is that dioxin levels in the USA have decreased 90% in the past 30 years while vinyl production has increased 300% during the same time period.

Life Cycle Assessment (LCA)

LCA is a scientific process that analyzes a product from cradle to grave and beyond. This process results in determining the environmental impacts of the entire product cycle in a quantitative manner. LCA has been recognized as one of the most important criteria in evaluating competitive materials by several greenbuilding rating organizations. With many European LCA reports completed and preliminary USA LCA product inventories being examined, it seems PVC piping, compares quite favorably to other non-plastic piping materials.

Manufacturing Industry Safety

According to 2006 statistics provided by the U.S. Bureau of Labor, the combination of PVC and other plastic piping manufacturing facilities, plastic pipe resin, compound and additive providers, and petrochemical extraction and refining facilities have significantly fewer reported employee illness and injury rates than other non-plastic piping industries. In addition, the plastic piping industry has a third fewer reported employee illness and injury rates compared to the average of all U.S. industries.

Boon to Trees and Animals

PVC should be embraced as one of the significant products that affords protection to the flora and fauna of our planet. The introduction and growth of PVC siding, decking, fencing, window siding, pipe, faux auto panel trim, and other products have saved the destruction of millions of trees. As a substitute for products that were predominantly made from animal hides and ivory tusks, PVC has prevented the killing of untold numbers of animals. The large growth and acceptance of PVC in reducing the need for tree harvesting and the slaughtering of animals are largely due to the durability, cost-effectiveness, and lack of maintenance required of PVC products.

World Health Issues

The United Nations estimate that more than 6,000 children a day (that's over 2 million a year) in the world die due to unsanitary drinking water and waste control. To address this issue, many PVC piping companies and associations (PPFA included) have either donated or sold, at cost, product and engineering services to dozens of non-profit organizations to improve the lives and hopes of third world country citizens. Because PVC pipe is lightweight, durable, easy and save to install, and cost-effective, most humanitarian and other engineering firms have realized that in designing potable water and sanitary waste systems, PVC piping is the material of choice.

Water – A Scarce Resource

Experts estimate that 700 water main breaks a day (over 250,000 a year) occur in North America wasting over 2.2 trillion gallons of potable water. The loss of revenues to the over 60,000 North American water utility companies total over $3 billion a year. To fix these aging mains, the U.S. government estimates that $23 billion a year for the next 20 years is needed. The American Water Works Association Research Foundation in a survey concluded that the life expectancy rating of PVC surpassed any other tested pipe material. A two year Canadian study found that for each 100 kilometers of water distribution pipe installed, PVC had only 0.7 breaks per year compared to 35.9 breaks for cast iron and 9.5 breaks for ductile iron. Communities around the world are favoring PVC water main and distribution systems due to this material's documented track record of unsurpassed durability and joining integrity.

One Final Word

Greenness and sustainability touches us all in practically everything we do—whether it is the car we drive, the house we live in, the vacations we take, the products we buy, or the hobbies that relax us. But no matter what we do, we need to leave a better tomorrow for the next generation. In this regard, comparing all the known facts and history of PVC, the use of PVC piping will continue now and in the future to provide a minimum footprint on the environment and a very positive impact on our planet.

Chapter

9

OTHER PLASTIC PIPING SYSTEMS

Plastic is and has been the fastest growing piping material in most markets it competes for decades due to its many inherent features and benefits.

Although PVC dominates the plastic pipe market underground, aboveground applications use many other plastic materials that handle applications that are not suited to the physical or mechanical properties of PVC. Although the materials have different properties than PVC, similar calculations and formulas are used in determining temperature-pressure relationships, expansion and contraction, support spacing, and other design issues. Manufacturers of the non-PVC plastic piping systems have detailed engineering information for their systems facilitating the task of the pipe design engineer.

This section of the *Design Guide* will give a brief outline of six plastic piping materials other than PVC used in commercial and industrial applications: ABS, CPVC, PE, PEX, PP, and PVDF. For free technical information and a more in-depth look at these materials, see the PPFA website www.ppfahome.org.

Acrylonitrile-Butadiene-Styrene (ABS)

General

ABS is a blend of polymers in which the minimum butadiene content is 6%, the minimum acrylonitrile content is 15%, the minimum styrene content is 15% and the maximum contents of all other monomers is not more than 5% plus other additives. It has been used as a piping material for over 55 years. ABS pipe and fittings for DWV use are made from compounds meeting the requirements of ASTM D 3965 Cell Classification 4-2-2-2-2 for pipe, and 3-2-2-2-2 for fittings. ABS pipe and fittings for pressure use are made from compounds meeting the requirements of ASTM D 3965 with cell classification 4-3-2-3-2 for pipe and fittings.

ABS pipe is available in solid wall and cellular (foam) core construction in Schedule 40 dimensions. These two forms may be used interchangeably for DWV applications. Cellular core construction involves the simultaneous extrusion of three layers into the pipe wall—a solid outer layer, a foam intermediate layer, and a solid inner layer. The three-layer pipe is lighter and more cost-effective for most DWV applications. The primary method of joining ABS piping systems is using solvent cementing.

Features and Benefits

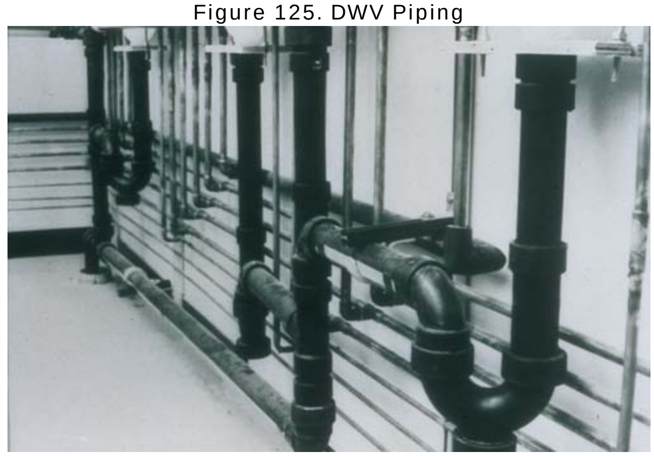
- Temperature range is -40°F (-40°C) to 158°F (70°C) for pressure applications and 176°F (80°C) for drainage applications
- No primer required to join
- High impact resistance
- Available in solid wall (only in Canada) and cellular-core piping

Applications

- Drain, waste and vent systems
- HVAC systems
- Industrial processing systems
- Mining slurries
- Special formulated compressed air / insert gas lines

Figure 124. Process Piping

Figure 125. DWV Piping



Code Status

ABS pipe and fittings are recognized as acceptable for use in DWV systems in all major model plumbing codes.

Chlorinated Poly (Vinyl Chloride) (CPVC)

General

CPVC is a resin made by post-chlorination of PVC. CPVC as a piping material has been successfully installed for almost 50 years. The additional chloride in the PVC polymer allows the maximum service temperature of CPVC to be extended an additional 60-70°F. CPVC compounds meet the requirements of ASTM Class 23447 as defined in ASTM Specification D 1784.

CPVC potable hot and cold water systems from ¼ to 2 inches in size are available in copper tube size (CTS) dimensions and sold in straight lengths and coils (smaller diameter piping) and capable of handling applications up to 100 psi and 180°F. For potable water systems above 2 inches, Sch 40 or Sch 80 piping is available up to a maximum diameter of 24 inches.

In fire suppression (fire sprinkler) systems, CPVC SDR 13.5 systems are available and capable of handling working pressures of 175 psi at 150°F. These systems have been successfully in use for almost three decades.

Chemical Waste Systems of CPVC have been introduced in North America in the last several years in sizes from 1-½ to 12-inch. The product size range, ease of joining, and maximum temperature limit of 220°F are several features that have allowed CPVC to gain market inroads.

CPVC is used in dozens of industrial applications and has very similar properties to PVC but can withstand higher temperatures. All the features and benefits mentioned for PVC also apply to CPVC piping systems. Also, similar to PVC, CPVC industrial piping systems are comprised of many fluid and air handling products such as pipe, fittings, valves, pumps, duct, rod, sheet, rod, fans, scrubbers, and other fluid handling products.

Recently, there has been a composite small diameter CPVC piping system introduced consisting of an interior and exterior pipe wall of CPVC, extruded around a metal tube. As of mid 2008, there has been no inclusion of this piping product in any building codes or standards.

The primary method of joining CPVC piping systems is solvent-cementing.

Features and Benefits

- Good up to 180-210°F depending on application
- Complete fluid and air handling ducting component systems
- Coils in small diameter CTS piping
- Complete fire suppression system
- Hot and cold water distribution systems up to 24" pipe diameter

Applications

- Hot and cold water distribution
- Chemical and industrial processing systems
- Fire suppression systems
- Chemical waste systems

Figure 126. Hot/Cold Water and Fire Sprinkler

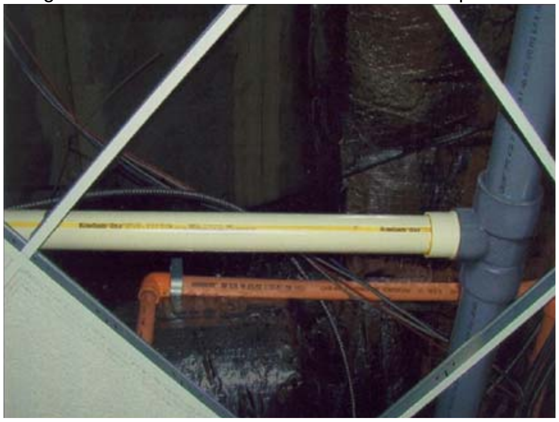


Figure 127. Process Piping

Code Status

Plumbing applications: CPVC piping for potable hot and cold water distribution systems is recognized in all model plumbing codes.

Plenum installation: CPVC plumbing pipe may be safe for installation in return air plenums; however, the installation must be approved by the local jurisdiction. Testing indicates that water-filled CPVC in diameters 6 inches or less will pass the 25/50 flame smoke developed requirements for non-metallic material in return air plenums. CPVC fire sprinkler pipe tested and listed in accordance with UL 1887, *Fire Test of Plastic Sprinkler Pipe for Flame and Smoke Characteristics,* meets the requirements of NFPA 90A for installation in return air plenums.

Polyethylene (PE)

General

PE, the most popular plastic resin in the world, is the second most widely used thermoplastic piping material and has been successfully used in piping applications for 60 years. It is produced by the polymerization of ethylene meeting the requirements of Grades PE 10, PE24, and PE34 as noted in ASTM D 3350. PE materials used for water service are often designated by a material designation codes such as PE2406 or PE3408. The material designation code is defined as follows:

- PE is the abbreviation for polyethylene.
- The first digit represents the density of the PE. The number "2" represents a medium-density material. The number "3" represents a high-density material.
- The second digit "4" represents the slow crack growth requirement of the thermoplastic which is defined in ASTM D 3350 as ether the ESCR (environmental stress crack) test in ASTM D 1693 or the PENT (polyethylene notched tensile) test in ASTM F 1473. For water service pipe the "4" represents an ESCR.
- The third and fourth digits represent the hydrostatic design stress (HDS) for water @ 73°F (23°C) divided by one hundred.

PE pipe is available in many forms and colors. For example, black or a solid color pipe, black pipe with coextruded color striping, black or natural pipe with a coextruded colored layer, and gas pipe, which is usually yellow or orange in color. The primary method of joining PE piping is heat fusion, although in small diameters for low pressure applications, mechanical joining is often used.

Features and Benefits

- Broadest range of pipe diameters
- Tough and very abrasive resistant
- Smaller pipe diameters available in coils
- High performance compounds go up to 200°F
- Complete piping system for natural gas distribution
- Preferred material for slip-lining in existing non-plastic municipal water and sewer lines
- Complete piping system for low leak (drip) irrigation
- Resistant to freeze damage

Applications

- Potable water service systems
- Forced main sewer
- Intake and outtake power plant piping
- Slip-lining

- Natural gas distribution systems
- Drainage (smooth and corrugated exterior)
- Conduit
- Geothermal systems
- Industrial processing systems
- Irrigation systems

Figure 128. Piping in Ice Skating Rink

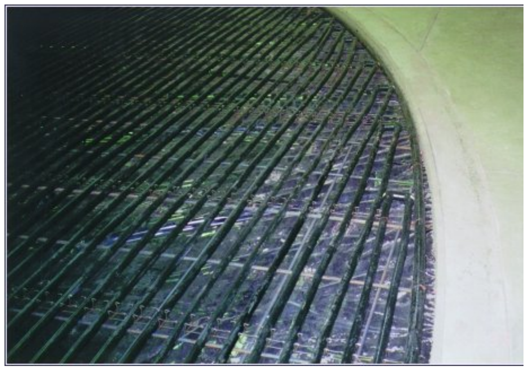


Figure 129. Power Plant Intake Piping Line

Code Status

PE is recognized by most model codes for water service lines and natural gas distribution.

Cross-linked Polyethylene (PEX)

General

PEX is a thermoset material made up of high-density polyethylene (HDPE) that is permanently linked by a process called crosslinking. The crosslinking process gives the piping material long-term stability and physical properties that allow for a constant pressure rated system at varying ranges of temperatures unlike thermoplastic piping materials. PEX has a 30-year plus history of successful use in Europe and has been used in North America for almost 25 years.

Features and Benefits

- Uses mechanical connections only
- Can use manifolds to speed up installation and improve performance
- Resistant to freeze damage (in most cases it can be frozen and thawed with no pipe damage)
- Available in coils
- Is flexible

Applications

- Potable hot and cold water distribution systems
- Radiant floor heating systems
- Snow and ice melt systems for driveways and ramps
- Turf conditioning services
- Fire suppression systems

Figure 130. Radiant Floor Heating

Figure 131. Permafrost Protection

Code Status

All major plumbing codes permit the use of PEX piping/tubing.

Polypropylene (PP)

General

PP is the lightest weight piping material with very good chemical resistance, even to many organic solvents. It is made by the polymerization of propylene. PP has two classifications. Type I is the most commonly used PP piping material; it is a homopolymer having better rigidity and strength but lower impact resistance than Type II. Type II PP is composed of copolymers of propylene and ethylene or other olefins. Type II has improved toughness over Type I material. In chemical drainage applications, heat stabilizers and flame retardant additives are added to PP to retard flammability and thermal aging. PP is also used in many more corrosive and higher temperature applications (180°F) than PVC. The primary method of joining PP piping systems is with heat fusion.

Features and Benefits

- Good up to 180°F
- Handles a broad range of chemical solutions
- Complete chemical drainage system with 30+ years in use
- Can be joined by butt-fusion, socket-fusion, or electro-fusion
- Complete air handling and fluid handling component systems

Applications

- Chemical drainage systems
- Hot and cold water distribution (mostly outside North America)
- Industrial process systems
- High purity water
- Gravity sewers

Figure 132. Lab Waste Drainage and High Purity Water Systems

Figure 133. PP Fabricated Semiconductor Process Work Station

Code Status

PP chemical waste drainage is accepted in most model codes in North America.

Polyvinylidene Fluoride (PVDF)

General

PVDF is a homopolymer produced by the polymerization of vinylidine with fluoride. It has excellent chemical and solvent resistances, broad working temperature ranges, unexcelled resistance to weathering effects, and good strength. Unpigmented (no additive colorization) PVDF is the preferred piping material in many semiconductor plants in applications handling high and ultra-high purity water systems. Of all the commonly used piping systems, PVDF is the most chemically resistant, handles the highest temperature (up to 275°F) and has the lowest flame and smoke development characteristics.

Features and Benefits

- Good up to 275°F
- Low fire spread and smoke development ratings
- Can be plenum rated
- The broadest range of chemical resistance of most piping systems
- Complete chemical drainage systems
- Excellent weathering characteristics
- The preferred piping material in high and ultra-high piping systems
- Can be joined using butt-fusion, socket fusion, and electro-fusion

Applications

- Chemical drainage systems
- Chemical processing systems
- High and ultra-high purity water systems
- Pulp and paper
- Nuclear waste processing
- Food and pharmaceutical processing
- Air plenum usage (PVDF has a maximum flame spread index of 25 and a maximum smoke development index of 50)
- Steam
- Petroleum fuel lines

Figure 134. High Purity Water Piping System

Figure 135. Sanitary Piping System in Plant

Code Status

PVDF chemical drainage systems are accepted in most model codes and are ideal for any air plenum installations.

Appendix A: PVC Product Safety Warnings

PVC piping, when installed and tested properly, is one of the most durable piping systems available. Yet, PVC has physical characteristics different than other piping materials that need to be addressed for a safe and long lasting installation. In the *Design Guide* there are steps showing the proper techniques of safely joining, installing and testing PVC piping systems. However, it is imperative that the manufacturer's joining, installation and testing instructions be completely followed. If you do not follow their instructions, it could cause life threatening personal injuries or severe damage to property. There is no subject more important than user safety. Therefore, the *Design Guide* offers below commonly listed warnings that are shown in most PVC product manufacturer's literature. These safety warnings do not profess to deal with all possible situations or risks that may be encountered in the use of PVC piping systems.

DO NOT CONVEY COMPRESSED AIR OR GASES OR PRESSURE TEST PVC PIPING SYSTEMS, OR ANY PART THEREOF, WITH COMPRESSED AIR OR GASES. FAILURE TO FOLLOW THIS WARNING COULD LEAD TO LIFE THREATENING INJURIES AND SEVERE PROPERTY DAMAGE.

IMPROPER INSTALLATION OR MISUSE OF TAPPING TOOLS MANY CAUSE RUPTURES IN PVC PIPING SYSTEMS UNDER HIGH PRESSURE, WHICH COULD LEAD TO LIFE THREATENING INJURIES AND SEVERE PROPERTY DAMAGE.

⚠ WARNING

WHEN JOINING PVC PIPING SYSTEM COMPONENTS USING SOLVENT CEMENT, THE SAFE HANDLING PROVISIONS OF ASTM F402 MUST BE FOLLOWED, INCLUDING BUT NOT LIMITED TO, USING APPROVED GLOVES AND EYE PROTECTION AND WORKING IN A WELL-VENTILATED ENVIRONMENT. FAILURE TO FOLLOW THIS WARNING COULD LEAD TO LIFE THREATENING INJURIES.

Contact the manufacturer of the relevant PVC piping system or its components regarding these warnings or any other safety concerns or questions.

APPENDIX B: ABBREVIATIONS AND ACRONYMS

Plastic Materials

Abbreviation	Definition
ABA	acrylonitrile butadiene acrylate
ABS	acrylonitrile-butadiene-styrene
ADC	allyl diglycol carbonate
AES	acrylonitrile ethylene styrene
ASA	acrylonitrile-styrene-acrylic
CA	cellulose acetate
CAB	cellulose acetate butyrate
CN	cellulose nitrate
CP	cellulose propionate
CPE	chlorinated polyethylene
CPET	crystallized polyethylene terephthalate
CPVC	chlorinated polyvinyl chloride
CTFE	chlorotrifluorethylene
DAP	diallyl phthalate
EC	ethyl cellulose
ECTFE	ethylene-chlorotrifluoroethylene
EEA	ethylene-ethyl acrylate
EMA	ethylene-methyl acrylate
EPM	ethylene propylene copolymer
EPS	expandable polystyrene
ETFE	ethylenetetrafluoroethylene
EVA	ethylene-vinyl acetate
EVAC	ethylene-vinyl acetate copolymer
FEP	fluorinated ethylenepropylene
FPVC	flexible polyvinyl chloride
FRP	fiberglass-reinforced plastics

Plastic Materials

Abbreviation	Definition
GFR	glass fiber reinforced
HDPE	high-density polyethylene
HIPS	high-impact polystyrene
HMW-HDPE	high-molecular-weight high-density polyethylene
LCP	liquid crystal polymers
LDPE	low-density polyethylene
LLDPE	linear low-density polyethylene
LMDPE	linear medium density polyethylene
MBS	methacrylate-butadiene-styrene
MDI	methylene diisocyanate
MDPE	medium-density polyethylene
MMA	methyl methacrylate
MPPO	modified polyethylene oxide
OPET	oriented polyethylene terephthalate
OPP	oriented polypropylene
OSA	olefin-modified styrene-acrylonitrite
PA	polyamide
PAI	polyamideimide
PAMS	poly alpha methylstyrene
PAN	polyacrylonitrile
PARA	polyarylamide
PAS	polyarylsulfone
PB	polybutylene
PBT	polybutylene terephthalate
PC	polycarbonate
PCT	polycyclohexylenedimethylene terephthalate
PCTFE	polychlorotrifluoroethylene
PCU	polycarbonate urethane
PDAP	poly diallyl phthalate
PFA	perfluoroalkoxy

Plastic Materials

Abbreviation	Definition
PE	polyethylene
PEEK	polyetheretherketone
PEI	polyetherimide
PEK	polyetherketone
PEO	biaxially oriented polyethylene
PES	polyethersulfone
PET	polyethylene terephthalate
PEX	cross-linked polyethylene
PFA	perfluoroalkoxy
PFPE	polyperfluoropolyether
PI	polyimide
PMMA	polymethyl methacrylate
PP	polypropylene
PPA	polyphthalamide
PPFR	polypropylene flame retardant
PPO	polyphenylene oxide
PPS	polyphenylene sulfide
PS	polystyrene
PSO	polysulfone
PTFE	polytetrafluoroethylene
PTMT	polytetramethylene terephthalate
PUR	polyurethane
PVAL	polyvinyl alcohol
PVB	polyvinyl butyral
PVC	polyvinyl chloride
PVC-O	polyvinyl chloride-molecular oriented
PVC-u	polyvinyl chloride-unplasticized
PVCA	polyvinyl chloride-acetate
PVDC	polyvinylidene chloride
PVDF	polyvinylidene fluoride

Plastic Materials

Abbreviation	Definition
PVF	polyvinyl fluoride
RTRP	reinforced thermosetting resin pipe
RPVC	rigid polyvinyl chloride
RTPU	rigid thermoplastic polyurethane
SAN	styrene-acrylonitrile
SB	styrene-butadiene
SBR	styrene-butadiene rubber
SMA	styrene-maleic anhydride
SPU	segmented polyurethane
ULDPE	ultra low density polyethylene
SR	styrene rubber
TFE	tetrafluoroethylene
TPE	thermoplastic elastomer
TPO	thermoplastic olefin
UHMWPE	ultrahigh-molecular weight polyethylene
UHMW-HDPE	ultrahigh-molecular weight high-density polyethylene
VCE	polyvinyl chloride-ethylene
VCEMA	polyvinyl chloride-ethylene-methyl acrylate
VCMA	polyvinyl chloride-methyl acrylate
VCVAC	polyvinyl chloride-vinyl acrylate
VCVDC	polyvinyl chloride-vinylidene chloride
VCM	vinylidene chloride monomer
VDC	vinylidene chloride
XLPE	cross-linked polyethylene

Association and Agency Acronyms

Acronym	Definition
AASHTO	American Association of State Highways & Transportation Officials
ACC	American Chemical Council
AGA	American Gas Association
ANSI	American National Standards Institute, inc.
APGA	American Public Gas Association
API	American Petroleum Institute
APWA	American Public Works Association
ASAE	American Society of Agriculture Engineers
ASCE	American Society of Civil Engineers
ASDWA	Association of State Drinking Water Administrators
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
ASHVE	American Society of Heating and Ventilating Engineers
ASME	American Society of Mechanical Engineers
ASNP	American Standard National Plumbing
ASPE	American Society of Plumbing Engineers
ASSE	American Society of Sanitary Engineers
ASTM	ASTM International, formerly American Society for Testing and Materials
ASTPHLD	Association of State and Territorial Public Health Laboratory Directors
AWWA	American Water Works Association
AWWRF	American Water Works Research Foundation
BEES	Building for Environmental and Economic Stability
BOCA	Building Officials and Code Administration International, Inc.
BNQ	Bureau de Normalization du Quebec
BS	British Standards Institution
CABO	The Council of American Building Officials
CERF	Civil Engineering Research Foundation
CFR	Code of Federal Regulations
CGSB	Canadian Government Specifications Board
CPPA	Corrugated Plastic Pipe Association

Association and Agency Acronyms

Acronym	Definition
CS	Commercial Standard
CSA	CSA International, formerly Canadian Standards Association
DIN	Deutsches Institut fur Normung
DOD	Department of Defense
DOT-OPSO	Department of Transportation-Office of Pipeline Safety Operations
DOT-TSI	U.S. Department of Transportation-Transportation Safety Institute
EPA	Environmental Protection Agency
FDA	Federal Drug Administration
FHA	Federal Housing Federation
FM	Factory Mutual
FS	Federal Standards
GPTC	Gas Piping Technology Committee
GTI	Gas Technology Institute
HSB	Hydrostatic Stress Board
HUD	Housing and Urban Development
IAPMO	International Associations of Plumbing and Mechanical Officials
IAPD	International Association of Plastic Distribution
ICBO	International Conference of Building Officials
ICC	International Codes Council
IMC	International Mechanical Code
IPC	International Plumbing Code
IRC	International Residential Code
ISO	International Standards Organization
LEED	Leadership on Energy and Environmental Design
JIS	Japanese Industrial Standard
MCAA	Mechanical Contractors Association of America
MIL	Department of Defense-Military Standard
MSS	Manufacturers Standardization Society of Value and Fittings Industry
NACE	National Association of Corrosion Engineers
NAHB	National Association of Home Builders

Association and Agency Acronyms

Acronym	Definition
NAPHCC	National Association of Plumbing, Heating, Cooling Contractors
NASSCO	National Association of Sewer Service Companies
NASTT	North American Society for Trenchless Technology
NBS	National Bureau of Standards
NFGS	Naval Guide Specifications
NEMA	National Electrical Manufacturers
NFPA	National Fire Protection Association
NRWA	National Rural Water Association
NSF	NSF International, formerly National Sanitary Foundation
NSPC	National Standard Plumbing Code
NSPI	National Swimming Pool Institute
NTSB	National Transportation Safety Board
NUCA	National Utility Contractors Association
NWRA	National Water Resources Association
NWWA	National Well Water Association
PDI	Plumbing and Drainage Institute
PHCC	National Association of Plumbing-Heating-Cooling Contractors
PPFA	Plastic Pipe and Fittings Association
PPI	Plastic Piping Institute
PS	Product Standard
SBCC	Southern Building Code Congress
SCA	Standards Council of Canada
SCS	Soil Conversation Service of U.S. Department of Agriculture
SIA	Sprinkler Irrigation Association
SPE	The Society of Plastic Engineers
SPI	The Society of the Plastics Industry, Inc.
SRI	Southwest Research Institute
UL	Underwriters Laboratories, Inc
UMC	Uniform Mechanical Code
Uni-Bell	Uni-Bell PVC Pipe Association

Association and Agency Acronyms

Acronym	Definition
UPC	Uniform Plumbing Code
USASI	United States of America Standards Institute
USDA	U.S. Department of Agriculture
USGBS	U.S. Green Building Council
VI	Vinyl Institute
VMA	Value Manufacturers Association of America
VPS	Voluntary Product Standards
WEF	Water Environment Federation
WUC	Western Underground Committee

Appendix C: Chemical Resistance

The chemical resistance data included in this appendix is a collection of the best present information of PVC's chemical resistance to over 750 chemicals. Most of the data is based on material test specimens immersed in a laboratory environment and to a lesser degree on field experience. There are many variables that may affect PVC's performance with each of the chemicals. This is a major reason that no company or other association and organization can guarantee the performance of any particular application. For any critical application, perform a test with manufacturer provided samples that duplicate the expected field conditions as closely as possible.

A major condition that can affect chemical resistance performance is when a PVC piping system experiences thermal or mechanical stress. Besides stress other accelerating factors that could affect chemical resistance are: chemical concentrations, combinations of chemicals, flow velocity and system internal working pressures.

Chemical Resistance Codes

When testing PVC's chemical resistance, the manufacturer's normal criteria for determining the resistance to chemical attack is based on immersed PVC samples being measured for swelling or weight loss and elongation at break. As a rule, swelling fewer than 3% or weight loss under 0.5% with no significant change in elongation at break will successfully qualify PVC to be recommended at a particular temperature. When testing specimens, if the swelling increases to over 8% or a weight loss of greater than 5.0% and/or elongation at break decreases 50% or greater, PVC is not normally recommended.

Chart Notes

- Material tested: Polyvinyl Chloride Type 1 Grade 1
- Temperature: Number reflects the maximum recommended temperature in °F
- NR = Not Recommended
- * * = Incomplete Data
- Chemical resistances of listed gases are for non-pressure environments
- Under certain temperature conditions, PVC piping with liquid hydrocarbons such as gasoline and jet fuels should be limited to short-term exposure

Chemical	Maximum Temperature	Chemical	Maximum Temperature
Acetaldehyde	NR	Ammonium Metaphosphate	140
Acetamide	* *	Ammonium Nitrate	140
Acetate Solvent, Crude	NR	Ammonium Persulphate	140
Acetate Solvent, Pure	NR	Ammonium Phosphate	140

Chemical	Maximum Temperature	Chemical	Maximum Temperature
Acetic Acid, 10%	140	Ammonium Sulfamate	* *
Acetic Acid, 20%	140	Ammonium Sulfate	140
Acetic Acid, 50%	73	Ammonium Sulfide	140
Acetic Acid, 80%	73	Ammonium Thiocyanate	140
Acetic Acid, Glacial	73	Ammonium Tartrate	140
Acetic Anhydride	NR	Amyl Acetate	NR
Acetone	NR	Alcohol, Amyl	NR
Acetonitrile	NR	Amyl Chloride	NR
Acetophenone	NR	Aniline	NR
Acetyl Chloride	NR	Aniline Chlorohydrate	NR
Acetylene	NR	Aniline Hydrochloride	NR
Acetyl Nitrile	NR	Anthraquinone Sulfonic Acid	140
Acrylic Acid	NR	Antifreeze	* *
Acrylonitrile	NR	Antimony Trichloride	140
Adipic Acid (Sat'd)	140	Aqua Regia	73
Allyl Alcohol	73	Aromatic Hydrocarbons	NR
Allyl Chloride	NR	Aragon	* *
Alums	140	Arsenic Acid	140
Aluminum Acetate	* *	Aryl Sulfonic Acid	140
Aluminum Ammonium	140	Asphalt	NR
Aluminum Chloride	140	Barium Carbonate	140
Aluminum Chrome	140	Barium Chloride	140
Aluminum Fluoride	73	Barium Hydroxide	140
Aluminum Hydroxide	140	Barium Nitrate	73
Aluminum Nitrate	140	Barium Sulfate	140
Aluminum Oxychloride	140	Barium Sulfide	140
Aluminum Potassium Sulfate	140	Beer	140
Aluminum Sulfate	140	Beet Sugar Liquids	140
Amines	* *	Benzaldehyde	73
Ammonia	140	Benzalkonium Chloride	NR
Ammonia, Gas	140	Benzene	NR
Ammonia, Aqua, 10%	NR	Benzene, Benzol	NR
Ammonia, (25% Aqueous Solution)	NR	Benzene Sulfonic Acid	140
Ammonia Hydroxide	100	Benzoic Acid (Sat'd)	140
Ammonia Liquid (Concentrated)	NR	Benzyl Chloride	* *
Ammonium Acetate	140	Benzyl Alcohol	NR
Ammonium Benzoate	* *	Bismuth Carbonate	140
Ammonium Bifluoride	140	Black Liquor	140
Ammonium Bisulfide	140	Bleach, Industrial (15% CI2)	140
Ammonium Carbonate	140	Bleach, 12.5% Active CI2	140
Ammonium Chloride	140	Bleach, 5.5% Active CI2	140
Ammonium Citrate	* *	Borax	140
Ammonium Dichromate	73	Boric Acid	140
Ammonium Fluoride, 10%	140	Brake Fluid	* *
Ammonium Fluoride, 25%	73	Breeders Pellets, Derive. Fish	140

Chemical	Maximum Temperature	Chemical	Maximum Temperature
Ammonium Hydroxide	73	Brine	140
Ammonium Metaphosphate	140	Bromic, Acid	140
Ammonium Nitrate	140	Bromine	NR
Ammonium Persulphate	140	Bromine, Liquid	NR
Ammonium Phosphate	140	Bromine, Vapor 25%	140
Bromine, Water	140	Caustic Soda	140
Bromine, Water, (Sat'd)	73	Cellosolve	73
Bromobenzene	NR	Cellosolve Acetate	73
Bromotoluene	NR	Chloracetic Acid	73
Butadiene	140	Cloracetyl Chloride	73
Butane	140	Chloral Hydrate	140
Butanol, Primary	NR	Chloramine	73
Butonol, Secondary	NR	Chloric Acid, 20%	140
Butyl Acetate	NR	Chlorinated Solvents	NR
Butyl Alcohol	140	Chlorinated Water, Up to 3500 ppm	140
Butyl Carbitol	* *	Chlorinated Water, Above 3500 ppm	NR
Butyl Cellsolve (2-butoxyethanol)	73	Chlorine Gas, Dry	NR
Butyl Chloride	* *	Chlorine Gas, Wet	NR
Butynediol	73	Chlorine, Liquid	NR
Butylene	73	Chlorine, trace in air	* *
Butyl Phenol	73	Chlorine Dioxide (sat'd aqueous sol.)	* *
Butyl Phthalate	NR	Chlorine Water (Sat'd)	140
Butyl Stearate	73	Chlorobenzene	NR
Butyric Acid	NR	Chlorobenzene Chloride	NR
Butyric Acid, Up to 1%	73	Chloroform	NR
Butyric Acid, Over 1%	* *	Chloropicrin	NR
Cadmium Acetate	* *	Chlorosulfonic Acid	73
Cadmium Chloride	* *	Chlorox Bleach Solution, 5.5% CI2	140
Cadmium Cyanide	140	Chromic Acid, 10%	140
Cadmium Sulfate	* *	Chromic Acid, 30%	73
Caffeine Citrate	73	Chromic Acid, 40%	73
Calcium Acetate	73	Chromic Acid, 50%	73
Calcium Bisulfide	NR	Chromium Nitrate	* *
Calcium Bisulfite	140	Chromium Potassium Nitrate	73
Calcium Carbonate	140	Chromium Potassium Sulfate	* *
Calcium Chlorate	140	Citric Acid (Sat'd)	140
Calcium Chloride	140	Citric Acid, 10%	140
Calcium Hydroxide	140	Citrus Oils	* *
Calcium Hypochlorite	140	Coconut Oil	140
Calcium Nitrate	140	Cod Liver Oil	* *
Calcium Oxide	140	Coffee	140
Calcium Sulfate	140	Coke Oven Gas	NR

Chemical	Maximum Temperature	Chemical	Maximum Temperature
Camphor Crystals	73	Copper Acetate, (Sat'd)	73
Cane Sugar Liquors	140	Copper Carbonate	140
Caprolactam	* *	Copper Chloride	140
Caprolactone	* *	Copper Cyanide	140
Caprylic Acid	* *	Copper Fluoride	140
CarbitolTM	NR	Copper Nitrate	140
Carbon Bisulfide	NR	Copper Salts	140
Carbon Dioxide, Wet	140	Copper Sulfate	140
Carbon Dioxide, Dry	140	Corn Oil	140
Carbon Disulfide	NR	Corn Syrup	140
Carbonic Acid	140	Cottonseed Oil	140
Carbon Monoxide	140	Creosote	NR
Carbon Tetrachloride	NR	Creosol	NR
Castor Oil	140	Cresylic Acid, 50%	140
Caustic Potash	140	Crotonaldehyde	NR
Crude Oil	73	Ethyl Chloride	NR
Cumene	* *	Ethyl Chlorohydrin	NR
Cupric Chloride	* *	Ethylene Bromide	NR
Cupric Fluoride	140	Ethylene Chloride	NR
Cupric Sulfate	140	Ethylene Chlorohydrin	NR
Cuprous Chloride	140	Ethylene Diamine	NR
Cyclohexane	NR	Ethylene Dichloride	NR
Cyclohexanol	NR	Ethyl Ether	NR
Cyclohexanone	NR	Ethylene Glycol, Up to 50%	140
Decalin	NR	Ethylene Glycol, Over 50%	140
D-Limonene	* *	Ethylene Oxide	NR
Desocyephedrine	73	Fatty Acids	140
Detergents	140	Ferric Acetate	140
Detergent Solution, Heavy Duty	140	Ferric Chloride	140
Dextrine	140	Ferric Hydroxide	140
Dextrose	140	Ferric Nitrate	140
Diacetone Alcohol	NR	Ferric Sulfate	140
Diazo Salts	140	Ferrous Chloride	140
Dibutyl Ethyl Phthalate	NR	Ferrous Hydroxide	140
Dibutyl Phthalate	NR	Ferrous Nitrate	140
Dibutyl Sebacate	73	Ferrous Sulfate	140
Dichlorobenzene	NR	Fish Oils	140
Dichloroethylene	NR	Fluorine Gas	NR
Diesel Fuels	140	Fluoboric Acid	140
Diethylamine	NR	Fluorosilicic Acid, 30%	140
Diethyl Cellosolve	* *	Formaldehyde, 35%	140
Diethyl Ether	73	Formic Acid, Up to 25%	73
Diglycolic Acid	140	Formic Acid, Anhydrous	73
Dill Oil	NR	Freon F-11	140
Dimethylamine	140	Freon F-12	140
Dimethylformamide	NR	Freon F-21	NR

Chemical	Maximum Temperature	Chemical	Maximum Temperature
Dimethyl Hydrazine	NR	Freon F-22	NR
Dioctyl Phthalate (DEHP)	NR	Freon F-113	140
Dioxane	NR	Freon F-114	140
Dioxane, 1.4	NR	Fructose	140
Disodium Phosphate	140	Fruit Juices, Pulp	140
Distilled Water	140	Furfural	NR
Divinylbenzene	NR	Gallic Acid	140
Dowtherm A	NR	Gas, Manufactured	73
Dursban TC	* *	Gas, Natural	140
EDTA, Tetrasodium	* *	Gasoline, Leaded	NR
Epsom salt	140	Gasoline, Unleaded	NR
Epichlorohydrin	NR	Gasoline, Sour	NR
Esters	NR	Gasoline, Refined	NR
Ethanol, Up to 5%	140	Gelatin	140
Ethanol, Over 5%	140	Gin	140
Ethers	NR	Glucose	140
Ethyl Acetate	NR	Glycerin	140
Ethyl Acetoacetate	NR	Glycerin, Glycerol	140
Ethyl Acrylate	NR	Glycolic Acid	140
Ethyl Benzene	NR	Glycol Ethers	140
Ethyl Bromide	NR	Grape Sugar, Juice	140
Green Liquor	140	Lauric Acid	140
Halocarbons Oils	* *	Lauryl Chloride	140
Heptane	140	Lead Acetate	140
Hexane	73	Lead Chloride	140
Hexanol	140	lead Nitrate	140
Hydraulic Oil	73	Lead Sulfate	140
Hydrazine	NR	Lemon Oil	* *
Hydrobromic Acid, Dilute	140	Ligroine	NR
Hydrobromic Acid, 20%	140	Lime Sulfur	73
Hydrobromic Acid, 50%	140	Limonene	* *
Hydrochloric Acid Dilute	140	Linoleic Acid	140
Hydrochloric Acid, 18%	140	Linoleic Oil	140
Hydrochloric Acid, 20%	140	Linseed Oil	140
Hydrochloric Acid Conc., 37%	140	Linseed Oil, Blue	73
Hydrocyanic Acid, 10%	140	Liqueurs	140
Hydrofluoric Acid, Dilute	73	Lithium Bromide (Brine)	140
Hydrofluoric Acid, Up to 3%	73	Lithium Chloride	140
Hydrofluoric Acid, 30%	73	Lithium Sulfate	140
Hydrofluoric Acid, 40%	73	Lubricating Oil, ASTM #1, #2, #3	140
Hydrofluoric Acid, 50%	73	Lux Liquid	NR
Hydrofluoric Acid, 100%	NR	Lye Solutions	140
Hydrofluosilicic Acid, 50%	140	Machine Oil	140
Hydrogen	140	Magnesium Carbonate	140
Hydrogen Cyanide	140	Magnesium Chloride	140

Chemical	Maximum Temperature	Chemical	Maximum Temperature
Hydrogen Fluoride	NR	Magnesium Citrate	140
Hydrogen Peroxide, Dilute	140	Magnesium Fluoride	* *
Hydrogen Peroxide, 30%	140	Magnesium Hydroxide	140
Hydrogen Peroxide, 50%	140	Magnesium Nitrate	140
Hydrogen Peroxide, 90%	140	Magnesium Oxide	* *
Hydrogen, Phosphide	140	Magnesium Salts, Inorganic	* *
Hydrogen Sulfide, Dry	140	Magnesium Sulfate	140
Hydrogen Sulfide, Aqueous Sol.	140	Maleic Acid	140
Hydroquinone	140	Maleic Acid (Sat'd)	140
Hydroxylamine Sulfate	140	Malic Acid	140
Hypochlorous Acid	140	Manganese Sulfate	140
Inks	* *	Mercuric Acid	* *
Iodine	NR	Mercuric Chloride	140
Iodine Solution, 10%	NR	Mercuric Cyanide	140
Iodine in Alcohol	NR	Mercuric Sulfate	140
Iron Salts	* *	Mercurous Nitrate	140
Isopropanol	140	Mercury	140
Isopropyl Alcohol	140	Methane	140
Isopropyl Ether	NR	Methanol	140
Isooctane	NR	Methoxyethyl Oleate	73
Jet Fuel, JP-4	NR	Methyl Acetate	NR
Jet Fuel, JP-5	NR	Methyl Amine	NR
Kerosene	NR	Methyl Bromide	NR
Ketones	NR	Methyl Cellosolve	NR
Ketchup	73	Methyl Chloride	NR
Kraft Liquor	140	Methyl Chloroform	NR
Lactic Acid, 25%	140	Methyl Ethyl Ketone	NR
Lactic Acid, 80%	73	Methyl Formate	* *
Lard Oil	140	Methyl Isobutyl Ketone	NR
Methyl Methacrylate	NR	Oxygen	140
Methyl Sulfate	73	Ozone	140
Methyl Sulfuric Acid	140	Ozonized Water	* *
Methylene Bromide	NR	Palm Oil	* *
Methylene Chloride	NR	Palmitic Acid, 10%	140
Methylene Chlorobromide	NR	Palmitic Acid, 70%	73
Methylene Iodine	NR	Paraffin	140
Methylisobutyl Carbinol	NR	Peanut Oil	* *
Milk	140	Pentachlorophenol	NR
Mineral Oil	140	Peracetic Acid, 40%	NR
Molasses	140	Perchloric Acid, 10%	73
Monochloroacetic Acid, 50%	140	Perchloric Acid, 70%	NR
Monochlorobenzene	NR	Perphosphate	73
Monoethanolamine	NR	Petrolatum	140
Morpholine	* *	Petroleum Oils, Sour	73
Motor Oil	140	Petroleum Oils, Refined	140
Muriatic Acid, Up to 30% HIC	140	Phenol	NR

Chemical	Maximum Temperature	Chemical	Maximum Temperature
Naphta	* *	Phenylhydrazine	NR
Naphthalene	NR	Phenylhdrazine Hydrochloride	NR
n-Heptane	NR	Phosgene, Liquid	NR
Natural Gas	140	Phosgene, Gas	NR
Nickel Acetate	73	Phosphoric Acid, 10%	140
Nickel Chloride	140	Phosphoric Acid, 50%	140
Nickel Nitrate	140	Phosphoric Acid, 85%	140
Nickel Sulfate	140	Phosphoric Anhydride	73
Nicotine	140	Phosphorous Pentoxide	73
Nicotinic Acid	140	Phosphorous, Red	73
Nitric Acid, 10%	140	Phosphorus Trichloride	NR
Nitric Acid, 30%	140	Phosphorus, Yellow	73
Nitric Acid, 40%	140	Photographic Solutions	140
Nitric Acid, 50%	73	Phthalic Acid, 10%	73
Nitric Acid, 70%	73	Picric Acid	NR
Nitric Acid, 100%	NR	Pine Oil	* *
Nitric Acid, Fuming	NR	Planting Solutions, Brass	140
Nitrobenzene	NR	Planting Solutions, Cadmium	140
Nitroglycerine	NR	Planting Solutions, Chrome	140
Nitrous Acid 10%	140	Planting Solutions, Copper	140
Nitrous Oxide	73	Planting Solutions, Gold	140
Nitroglycol	NR	Planting Solutions, Indium	140
Nonionic Surfactants	140	Planting Solutions, Lead	140
1-Octanol	* *	Planting Solutions, Nickel	140
Ocenol	* *	Planting Solutions, Rhodium	140
Oils and Fats	140	Planting Solutions, Silver	140
Oils, Edible	* *	Planting Solutions, Tin	140
Oils, Vegetable	* *	Planting Solutions, Zinc	140
Oils, Sour Crude	* *	Polyethylene Glycol	* *
Oleic Acid	140	Polypropylene Glycol	* *
Oleum	NR	Potash	140
Olive Oil	140	Potassium Acetate	* *
Oxalic Acid (Sat'd)	* *	Potassium Alum	140
Oxalic Acid, 20%	140	Potassium Aluminum Sulfate	140
Oxalic Acid, 50%	140	Potassium Amyl Xanthate	73
Potassium Bicarbonate	140	Silver Chloride	* *
Potassium Bichromate	140	Silver Cyanide	140
Potassium Bisulfate	140	Silver Nitrate	140
Potassium Borate	140	Silver Sulfate	140
Potassium Bromate	140	Soaps	140
Potassium Bromide	140	Sodium Acetate	140
Potassium Carbonate	140	Sodium Aluminate	140
Potassium Chlorate	140	Sodium Alum	140
Potassium Chloride	140	Sodium Arsenate	140
Potassium Chromate	140	Sodium Benzoate	140
Potassium Cyanide	140	Sodium Bicarbonate	140

Chemical	Maximum Temperature	Chemical	Maximum Temperature
Potassium Dichromate	140	Sodium Bichromate	140
Potassium Ethyl Xanthate	73	Sodium Bisulfate	140
Potassium Ferricyanide	140	Sodium Bisulfite	140
Potassium Ferrocyanide	140	Sodium Borate	140
Potassium Fluoride	140	Sodium Bromide	140
Potassium Hydroxide	140	Sodium Carbonate	140
Potassium Hydroxide, 50%	140	Sodium Chlorate	73
Potassium Hypochlorite	140	Sodium Chloride	140
Potassium Iodine	73	Sodium Chlorite	NR
Potassium Nitrate	140	Sodium Chromate	* *
Potassium Perborate	140	Sodium Cyanide	140
Potassium Perchlorate, (Sat'd)	140	Sodium Dichromate	140
Potassium Permanganate, 10%	140	Sodium Ferricyanide	140
Potassium Permanganate, 25%	73	Sodium Ferrocyanide	140
Potassium Persulphate, (Sat'd)	140	Sodium Fluoride	140
Potassium Phosphate	* *	Sodium Formate	* *
Potassium Sulfate	140	Sodium Hydroxide, 15%	140
Potassium Sulfite	140	Sodium Hydroxide, 30%	140
Potassium Tripolyphosphate	* *	Sodium Hydroxide, 50%	140
Propane	140	Sodium Hydroxide, 70%	140
Propanol, Up to 0.5%	* *	Sodium Hypobromite	* *
Propanol, Over 0.5%	* *	Sodium Hypochlorite, 15%	73
Propargyl Alcohol	140	Sodium Hypochlorite (Set's)	73
Propionic Acid, Up to 2%	* *	Sodium Iodine	140
Propionic Acid, Over 2%	* *	Sodium Metaphosphate	140
Propyl Alcohol	140	Sodium Nitrate	140
Propylene Dichloride	NR	Sodium Nitrite	140
Propylene Glycol, Up to 25%	140	Sodium Palmitrate Solution, 5%	140
Propylene Glycol, Up to 50%	140	Sodium Perborate	140
Propylene Oxide	NR	Sodium Perchlorate	140
Pyridine	NR	Sodium Peroxide	140
Pyrogallicia Acid	73	Sodium Phosphate, Alkaline	140
Quinone	* *	Sodium Phosphate, Acid	140
Quaternary Ammonium Salts	* *	Sodium Phosphate, Neutral	140
Rayon Coagulating Bath	140	Sodium Silicate	140
Salicylic Acid	140	Sodium Sulfate	140
Sea Water	140	Sodium Sulfide	140
Selenic Acid	140	Sodium Sulfite	140
Silicic Acid	140	Sodium Thiosulfate	140
Silicone Oil	73	Sodium Tripolyphosphate	* *
Solicylaldehyde	NR	Titanium Tetrachloride	* *
Sour Crude Oil	140	Toluene, Toluol	NR
Soybean Oil	* *	Toluene-Kerosene, 25%-75%	NR
Stannic Chloride	140	Tomato Juice	140
Stannous Chloride	140	Toxaphene-Xylene, 90%-100%	NR
Stannous Sulfate	* *	Transformer Oil	140

Chemical	Maximum Temperature	Chemical	Maximum Temperature
Starch	140	Transformer Oil, DTE/30	* *
Stearic Acid	140	Tribute	* *
Stoddard's Solvent	NR	Tributyl Citrate	73
Strontium Chloride	* *	Tributyl Phosphate	NR
Styrene	* *	Trichloroacetic Acid	140
Succinic Acid	140	Trichloroethane	NR
Sugar	140	Trichloroethylene	NR
Sulfamic Acid	NR	Triethanolamine	73
Sulfate Liquors	140	Triethylamine	140
Sulfite Liquors	140	Triethylpropane	73
Sulfur	140	Trisodium Phosphate	140
Sulfur Chloride	* *	Turpentine	140
Sulfur Dioxide, Dry	140	Urea	140
Sulfur Dioxide, Wet	73	Urine	140
Sulfur Trioxide	140	Vaseline	NR
Sulfur Trioxide, Gas	73	Vegetable Oil	140
Sulfur Acid, 10%	140	Vinegar	140
Sulfur Acid, 20%	140	Vinegar, White	140
Sulfur Acid, 30%	140	Vinyl Acetate	NR
Sulfur Acid, 50%	140	Water	140
Sulfur Acid, 60%	140	Water, Acid Mine	140
Sulfur Acid, 70%	140	Water, Deionized	140
Sulfur Acid, 80%	140	Water, Demineralized	140
Sulfur Acid, 90%	73	Water, Distilled	140
Sulfur Acid, 94%	NR	Water, Potable	140
Sulfur Acid, 98%	NR	Water, Salt	140
Sulfur Acid, 100%	NR	Water, Sea	140
Sulfurous Acid	NR	Water, Sewage	140
Tall Oil	140	Water, Swimming pool	140
Tannic Acid, 10%	140	WD 40	* *
Tannic Acid, 30%	* *	Whiskey	140
Tanning Liquors	140	White Liquor	140
Tar	NR	Wines	140
Tartaric Acid	140	Xylene	NR
Terpenes	* *	Zinc Acetate	* *
Tetraethyl Lead	73	Zinc Bromide	140
Tetrahydrodurane	NR	Zinc Carbonate	* *
Tetrahydrofuran	NR	Zinc Chloride	140
Tetralin	NR	Zinc Nitrate	140
Tetra Sodium Pyrophosphate	140	Zinc Oxide	* *
Texanol	* *	Zinc Phosphate	* *
Thionyl Chloride	NR	Zinc Stearate	* *
Thread Cutting Oils	73	Zinc Sulfate	140

Source: Adapted from Charlotte Pipe, IPEX, NIBCO, and Plastic Pipe Institute data

APPENDIX D: PVC PIPING FRICTION-LOSS TABLES

FRICTION LOSS AND FLOW VELOCITY FOR SCHEDULE 40 THERMOPLASTIC PIPE

(Friction head and friction loss are per 100 feet of pipe.) CAUTION: Flow velocity should not exceed 5 feet per second. ABS and PVC pipe cannot be used for compressed air service.
Flow velocity required to obtain a self cleaning drain, waste, and vent plumbing system is 2.0 to 2.5 feet per second.

1/2 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
1	1.13	2.08	0.90
2	2.26	4.16	1.80
5	5.64	23.44	10.15
7	7.90	43.06	18.64
10	11.28	82.02	35.51

4 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
20	0.51	0.03	0.013
25	0.64	0.04	0.017
30	0.77	0.06	0.026
35	0.89	0.08	0.035
40	1.02	0.11	0.048
45	1.15	0.13	0.056
50	1.28	0.16	0.069
60	1.53	0.22	0.095
70	1.79	0.30	0.13
75	1.92	0.34	0.15
80	2.05	0.38	0.16
90	2.30	0.47	0.20
100	2.56	0.58	0.25
125	3.20	0.88	0.38
150	3.84	1.22	0.53
175	4.48	1.63	0.71
200	5.11	2.08	0.90
250	6.40	3.15	1.36
300	7.67	4.41	1.91
350	8.95	5.87	2.55
400	10.23	7.52	3.26

3/4 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
1	0.63	0.51	0.22
2	1.26	1.02	0.44
5	3.16	5.73	2.48
7	4.43	10.52	4.56
10	6.32	20.04	8.68
15	9.48	42.46	18.39
20	12.65	72.34	31.32

5 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
30	0.49	0.02	0.009
35	0.57	0.03	0.013
40	0.65	0.03	0.013
45	0.73	0.04	0.017
50	0.81	0.05	0.022
60	0.97	0.07	0.030
70	1.14	0.10	0.043
75	1.22	0.11	0.048
80	1.30	0.13	0.056
90	1.46	0.16	0.069
100	1.62	0.19	0.082
125	2.03	0.29	0.125
150	2.44	0.40	0.17
175	2.84	0.54	0.235
200	3.25	0.69	0.30
250	4.06	1.05	0.45
300	4.87	1.46	0.63
350	5.69	1.95	0.85
400	6.50	2.49	1.08
450	7.31	3.09	1.34
500	8.12	3.76	1.63

1 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.77	0.55	0.24
5	1.93	1.72	0.75
7	2.72	3.17	1.37
10	3.86	6.02	2.61
15	5.79	12.77	5.53
20	7.72	21.75	9.42
25	9.65	32.88	14.22
30	11.58	46.08	19.95

6 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
50	0.56	0.02	0.009
60	0.67	0.03	0.013
70	0.79	0.04	0.017
75	0.84	0.05	0.022
80	0.90	0.05	0.022
90	1.01	0.06	0.026
100	1.12	0.08	0.035
125	1.41	0.12	0.052
150	1.69	0.16	0.069
175	1.97	0.22	0.096
200	2.25	0.28	0.12
250	2.81	0.43	0.19
300	3.37	0.60	0.26
350	3.94	0.79	0.34
400	4.49	1.01	0.44
450	5.06	1.26	0.55
500	5.62	1.53	0.66
750	8.43	3.25	1.41
1000	11.24	5.54	2.40

1 1/4 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.44	0.14	0.06
5	1.11	0.44	0.19
7	1.55	0.81	0.35
10	2.21	1.55	0.67
15	3.31	3.28	1.42
20	4.42	5.59	2.42
25	5.52	8.45	3.66
30	6.63	11.85	5.13
35	7.73	15.76	6.82
40	8.84	20.18	8.74
45	9.94	25.10	10.87
50	11.05	30.51	13.21

8 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
125	0.65	0.03	0.012
150	0.81	0.035	0.015
175	0.97	0.04	0.017
200	1.14	0.055	0.024
250	1.30	0.07	0.030
300	1.63	0.11	0.048
350	1.94	0.16	0.069
400	2.27	0.21	0.091
450	2.59	0.27	0.12
500	2.92	0.33	0.14
750	3.24	0.40	0.17
1000	4.86	0.85	0.37
1250	6.48	1.45	0.63
1500	8.11	2.20	0.95
2000	9.72	3.07	1.33

1 1/2 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.33	0.07	0.03
5	0.81	0.22	0.09
7	1.13	0.38	0.17
10	1.62	0.72	0.31
15	2.42	1.53	0.66
20	3.23	2.61	1.13
25	4.04	3.95	1.71
30	4.85	5.53	2.39
35	5.66	7.36	3.19
40	6.47	9.43	4.08
45	7.27	11.73	5.08
50	8.08	14.25	6.17
60	9.70	19.98	8.65

10 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
200	0.82	0.027	0.012
250	1.03	0.035	0.015
300	1.23	0.05	0.022
350	1.44	0.065	0.028
400	1.64	0.09	0.039
450	1.85	0.11	0.048
500	2.05	0.13	0.056
750	3.08	0.28	0.12
1000	4.11	0.48	0.21
1250	5.14	0.73	0.32
1500	6.16	1.01	0.44
2000	8.21	1.72	0.74
2500	10.27	2.61	1.13

2 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
5	0.49	0.066	0.029
7	0.69	0.11	0.048
10	0.98	0.21	0.091
15	1.46	0.45	0.19
20	1.95	0.76	0.33
25	2.44	1.15	0.50
30	2.93	1.62	0.70
35	3.41	2.15	0.93
40	3.90	2.75	1.19
45	4.39	3.43	1.49
50	4.88	4.16	1.80
60	5.85	5.84	2.53
70	6.83	7.76	3.36
75	7.32	8.82	3.82
80	7.80	9.94	4.30
90	8.78	12.37	5.36
100	9.75	15.03	6.51

12 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
350	1.01	0.027	0.012
400	1.16	0.04	0.017
450	1.30	0.05	0.022
500	1.45	0.06	0.026
750	2.17	0.12	0.052
1000	2.89	0.20	0.087
1250	3.62	0.31	0.13
1500	4.34	0.43	0.19
2000	5.78	0.73	0.32
2500	7.23	1.11	0.49
3000	8.68	1.55	0.67
3500	10.12	2.07	0.90
4000	11.07	2.66	1.15

2 1/2 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
5	0.30	0.038	0.016
7	0.49	0.051	0.023
10	0.68	0.09	0.039
15	1.03	0.19	0.082
20	1.37	0.32	0.14
25	1.71	0.49	0.21
30	2.05	0.68	0.29
35	2.39	0.91	0.39
40	2.73	1.16	0.50
45	3.08	1.44	0.62
50	3.42	1.75	0.76
60	4.10	2.46	1.07
70	4.79	3.27	1.42
75	5.13	3.71	1.61
80	5.47	4.19	1.81
90	6.15	5.21	2.26
100	6.84	6.33	2.74
125	8.55	9.58	4.15
150	10.26	13.41	5.81

14 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
500	1.18	0.03	0.01
750	1.77	0.07	0.03
1000	2.37	0.12	0.05
1250	2.96	0.19	0.08
1500	3.56	0.27	0.12
2000	4.74	0.46	0.20
2500	5.93	0.70	0.30
3000	7.12	0.98	0.42
3500	8.30	1.30	0.56
4000	9.49	1.67	0.72
4500	10.68	2.08	0.90
5000	11.86	2.53	1.09
5500	13.05	3.02	1.31
6000	14.24	3.55	1.54
6500	15.42	4.11	1.78
7000	16.61	4.72	2.04
7500	17.79	5.36	2.32

3 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
5	0.22	0.015	0.007
7	0.31	0.021	0.009
10	0.44	0.03	0.013
15	0.66	0.07	0.030
20	0.88	0.11	0.048
25	1.10	0.17	0.074
30	1.33	0.23	0.10
35	1.55	0.31	0.13
40	1.77	0.40	0.17
45	1.99	0.50	0.22
50	2.21	0.60	0.26
60	2.65	0.85	0.37
70	3.09	1.13	0.49
75	3.31	1.28	0.55
80	3.53	1.44	0.62
90	3.98	1.80	0.78
100	4.42	2.18	0.94
125	5.52	3.31	1.43
150	6.63	4.63	2.00
175	7.73	6.16	2.67
200	8.83	7.88	3.41
250	11.04	11.93	5.17

16 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
500	0.91	0.02	0.01
750	1.36	0.04	0.02
1000	1.82	0.07	0.03
1250	2.27	0.10	0.04
1500	2.72	0.14	0.06
2000	3.63	0.24	0.10
2500	4.54	0.37	0.16
3000	5.45	0.51	0.22
3500	6.36	0.68	0.29
4000	7.26	0.87	0.38
4500	8.17	1.09	0.47
5000	9.08	1.32	0.57
5500	9.99	1.58	0.68
6000	10.90	1.85	0.80
6500	11.80	2.15	0.93
7000	12.71	2.46	1.06
7500	13.62	2.80	1.21
8000	14.53	3.15	1.37
8500	15.44	3.53	1.53
9000	16.35	3.92	1.69
9500	17.26	4.34	1.87
10000	18.16	4.77	2.06

Source: Adapted from Charlotte Pipe Data

FRICTION LOSS AND FLOW VELOCITY FOR SCHEDULE 80 THERMOPLASTIC PIPE

(Friction head and friction loss are per 100 feet of pipe.)

CAUTION: Flow velocity should not exceed 5 feet per second. PVC and CPVC pipe cannot be used for compressed air service.

½ in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
1	1.48	4.02	1.74
2	2.95	8.03	3.48
5	7.39	45.23	19.59
7	10.34	83.07	35.97

4 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
20	0.57	0.04	0.017
25	0.72	0.06	0.026
30	0.86	0.08	0.035
35	1.00	0.11	0.048
40	1.15	0.14	0.061
45	1.29	0.17	0.074
50	1.43	0.21	0.091
60	1.72	0.30	0.13
70	2.01	0.39	0.17
75	2.15	0.45	0.19
80	2.29	0.50	0.22
90	2.58	0.63	0.27
100	2.87	0.76	0.33
125	3.59	1.16	0.50
150	4.30	1.61	0.70
175	5.02	2.15	0.93
200	5.73	2.75	1.19
250	7.16	4.16	1.81
300	8.60	5.83	2.52
350	10.03	7.76	3.36
400	11.47	9.93	4.30

¾ in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
1	0.74	0.86	0.37
2	1.57	1.72	0.74
5	3.92	9.67	4.19
7	5.49	17.76	7.69
10	7.84	33.84	14.65
15	11.76	71.70	31.05

5 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
30	0.54	0.03	0.013
35	0.63	0.04	0.017
40	0.72	0.04	0.017
45	0.81	0.06	0.026
50	0.90	0.07	0.030
60	1.08	0.10	0.043
70	1.26	0.13	0.056
75	1.35	0.14	0.061
80	1.44	0.16	0.069
90	1.62	0.20	0.087
100	1.80	0.24	0.10
125	2.25	0.37	0.16
150	2.70	0.52	0.23
175	3.15	0.69	0.30
200	3.60	0.88	0.38
250	4.50	1.34	0.58
300	5.40	1.87	0.81
350	6.30	2.49	1.08
400	7.19	3.19	1.38
450	8.09	3.97	1.72
500	8.99	4.82	2.09

1 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.94	0.88	0.38
5	2.34	2.75	1.19
7	3.28	5.04	2.19
10	4.68	9.61	4.16
15	7.01	20.36	8.82
20	9.35	34.68	15.02
25	11.69	52.43	22.70
30	14.03	73.48	31.82

6 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
50	0.63	0.03	0.013
60	0.75	0.04	0.017
70	0.88	0.05	0.022
75	0.94	0.06	0.026
80	1.00	0.07	0.030
90	1.13	0.08	0.035
100	1.25	0.10	0.043
125	1.57	0.16	0.068
150	1.88	0.22	0.095
175	2.20	0.29	0.12
200	2.51	0.37	0.16
250	3.14	0.56	0.24
300	3.76	0.78	0.34
350	4.39	1.04	0.45
400	5.02	1.33	0.58
450	5.64	1.65	0.71
500	6.27	2.00	0.87
750	9.40	4.25	1.84
1000	12.54	7.23	3.13

1¼ in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.52	0.21	0.09
5	1.30	0.66	0.29
7	1.82	1.21	0.53
10	2.60	2.30	1.00
15	3.90	4.87	2.11
20	5.20	8.30	3.59
25	6.50	12.55	5.43
30	7.80	17.59	7.62
35	9.10	23.40	10.13
40	10.40	29.97	12.98
45	11.70	37.27	16.14
50	13.00	45.30	19.61

8 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
125	0.90	0.045	0.019
150	1.07	0.05	0.022
175	1.25	0.075	0.033
200	1.43	0.09	0.039
250	1.79	0.14	0.61
300	2.14	0.20	0.087
350	2.50	0.27	0.12
400	2.86	0.34	0.15
450	3.21	0.42	0.18
500	3.57	0.51	0.22
750	5.36	1.08	0.47
1000	7.14	1.84	0.80
1250	8.93	2.78	1.20
1500	10.71	3.98	1.68

1½ in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.38	0.10	0.041
5	0.94	0.30	0.126
7	1.32	0.55	0.24
10	1.88	1.04	0.45
15	2.81	2.20	0.95
20	3.75	3.75	1.62
25	4.69	5.67	2.46
30	5.63	7.95	3.44
35	6.57	10.58	4.58
40	7.50	13.55	5.87
45	8.44	16.85	7.30
50	9.38	20.48	8.87
60	11.26	28.70	12.43

10 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
200	0.90	0.036	0.015
250	1.14	0.045	0.02
300	1.36	0.07	0.03
350	1.59	0.085	0.037
400	1.81	0.11	0.048
450	2.04	0.14	0.061
500	2.27	0.17	0.074
750	3.40	0.36	0.16
1000	4.54	0.61	0.26
1250	5.67	0.92	0.40
1500	6.80	1.29	0.56
2000	9.07	2.19	0.95
2500	11.34	3.33	1.44

2 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
5	0.56	0.10	0.040
7	0.78	0.15	0.065
10	1.12	0.29	0.13
15	1.68	0.62	0.27
20	2.23	1.06	0.46
25	2.79	1.60	0.69
30	3.35	2.25	0.97
35	3.91	2.99	1.29
40	4.47	3.83	1.66
45	5.03	4.76	2.07
50	5.58	5.79	2.51
60	6.70	8.12	3.52
70	7.82	10.80	4.68
75	8.38	12.27	5.31
80	8.93	13.83	5.99
90	10.05	17.20	7.45
100	11.17	20.90	9.05

12 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
350	1.12	0.037	0.016
400	1.28	0.05	0.022
450	1.44	0.06	0.026
500	1.60	0.07	0.030
750	2.40	0.15	0.065
1000	3.20	0.26	0.11
1250	4.01	0.40	0.17
1500	4.81	0.55	0.24
2000	6.41	0.94	0.41
2500	8.01	1.42	0.62
3000	9.61	1.99	0.86
3500	11.21	2.65	1.15
4000	12.82	3.41	1.48

2½ in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
5	0.39	0.05	0.022
7	0.54	0.07	0.032
10	0.78	0.12	0.052
15	1.17	0.26	0.11
20	1.56	0.44	0.19
25	1.95	0.67	0.29
30	2.34	0.94	0.41
35	2.73	1.25	0.54
40	3.12	1.60	0.69
45	3.51	1.99	0.86
50	3.90	2.42	1.05
60	4.68	3.39	1.47
70	5.46	4.51	1.95
75	5.85	5.12	2.22
80	6.24	5.77	2.50
90	7.02	7.18	3.11
100	7.80	8.72	3.78
125	9.75	13.21	5.72
150	11.70	18.48	8.00

14 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
500	1.31	0.04	0.02
750	1.96	0.09	0.04
1000	2.62	0.16	0.07
1250	3.27	0.25	0.11
1500	3.92	0.34	0.15
2000	5.23	0.59	0.25
2500	6.54	0.88	0.38
3000	7.85	1.24	0.54
3500	9.16	1.66	0.72
4000	10.46	2.12	0.92
4500	11.77	2.64	1.14
5000	13.07	3.20	1.38
5500	14.39	3.83	1.66
6000	15.70	4.49	1.95
6500	17.00	5.21	2.26
7000	18.31	5.99	2.60

3 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
5	0.25	0.02	0.009
7	0.35	0.028	0.012
10	0.50	0.04	0.017
15	0.75	0.09	0.039
20	1.00	0.15	0.065
25	1.25	0.22	0.095
30	1.49	0.31	0.13
35	1.74	0.42	0.18
40	1.99	0.54	0.23
45	2.24	0.67	0.29
50	2.49	0.81	0.35
60	2.99	1.14	0.49
70	3.49	1.51	0.65
75	3.74	1.72	0.74
80	3.99	1.94	0.84
90	4.48	2.41	1.04
100	4.98	2.93	1.27
125	6.23	4.43	1.92
150	7.47	6.20	2.68
175	8.72	8.26	3.58
200	9.97	10.57	4.58
250	12.46	16.00	6.93

16 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
500	0.99	0.02	0.01
750	1.49	0.05	0.02
1000	1.99	0.08	0.04
1250	2.49	0.13	0.05
1500	2.99	0.17	0.08
2000	3.99	0.30	0.13
2500	4.99	0.46	0.19
3000	5.98	0.64	0.28
3500	6.98	0.86	0.37
4000	7.98	1.09	0.48
4500	8.98	1.364	0.59
5000	9.97	1.66	0.72
5500	10.97	1.99	0.86
6000	11.97	2.324	1.00
6500	12.97	2.69	1.17
7000	13.96	3.09	1.33
7500	14.96	3.51	1.52
8000	15.96	3.96	1.71
8500	16.96	4.43	1.92
9000	17.95	4.93	2.13

Source: Adapted from Charlotte Pipe Data

FRICTION LOSS AND FLOW VELOCITY FOR SDR 21 THERMOPLASTIC PIPE

(Friction head and friction loss are per 100 feet of pipe.)

CAUTION: Flow velocity should not exceed 5 feet per second. PVC and CPVC pipe cannot be used for compressed air service.

½ in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
1	0.84	1.00	0.44
2	1.67	2.00	0.87
5	4.17	11.25	4.87
7	5.84	20.66	8.95
10	8.34	39.34	17.03

4 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
20	0.50	0.03	0.013
25	0.62	0.04	0.017
30	0.75	0.06	0.026
35	0.87	0.08	0.035
40	1.00	0.10	0.043
45	1.12	0.12	0.052
50	1.25	0.15	0.065
60	1.50	0.21	0.091
70	1.75	0.28	0.12
75	1.87	0.32	0.14
80	2.00	0.36	0.16
90	2.25	0.45	0.19
100	2.50	0.54	0.23
125	3.13	0.82	0.36
150	3.75	1.15	0.50
175	4.37	1.54	0.67
200	4.99	1.96	0.85
250	6.24	2.97	1.29
300	7.49	4.16	1.80
350	8.74	5.54	2.40
400	9.99	7.09	3.07
450	11.24	8.82	3.82
500	12.48	10.72	4.64

¾ in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
1	0.50	0.28	0.12
2	0.99	0.56	0.24
5	2.47	3.14	1.36
7	3.46	5.76	2.49
10	4.94	10.96	4.75
15	7.40	23.23	10.06
20	9.87	39.57	17.13

5 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
30	0.49	0.02	0.009
35	0.57	0.03	0.013
40	0.65	0.04	0.017
45	0.74	0.04	0.017
50	0.82	0.05	0.022
60	0.98	0.08	0.035
70	1.14	0.10	0.043
75	1.23	0.11	0.048
80	1.31	0.13	0.056
90	1.47	0.16	0.069
100	1.63	0.19	0.082
125	2.04	0.30	0.13
150	2.45	0.41	0.18
175	2.86	0.55	0.24
200	3.27	0.70	0.30
250	4.09	1.06	0.46
300	4.90	1.48	0.64
350	5.72	1.98	0.86
400	6.54	2.53	1.10
450	7.35	3.14	1.36
500	8.17	3.82	1.65
750	12.26	8.09	3.50

1 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.60	0.30	0.13
5	1.50	0.93	0.41
7	2.09	1.70	0.74
10	2.99	3.24	1.40
15	4.49	6.86	2.97
20	5.98	11.68	5.06
25	7.48	17.66	7.65
30	8.97	24.76	10.72
35	10.47	32.94	14.26

6 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
50	0.58	0.02	0.009
60	0.69	0.03	0.013
70	0.81	0.04	0.017
75	0.86	0.05	0.022
80	0.92	0.05	0.022
90	1.04	0.07	0.030
100	1.15	0.08	0.035
125	1.44	0.125	0.054
150	1.73	0.18	0.078
175	2.02	0.24	0.103
200	2.31	0.30	0.13
250	2.89	0.46	0.20
300	3.46	0.63	0.27
350	4.04	0.85	0.37
400	4.61	1.08	0.47
450	5.19	1.34	0.58
500	5.76	1.63	0.71
750	8.64	3.46	1.50
1000	11.53	5.89	2.55

1¼ in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.37	0.095	0.04
5	0.93	0.30	0.13
7	1.31	0.54	0.23
10	1.86	1.02	0.44
15	2.79	2.16	0.94
20	3.72	3.68	1.59
25	4.65	5.56	2.41
30	5.58	7.80	3.38
35	6.51	10.37	4.49
40	7.44	13.28	5.75
45	8.37	16.52	7.15
50	9.30	20.08	8.69
60	11.17	28.14	12.18

8 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
100	0.67	0.03	0.012
125	0.85	0.037	0.015
150	1.02	0.05	0.022
175	1.19	0.065	0.028
200	1.36	0.08	0.035
250	1.70	0.125	0.054
300	2.04	0.18	0.078
350	2.38	0.24	0.103
400	2.72	0.30	0.13
450	3.06	0.37	0.16
500	3.40	0.45	0.19
750	5.10	0.96	0.42
1000	6.80	1.63	0.64
1250	8.50	2.47	1.07
1500	10.19	3.45	1.49
2000	13.59	5.87	2.54

1½ in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.29	0.05	0.022
5	0.71	0.15	0.065
7	0.99	0.28	0.12
10	1.41	0.52	0.23
15	2.12	1.11	0.48
20	2.83	1.89	0.82
25	3.54	2.85	1.23
30	4.24	4.00	1.73
35	4.95	5.32	2.30
40	5.66	6.81	2.95
45	6.36	8.47	3.67
50	7.07	10.29	4.46
60	8.49	14.42	6.24
70	9.90	19.19	8.31
75	10.61	21.80	9.44

10 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
200	0.86	0.027	0.012
250	1.10	0.045	0.020
300	1.31	0.06	0.026
350	1.54	0.08	0.035
400	1.75	0.10	0.043
450	1.97	0.13	0.056
500	2.19	0.15	0.065
750	3.29	0.33	0.14
1000	4.38	0.56	0.24
1250	5.48	0.85	0.37
1500	6.57	1.18	0.51
2000	8.76	2.02	0.87
2500	10.96	3.06	1.33
3000	13.15	4.27	1.85

2 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.18	0.023	0.010
5	0.45	0.06	0.025
7	0.63	0.081	0.035
10	0.90	0.17	0.074
15	1.35	0.37	0.16
20	1.80	0.63	0.27
25	2.25	0.95	0.41
30	2.71	1.34	0.58
35	3.16	1.78	0.77
40	3.61	2.27	0.98
45	4.06	2.83	1.23
50	4.51	3.44	1.49
60	5.41	4.82	2.09
70	6.31	6.41	2.78
75	6.76	7.29	3.16
80	7.21	8.21	3.55
90	8.12	10.21	4.42
100	9.02	12.41	5.37

12 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
350	1.08	0.036	0.016
400	1.24	0.04	0.017
450	1.40	0.06	0.026
500	1.55	0.07	0.030
750	2.33	0.14	0.061
1000	3.11	0.24	0.10
1250	3.89	0.37	0.16
1500	4.66	0.51	0.22
2000	6.22	0.87	0.38
2500	7.77	1.33	0.57
3000	9.33	1.85	0.08
3500	10.88	2.47	1.07
4000	12.44	3.17	1.37
4500	13.99	3.93	1.70

2½ in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
5	0.31	0.031	0.014
7	0.43	0.044	0.020
10	0.61	0.07	0.03
15	0.92	0.14	0.061
20	1.23	0.25	0.11
25	1.53	0.37	0.16
30	1.84	0.52	0.23
35	2.15	0.70	0.30
40	2.45	0.89	0.39
45	2.76	1.11	0.48
50	3.07	1.35	0.58
60	3.68	1.89	0.82
70	4.29	2.51	1.09
75	4.60	2.85	1.23
80	4.91	3.22	1.39
90	5.52	4.00	1.73
100	6.14	4.86	2.10
125	7.67	7.36	3.19
150	9.20	10.30	4.46
175	10.74	13.72	5.94

3 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
5	0.20	0.015	0.006
7	0.29	0.021	0.009
10	0.41	0.03	0.013
15	0.62	0.06	0.026
20	0.83	0.09	0.039
25	1.03	0.14	0.061
30	1.24	0.20	0.087
35	1.45	0.27	0.12
40	1.65	0.34	0.15
45	1.86	0.42	0.18
50	2.06	0.51	0.22
60	2.48	0.72	0.31
70	2.89	0.96	0.42
75	3.10	1.09	0.47
80	3.30	1.23	0.53
90	3.72	1.52	0.66
100	4.13	1.85	0.80
125	5.17	2.81	1.22
150	6.19	3.93	1.70
175	7.23	5.23	2.26
200	8.26	6.69	2.90
250	10.33	10.13	4.39

Source: Adapted from Charlotte Pipe Data

FRICTION LOSS AND FLOW VELOCITY FOR SDR 26 THERMOPLASTIC PIPE

(Friction head and friction loss are per 100 feet of pipe.)

CAUTION: Flow velocity should not exceed 5 feet per second. PVC and CPVC pipe cannot be used for compressed air service.

1/2 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
1	0.84	1.00	0.43
2	1.67	2.00	0.86
5	4.17	11.25	4.87
7	5.84	20.66	8.95
10	8.34	39.34	17.03

3/4 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
1	0.50	0.28	0.12
2	0.99	0.56	0.24
5	2.47	3.14	1.36
7	3.46	5.76	2.49
10	4.94	10.96	4.74
15	7.40	23.23	10.06
20	9.87	39.57	17.13

1 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.59	0.29	0.13
5	1.48	0.91	0.39
7	2.08	1.66	0.72
10	2.96	3.16	1.37
15	4.44	6.69	2.90
20	5.92	11.40	4.94
25	7.40	17.23	7.46
30	8.88	24.15	10.46
35	10.36	32.13	13.91

1 1/4 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.36	0.085	0.037
5	0.90	0.27	0.117
7	1.25	0.49	0.21
10	1.79	0.92	0.40
15	2.68	1.96	0.85
20	3.58	3.34	1.45
25	4.47	5.04	2.18
30	5.36	7.07	3.06
35	6.26	9.41	4.07
40	7.15	12.05	5.22
45	8.04	14.98	6.49
50	8.94	18.21	7.88

1 1/2 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.27	0.02	0.0087
5	0.68	0.14	0.059
7	0.96	0.25	0.104
10	1.36	0.47	0.20
15	2.04	1.00	0.43
20	2.72	1.71	0.74
25	3.40	2.59	1.12
30	4.08	3.63	1.57
35	4.76	4.83	2.09
40	5.44	6.18	2.68
45	6.12	7.69	3.33
50	6.80	9.34	4.04
60	8.16	13.10	5.67
70	9.52	17.42	7.54
75	10.19	19.80	8.57
80	10.87	22.31	9.66
90	12.23	27.75	12.02
100	13.59	33.73	14.61

2 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
2	0.17	0.01	0.004
5	0.44	0.045	0.020
7	0.61	0.08	0.035
10	0.87	0.16	0.069
15	1.30	0.33	0.14
20	1.73	0.57	0.25
25	2.16	0.86	0.37
30	2.60	1.21	0.52
35	3.03	1.61	0.70
40	3.46	2.06	0.89
45	3.90	2.56	1.11
50	4.33	3.11	1.35
60	5.19	4.36	1.89
70	6.06	5.80	2.51
75	6.49	6.60	2.86
80	6.92	7.43	3.22
90	7.79	9.25	4.01
100	8.66	11.24	4.87

2 1/2 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
5	0.30	0.025	0.011
7	0.42	0.035	0.015
10	0.59	0.06	0.026
15	0.88	0.13	0.056
20	1.18	0.22	0.095
25	1.47	0.34	0.15
30	1.77	0.47	0.20
35	2.06	0.63	0.27
40	2.35	0.81	0.35
45	2.65	1.00	0.43
50	2.94	1.22	0.53
60	3.53	1.71	0.74
70	4.12	2.27	0.98
75	4.41	2.58	1.12
80	4.71	2.91	1.26
90	5.30	3.62	1.57
100	5.89	4.39	1.90
125	7.36	6.65	2.88
150	8.83	9.31	4.03
175	10.31	12.40	5.37

3 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
5	0.20	0.01	0.0045
7	0.28	0.014	0.0063
10	0.40	0.02	0.009
15	0.59	0.05	0.022
20	0.79	0.09	0.039
25	0.99	0.13	0.056
30	1.19	0.18	0.078
35	1.39	0.24	0.10
40	1.59	0.31	0.13
45	1.78	0.38	0.16
50	1.98	0.47	0.20
60	2.38	0.65	0.28
70	2.78	0.87	0.38
75	2.97	0.99	0.43
80	3.17	1.11	0.48
90	3.57	1.38	0.60
100	3.97	1.68	0.73
125	4.96	2.54	1.10
150	5.95	3.56	1.54
175	6.94	4.74	2.05
200	7.93	6.07	2.63
250	9.92	9.18	3.98

4 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
20	0.48	0.02	0.009
25	0.60	0.04	0.017
30	0.72	0.05	0.022
35	0.84	0.07	0.030
40	0.96	0.09	0.039
45	1.08	0.11	0.048
50	1.20	0.14	0.061
60	1.44	0.19	0.082
70	1.67	0.25	0.11
75	1.79	0.29	0.13
80	1.91	0.32	0.14
90	2.15	0.40	0.17
100	2.39	0.49	0.21
125	2.99	0.74	0.33
150	3.59	1.04	0.45
175	4.19	1.39	0.60
200	4.79	1.77	0.77
250	5.98	2.68	1.16
300	7.18	3.75	1.62
350	8.38	5.00	2.17
400	9.57	6.39	2.77
450	10.77	7.95	3.44
500	11.96	9.66	4.18

5 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
30	0.47	0.02	0.009
35	0.55	0.03	0.013
40	0.63	0.03	0.013
45	0.71	0.04	0.017
50	0.78	0.05	0.022
60	0.94	0.07	0.030
70	1.10	0.09	0.039
75	1.18	0.10	0.043
80	1.25	0.12	0.052
90	1.41	0.14	0.061
100	1.57	0.18	0.078
125	1.96	0.27	0.12
150	2.35	0.37	0.16
175	2.74	0.50	0.22
200	3.13	0.63	0.27
250	3.92	0.96	0.42
300	4.70	1.34	0.58
350	5.49	1.79	0.77
400	6.27	2.28	0.99
450	7.05	2.84	1.23
500	7.84	3.45	1.49
750	11.75	7.31	3.17

6 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
50	0.55	0.02	0.009
60	0.66	0.03	0.013
70	0.77	0.04	0.017
75	0.83	0.04	0.017
80	0.88	0.05	0.022
90	0.99	0.06	0.026
100	1.10	0.07	0.030
125	1.39	0.11	0.047
150	1.66	0.16	0.069
175	1.94	0.21	0.091
200	2.21	0.27	0.12
250	2.76	0.41	0.18
300	3.31	0.57	0.25
350	3.87	0.76	0.33
400	4.42	0.97	0.42
450	4.97	1.21	0.52
500	5.52	1.47	0.64
750	8.28	3.12	1.35
1000	11.05	5.31	2.30

8 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
100	0.66	0.03	0.012
125	0.83	0.037	0.015
150	0.98	0.04	0.017
175	1.14	0.06	0.026
200	1.30	0.07	0.030
250	1.63	0.11	0.048
300	1.95	0.16	0.069
350	2.28	0.21	0.091
400	2.61	0.27	0.12
450	2.93	0.33	0.14
500	3.26	0.41	0.18
750	4.89	0.86	0.37
1000	6.51	1.47	0.64
1250	8.15	2.23	0.96
1500	9.77	3.11	1.35
2000	13.03	5.30	2.29

10 in.

Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
200	0.83	0.027	0.012
250	1.05	0.04	0.017
300	1.26	0.05	0.022
350	1.47	0.075	0.033
400	1.68	0.09	0.039
450	1.89	0.11	0.048
500	2.10	0.14	0.061
750	3.14	0.29	0.13
1000	4.19	0.50	0.22
1250	5.27	0.76	0.33
1500	6.29	1.06	0.46
2000	8.38	1.81	0.78
2500	10.48	2.74	1.19
3000	12.58	3.84	1.66

12 in.

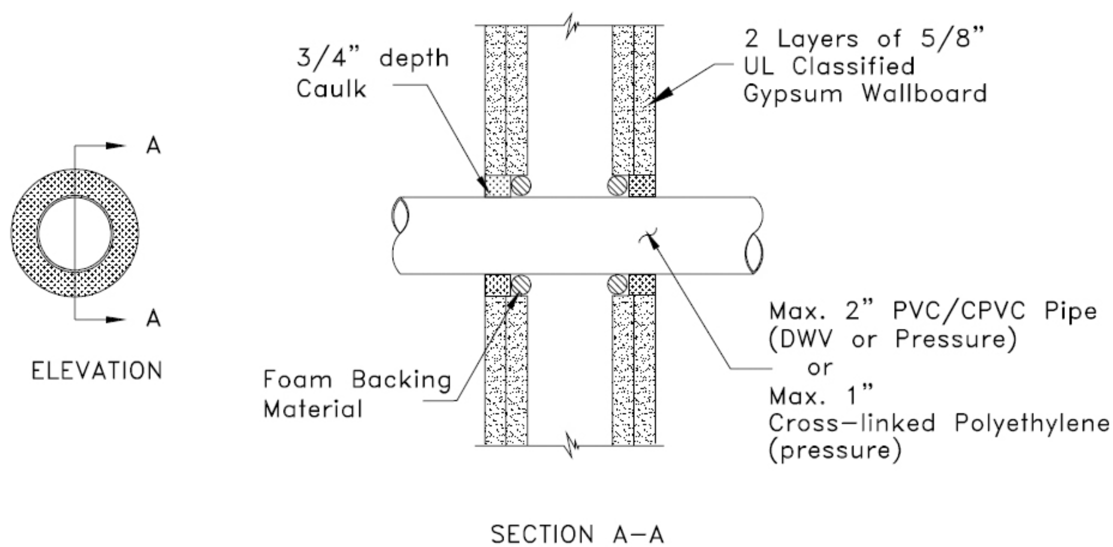
Gallons Per Minute	Velocity Feet Per Second	Friction Head Feet	Friction Loss Pounds Per Square Inch
350	1.04	0.04	0.017
400	1.19	0.04	0.017
450	1.34	0.05	0.022
500	1.49	0.06	0.026
750	2.23	0.13	0.056
1000	2.98	0.22	0.095
1250	3.73	0.34	0.15
1500	4.47	0.46	0.20
2000	5.96	0.79	0.34
2500	7.45	1.20	0.52
3000	8.94	1.67	0.72
3500	10.43	2.22	0.96
4000	11.92	2.86	1.24
4500	13.41	3.54	1.53

Source: Adapted from Charlotte Pipe Data

APPENDIX E: PARTIAL LISTING OF FIRE STOP INSTALLATIONS

Source: PPFA's "Firestopping Plastic Pipe in Fire Resistive Construction"

Wall Penetration – 2 Hour Rating

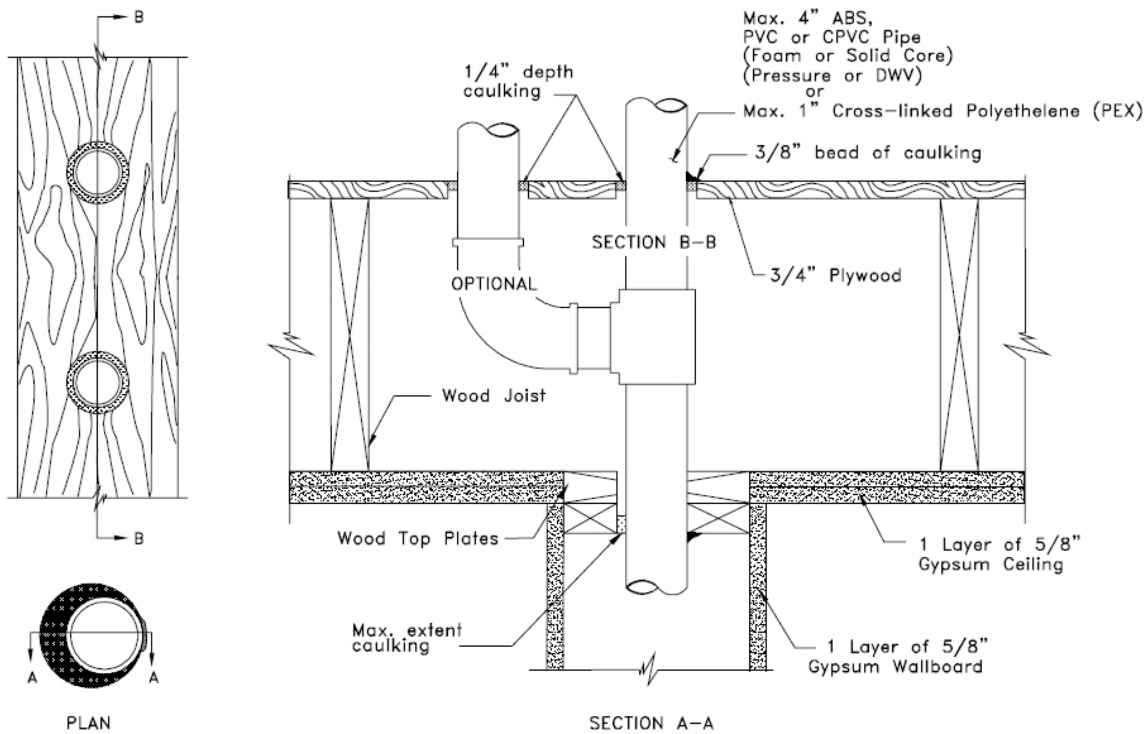


SYSTEM CONFIGURATION INFORMATION																
PRODUCT(S)			PENETRATING ITEM(S)			HOLE SIZE	ANNULAR SPACING		ADDITIONAL INSTALLATION MATERIALS AND AIDS			BACKING MATERIAL		ASTM E 814 RATING	
FILL MAT'L	MIN. THICK.	OTHER	TYPE	SIZE	INSULATION	MAX.	MIN.	MAX.	WIRE MESH	STEELE SLEEVE	OTHER	TYPE	DEPTH	T	F
caulk	3/4" both sides	none	PVC/CPVC SCH 40 closed/open PEX SDR 9	up to 2" up to 1"	none	3 5/8"	5/8"	5/8"	none	none	none	Foam backer rod	N/A	1 1/2	2

These instructions are for the installation of through-penetration fire stop system in a minimum 5" thick steel or wood stud fire rated gypsum wallboard partitions as listed by Underwriters Laboratories Inc. Refer to above drawings and System Configuration Information for component details.

1. Clean all hole, pipe and insulation surfaces in penetration area to remove loose debris, dirt, oil, wax, grease, old caulking, and the like.
2. Install backing material by firmly packing annular space with foam backer rod from both sides of wall. Recess backing material at least 3/4" in from both sides of wall to accommodate the required fill depth of caulk.
3. Gun, trowel and/or pump firestopping sealant to minimum 3/4" depth on both sides of wall. Trowel sealant surfaces flush with wall surfaces and to a smooth defect-free finish.

Floor Penetration – 1 Hour Rating



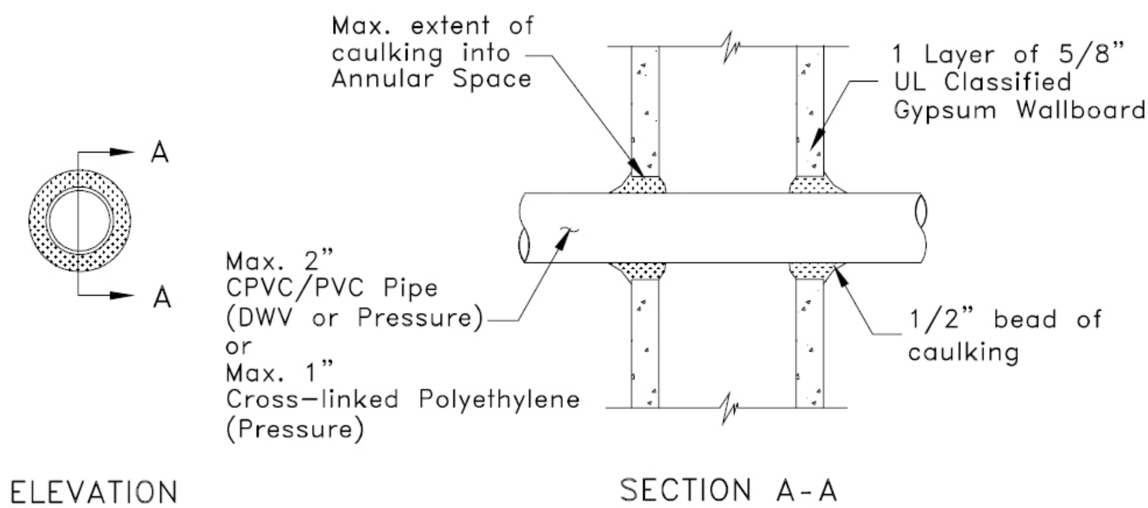
SYSTEM CONFIGURATION INFORMATION															
PRODUCT(S)			PENETRATING ITEM(S)			HOLE SIZE	ANNULAR SPACING		ADDITIONAL INSTALLATION MATERIALS AND AIDS			BACKING MATERIAL		ASTM E 814 RATING	
FILL MAT'L	MIN. THICK.	OTHER	TYPE	SIZE	INSULATION	MAX.	MIN.	MAX.	WIRE MESH	STEELE SLEEVE	OTHER	TYPE	DEPTH	T	F
caulk	1/4" top Max. Extent bottom	none	PVC, ABS (foam or solid core) SCH 40 CPVC SDR17 (or heavier), closed or vented	up to 4" I.D. up to 1" PEX	none	4 3/4"	0"	1/4"	none	none	none	none	N/A	N/A	1

These instructions are for the installation of through-penetration fire stop system in a wood floor/ceiling and chase wall construction as listed in the individual L500 floor designs and U300 wall designs, respectively by Underwriters Laboratories Inc. Refer to above drawings and System Configuration Information for component details.

1. Cut hole in wood floor and top plates to required size to accommodate pipe penetration and allowable annular spacing. Do not exceed maximum specified hole diameter.
2. Install up to 4" I.D. ABS, PVC or CPVC (foam or solid core) vented (DWV) or closed (pressure) pipe or up to 1" I.D. PEX tubing. Support pipe rigidly on both sides of floor/ceiling.
3. Gun, trowel and/or pump sealant to a 1/4" depth in annular space of penetration(s) on top of wood floor and a 3/8" bead at all zero annular spaces. Trowel sealant surfaces flush with floor surface and to a smooth defect-free finish.

4. Gun, trowel and/or pump sealant to a maximum extent depth in the annular space of wood plates and 3/8" bead at all zero annular spaces. Trowel sealant surfaces flush with bottom of top plates and to a smooth defect-free finish.

Wall Penetration – 1 Hour Rating

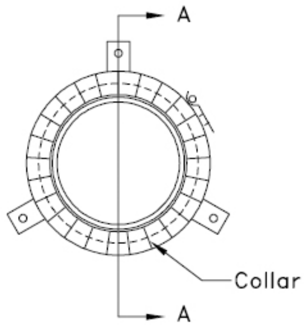


SYSTEM CONFIGURATION INFORMATION																
PRODUCT(S)			PENETRATING ITEM(S)			HOLE SIZE	ANNULAR SPACING		ADDITIONAL INSTALLATION MATERIALS AND AIDS			BACKING MATERIAL		ASTM E 814 RATING	
FILL MAT'L	MIN. THICK.	OTHER	TYPE	SIZE	INSULATION	MAX.	MIN.	MAX.	WIRE MESH	STEELE SLEEVE	OTHER	TYPE	DEPTH	T	F
caulk	Max. extent	none	PVC/CPVC SCH 40 closed/open PEX SDR 9	up to 2" up to 1"	none	3 5/8"	5/8"	5/8"	none	none	none	none	N/A	1	1

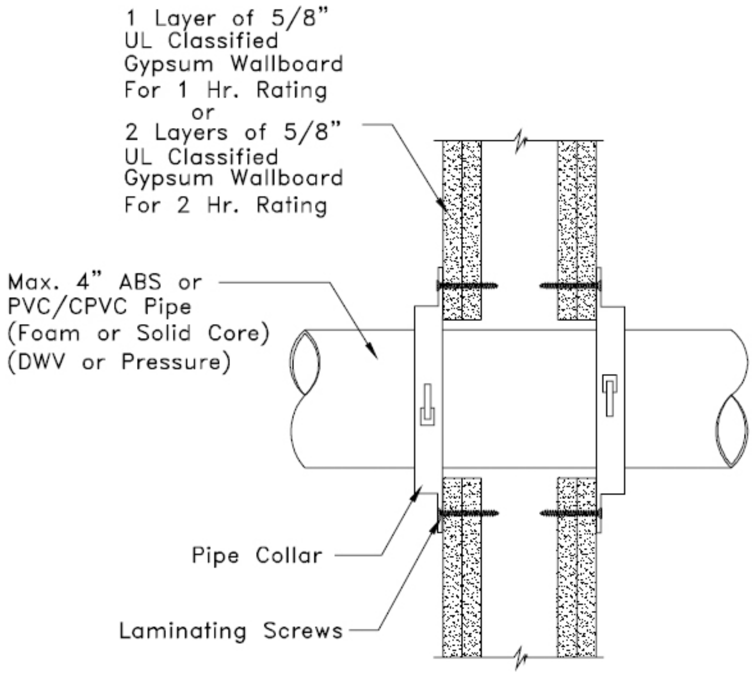
These instructions are for the installation of through-penetration fire stop system in a minimum 5" thick steel or wood stud fire rated gypsum wallboard partitions as listed by Underwriters Laboratories Inc. Refer to above drawings and System Configuration Information for component details.

1. Clean all hole, pipe and insulation surfaces in penetration area to remove loose debris, dirt, oil, wax, grease, old caulking, and the like.
2. Gun, trowel and/or pump firestopping sealant to the max. extent in the annular space on both sides of wall. Trowel sealant surfaces flush with wall surfaces and to a smooth defect-free finish. Apply 1/2" diameter caulking bead around perimeter of pipe on both sides of wall and tool smooth.

Wall Penetration – 1 or 2 Hour Rating



ELEVATION



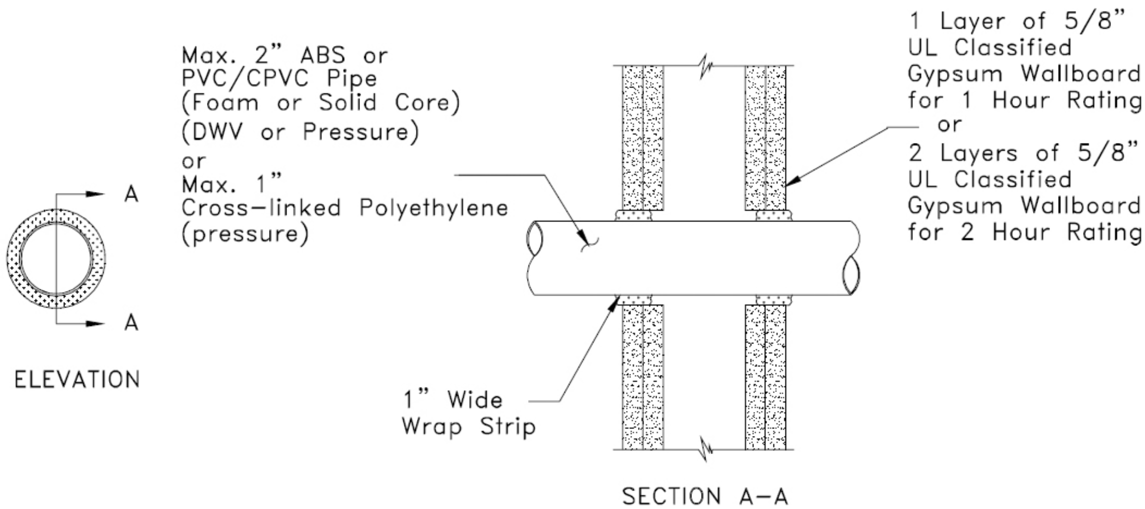
SECTION A–A

SYSTEM CONFIGURATION INFORMATION															
PRODUCT(S)			PENETRATING ITEM(S)			HOLE SIZE	ANNULAR SPACING		ADDITIONAL INSTALLATION MATERIALS AND AIDS			BACKING MATERIAL		ASTM E 814 RATING	
FILL MAT'L	MIN. THICK.	OTHER	TYPE	SIZE	INSULATION	MAX.	MIN.	MAX.	WIRE MESH	STEELE SLEEVE	OTHER	TYPE	DEPTH	T	F
pipe collar	none	none	ABS or PVC/CPVC (foam or solid core) SCH 40 (or heavier), closed or vented	up to 4" I.D.	none	5"	1/4" For pipe 3" or less 0"	1/4" For pipe 3" or less 1/2"	none	none	minimum 1 7/8" laminating screws	none	N/A	0	2 or 1

These instructions are for the installation of through-penetration fire stop system in a minimum 5" thick steel or wood stud fire rated gypsum wallboard partitions as listed by Underwriters Laboratories Inc. Refer to above drawings and System Configuration Information for component details.

1. Cut hole in gypsum wallboard in required size to accommodate pipe penetration and allowable annular spacing. Do not exceed maximum specified hole diameter.
2. Install up to 4" I.D. ABS or PVC/CPVC(foam or solid core) vented (DWV) or closed (pressure) pipe. Support pipe rigidly on both sides of wall.
3. Clean all hole and pipe surfaces in penetration area to remove loose debris, dirt, oil, wax, grease, old caulking, and the like.
4. Install appropriate size Pipe Collar for corresponding plastic pipe diameter on both sides of wall. Secure collar in place through anchor tabs with minimum 1 7/8" gypsum laminating screws.

Wall Penetration – 1 or 2 Hour Rating

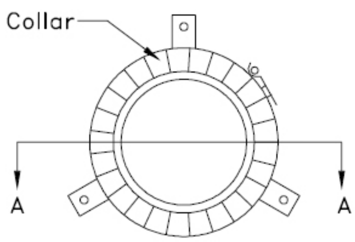


SYSTEM CONFIGURATION INFORMATION															
PRODUCT(S)			PENETRATING ITEM(S)			HOLE SIZE	ANNULAR SPACING		ADDITIONAL INSTALLATION MATERIALS AND AIDS			BACKING MATERIAL		ASTM E 814 RATING	
FILL MAT'L	MIN. THICK.	OTHER	TYPE	SIZE	INSULATION	MAX.	MIN.	MAX.	WIRE MESH	STEELE SLEEVE	OTHER	TYPE	DEPTH	T	F
Wrap Strip	1" both sides	none	ABS or PVC/CPVC pipe, SCH 40 (or heavier) closed/vented PEX SDR 9	up to 2"I. D. up to 1"	none	3"	5/16"	5/16"	none	none	none	none	N/A	0	2 or 1

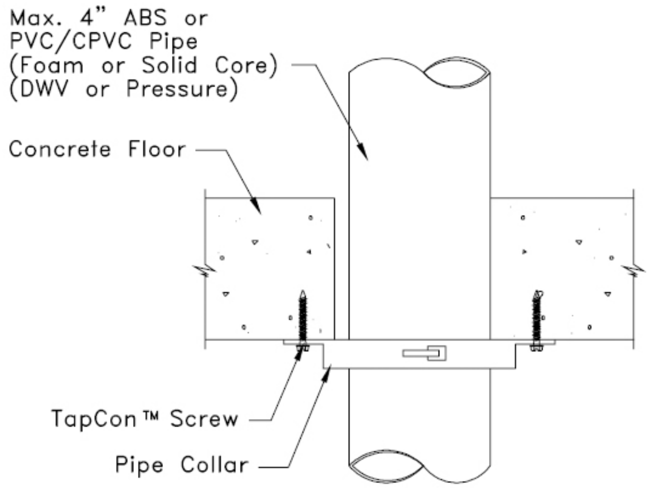
These instructions are for the installation of through-penetration fire stop system in a minimum 5" thick steel or wood stud fire rated gypsum wallboard partitions as listed by Underwriters Laboratories Inc. Refer to above drawings and System Configuration Information for component details.

1. Clean all hole and pipe surfaces in penetration area to remove loose debris, dirt, oil, wax, grease, old caulking, and the like.
2. Tightly wrap 1 layer of 1" wide Wrap Strip around pipe and secure with tie wire. Recess into annular space such that 1/4" extends beyond the surface of the wall on each side.

Floor Penetration – 3 Hour Rating



PLAN



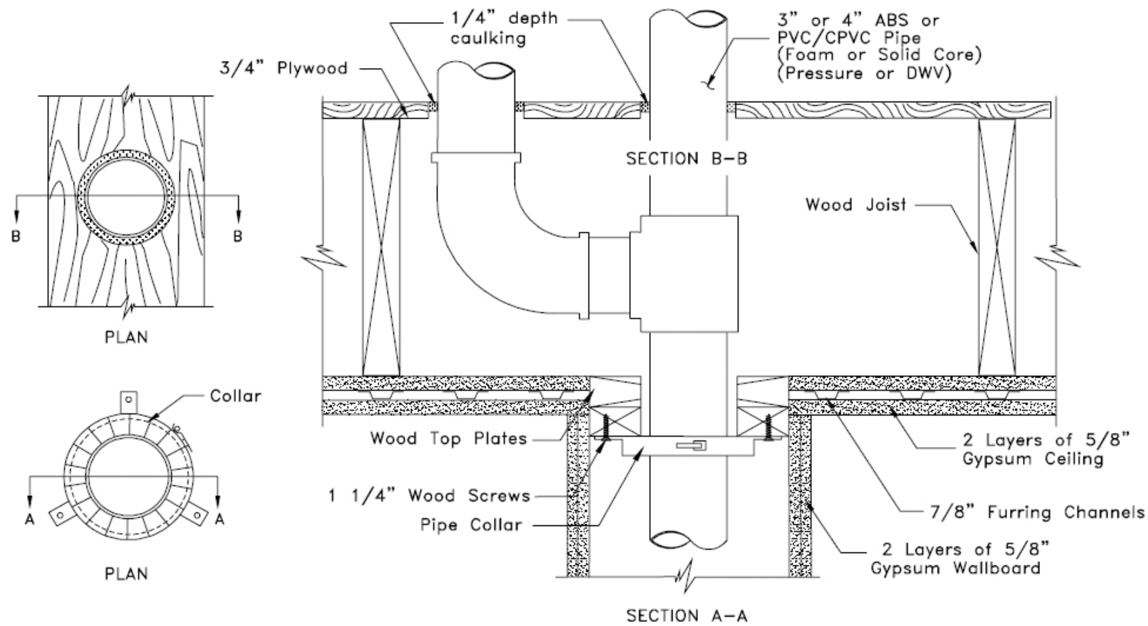
SECTION A–A

SYSTEM CONFIGURATION INFORMATION															
PRODUCT(S)			PENETRATING ITEM(S)			HOLE SIZE	ANNULAR SPACING		ADDITIONAL INSTALLATION MATERIALS AND AIDS			BACKING MATERIAL		ASTM E 814 RATING	
FILL MAT'L	MIN. THICK.	OTHER	TYPE	SIZE	INSULATION	MAX.	MIN.	MAX.	WIRE MESH	STEELE SLEEVE	OTHER	TYPE	DEPTH	T	F
pipe collar	none	none	ABS or PVC/CPVC (foam or solid core) SCH 40 (or heavier), closed or vented	Up to 4" I.D.	none	5"	0"	1/2"	none	none	1/4"x1 1/4" concrete anchor screws	none	N/A	3	3

These instructions are for the installation of through-penetration fire stop system in a minimum 4 1/2" thick lightweight or normal weight (100-150 pcf) concrete or hollow-core floors as listed by Underwriters Laboratories Inc. Refer to above drawings and System Configuration Information for component details.

1. Cut hole in concrete floor in required size to accommodate pipe penetration and allowable annular spacing. Do not exceed maximum specified hole diameter.
2. Install up to 4" I.D. ABS or PVC/CPVC(foam or solid core) vented (DWV) or closed (pressure) pipe. Support pipe rigidly on both sides of floor.
3. Clean all hole and pipe surfaces in penetration area to remove loose debris, dirt, oil, wax, grease, old caulking, and the like.
4. Install appropriate size Pipe Collar for corresponding plastic pipe diameter on bottom side of floor. Secure collar in place through anchor tabs with 1/4"x1 1/4" TapCon™ concrete anchor screws.

Floor Penetration – 2 Hour Rating

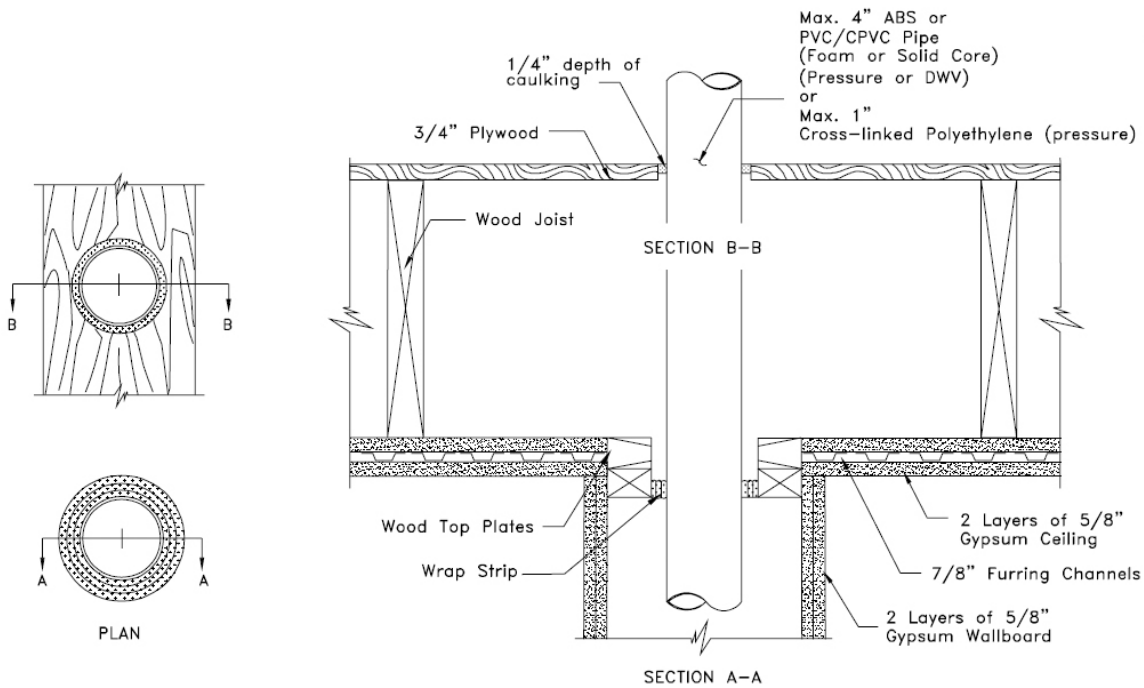


SYSTEM CONFIGURATION INFORMATION															
PRODUCT(S)			PENETRATING ITEM(S)			HOLE SIZE	ANNULAR SPACING		ADDITIONAL INSTALLATION MATERIALS AND AIDS			BACKING MATERIAL		ASTM E 814 RATING	
FILL MAT'L	MIN. THICK.	OTHER	TYPE	SIZE	INSULATION	MAX.	MIN.	MAX.	WIRE MESH	STEELE SLEEVE	OTHER	TYPE	DEPTH	T	F
pipe collar & 1000	None 1/4"	none	ABS or PVC/CPVC (foam or solid core) SCH 40 (or heavier), closed or vented	3" or 4" I.D.	none	5"	1/4"	1/4"	none	none	minimum 1 1/4" wood screws	none	N/A	2	2

These instructions are for the installation of through-penetration fire stop system in a wood floor/ceiling construction as listed by Underwriters Laboratories Inc. Refer to above drawings and System Configuration Information for component details.

1. Cut hole in wood floor and top plates to required size to accommodate pipe penetration and allowable annular spacing. Do not exceed maximum specified hole diameter.
2. Install 3"or 4 " I.D. ABS or PVC/CPVC(foam or solid core) vented (DWV) or closed (pressure) pipe. Support pipe rigidly on both sides of floor/ceiling.
3. Gun, trowel and/or pump sealant to a 1/4" depth in annular space on top of wood floor. Trowel sealant surfaces flush with floor surface and to a smooth defect-free finish.
4. Install appropriate size Pipe Collar for corresponding plastic pipe diameter on bottom side of wood plates. Secure collar in place through anchor tabs with 1 1/4" wood screws in conjunction with 1/4" x 5/8" washers.

Floor Penetration – 2 Hour Rating



SYSTEM CONFIGURATION INFORMATION															
PRODUCT(S)			PENETRATING ITEM(S)			HOLE SIZE	ANNULAR SPACING		ADDITIONAL INSTALLATION MATERIALS AND AIDS			BACKING MATERIAL		ASTM E 814 RATING	
FILL MAT'L	MIN. THICK.	OTHER	TYPE	SIZE	INSULATION	MAX.	MIN.	MAX.	WIRE MESH	STEELE SLEEVE	OTHER	TYPE	DEPTH	T	F
wrap strips & caulk	1" 1/4"	none	ABS or PVC/CPVC (foam or solid core) SCH 40 (or heavier), closed/vented PEX SDR 9	up to 4" I.D. up to 1"	none	6" 5"	1/2" (Plates) 1/4" (Ply-wood)	3/4" (Plates) 1/4" (Ply-wood)	none	none	none	none	N/A	2	2

These instructions are for the installation of through-penetration fire stop system in a wood floor/ceiling construction as listed by Underwriters Laboratories Inc. Refer to above drawings and System Configuration Information for component details.

1. Cut hole in wood floor and top plates to required size to accommodate pipe penetration and allowable annular spacing. Do not exceed maximum specified hole diameter.
2. Install up to 4 " I.D. ABS or PVC/CPVC(foam or solid core) vented (DWV) or closed (pressure) or up to 1" Crosslinked Polyethylene (pressure) pipe. Support pipe rigidly on both sides of floor/ceiling.
3. Gun, trowel and/or pump sealant to a 1/4" depth in annular space on top of wood floor. Trowel sealant surfaces flush with floor surface and to a smooth defect-free finish.
4. Tightly wrap 3 layers of 1" wide Wrap Strip around pipe from bottom side of top plates and recess into annular space flush with bottom surface of top plates. For pipes less than 3", use 2 layers of 1" wide wrap strips.

Appendix F: Conversion Charts & Useful Formulas

Source: Adapted from IPEX, Inc. and NIBCO, Inc.

Charts

Formulas

Charts

Table E-l. Pipe Capacity

Pipe Size (in.)	Outside Diameter – IPS OD Pipe			Volume for 1 foot length of pipe				
	inch	feet	cm	in^3	ft^3	cm^3	US Gal	Imp Gal
1/4	0.250	0.021	0.098	0.589	0.0003	9.648	0.003	0.002
3/8	0.375	0.031	0.148	1.325	0.001	21.708	0.006	0.005
1/2	0.500	0.042	0.197	2.355	0.001	38.591	0.010	0.008
3/4	0.750	0.063	0.295	5.299	0.003	86.831	0.023	0.019
1	1.000	0.083	0.394	9.420	0.005	154.366	0.041	0.034
1 1/4	1.250	0.104	0.492	14.719	0.009	241.196	0.064	0.053
1 1/2	1.500	0.125	0.591	21.195	0.012	347.322	0.092	0.076
2	2.000	0.167	0.787	37.680	0.022	617.462	0.163	0.136
3	3.000	0.250	1.181	84.780	0.049	1,389.290	0.367	0.306
4	4.000	0.333	1.575	150.720	0.087	2,469.849	0.652	0.543
5	5.000	0.417	1.969	235.500	0.136	3,859.139	1.019	0.849
6	6.000	0.500	2.362	339.120	0.196	5,557.159	1.468	1.222
8	8.000	0.667	3.150	602.880	0.349	9,879.395	2.610	2.173
10	10.000	0.833	3.937	942.000	0.545	15,436.554	4.078	3.396
12	12.000	1.000	4.724	1,356.480	0.785	22,228.638	5.872	4.890
14	14.000	1.167	5.512	1,846.320	1.068	30,255.646	7.993	6.655
16	16.000	1.333	6.299	2,411.520	1.396	39,517.578	10.439	8.693
18	18.000	1.500	7.087	3,052.080	1.766	50,014.435	13.212	11.002
20	20.000	1.667	7.874	3,768.000	2.181	61,746.216	16.312	13.582
24	24.000	2.000	9.449	5,425.920	3.140	88,914.551	23.489	19.559

Table E-2. Weights of Water

Units of Volume	Weight	
	pounds	kilograms
1 US Gallon	8.350	3.791
1 Imperial Gallon	10.020	4.549
1 litre	2.210	1.003
1 cubic yard	1,685.610	765.267
1 cubic foot	62.430	28.343
1 cubic inch	0.036	0.016
1 cubic cm	0.002	0.001
1 cubic metre	2,210.000	1,000.000

Table E-3. Decimal & Millimeter Equivalents of Fractions

Inches		Millimeters	Inches		Millimeters
Fractions	Decimals		Fractions	Decimals	
1/64	0.015625	0.397	33/64	0.515625	13.097
1/32	0.03125	0.794	17/32	0.53125	13.494
3/64	0.046875	1.191	35/64	0.546875	13.891
1/16	0.0625	1.588	9/16	0.5625	14.288
5/64	0.078125	1.984	37/64	0.578125	14.684
3/32	0.09375	2.381	19/32	0.59375	15.081
7/64	0.109375	2.778	39/64	0.609375	15.478
1/8	0.125	3.175	5/8	0.625	15.875
9/64	0.140625	3.572	41/64	0.640625	16.272
5/32	0.15625	3.969	21/32	0.65625	16.669
11/64	0.171875	4.366	43/64	0.671875	17.066
3/16	0.1875	4.763	11/16	0.6875	17.463
13/64	0.203125	5.159	45/64	0.703125	17.859
7/32	0.21875	5.556	23/32	0.71875	18.256
15/64	0.23475	5.953	47/64	0.734375	18.653
1/4	0.250	6.350	3/4	0.750	19.050
17/64	0.265625	6.747	49/64	0.765625	19.447
9/32	0.28125	7.144	25/32	0.78125	19.844
19/64	0.296875	7.541	51/64	0.796875	20.241
5/16	0.3125	7.938	13/16	0.8125	20.638
21/64	0.328125	8.334	53/64	0.828125	21.034
11/32	0.34375	8.731	27/32	0.83475	21.431
23/64	0.359375	9.128	55/64	0.859375	21.828
3/8	0.375	9.525	7/8	0.875	22.225
25/64	0.390625	9.922	57/64	0.890625	22.622
13/32	0.40625	10.319	29/32	0.90625	23.019
27/64	0.421875	10.716	59/64	0.921875	23.416
7/16	0.4375	11.113	15/16	0.9375	23.813
29/64	0.453125	11.509	61/64	0.953125	24.209
15/32	0.46875	11.906	31/32	0.96875	24.606
31/64	0.484375	12.303	63/64	0.984375	25.003
1/2	0.500	12.700	1	1.000	25.400

Table E-4. Volume Conversion

Units of Volume	in^3	ft^3	yd^3	cm^3	m^3	liter	U.S. gal.	Imp. gal.
cubic inch	1	0.00058	-	16.387	-	0.0164	0.0043	0.0036
cubic foot	1728	1	0.0370	28,317.8	0.0283	28.32	7.481	6.229
cubic yard	46,656	27	1	-	0.7646	764.55	201.97	168.8
cubic centimeter	0.0610	-	-	1	-	0.001	0.0003	0.0002
cubic meter	61,023.7	35.31	1.308	-	1	1000	264.17	220.0
liter	61.02	0.0353	0.0013	1000	0.001	1	0.2642	0.22
U.S. gallon	231	0.1337	0.0050	3785.4	0.0038	3.785	1	0.8327
Imp. gallon	277.42	0.1605	0.0059	4546.1	0.0045	4.546	1.201	1

Table E-5. Pressure Conversion

Units of Pressure	atm	bar	lb/in^2	lb/ft^2	kg/cm^2	kg/m^2	inch H_2O	inch Hg	inch air	ft H_2O	ft air	mm Hg	mm H_2O	kilopascal	N/m^2
atmosphere (atm)	1	0.987	0.068	-	0.968	-	0.002	0.033	-	0.029	-	0.001	-	0.01	-
bar	1.013	1	0.069	-	0.981	-	0.002	0.034	-	0.03	-	0.001	-	0.01	-
pound per square inch (psi)	14.7	14.5	1	0.007	14.22	0.001	0.036	0.491	-	0.434	0.001	0.019	0.001	0.145	-
pound per square foot (psf)	2,116	2,089	144	1	2,048	0.205	5.2	70.73	0.006	62.43	0.076	2.784	0.205	20.89	0.021
kilogram per square centimeter	1.033	1.02	0.07	-	1	0.0001	0.003	0.035	-	0.03	-	0.001	-	0.01	-
kilogram per square meter	10,332	10,197	703	4.88	10,000	1	25.4	345.3	0.031	304.8	0.373	13.6	1	101.97	0.102
inch of water (H_2O) (4°C)	406.78	401.46	27.68	0.192	393.7	0.039	1	13.6	0.001	12	0.015	0.535	0.039	4.015	0.004
inch of mercury (Hg) (0°C)	29.921	29.53	2.036	0.014	28.96	0.003	0.074	1	-	0.883	0.001	0.039	0.003	0.295	-
inch of air (15°C)	332,005	327,664	22,592	148.7	321,328	32.13	816.2	11,096	1	9,794	12	436.8	32.13	3,277	3.106
foot of water (4°C)	33.9	33.46	2.307	0.016	32.81	0.003	0.083	1.133	-	1	-	0.045	0.003	0.335	-
foot of air (15°C)	27,677	27,305	1,883	13.07	26,777	2.678	0.006	924.7	0.083	816.2	1	36.4	2.678	273.1	0.273
millimeter of mercury (0°C)	760	750	51.71	0.36	735.6	0.074	1.868	25.4	0.002	22.42	0.027	1	0.074	7.5	0.008
millimeter of water (4°C)	10,332	10,197	703	4.88	10,000	1	25.4	345.3	0.031	304.8	0.373	13.6	1	101.97	0.102
kilopascal (kP)	101.3	100	6.89	0.048	98.07	0.01	0.249	3.386	-	2.99	0.004	0.133	0.01	1	0.001
Newton per square meter	-	-	-	0.021	-	0.102	0.004	-	3.277	-	0.273	0.008	0.102	0.001	1

Table E-6. Flow Conversion

Units of Flow Rate	US gps	US gpm	US gph	US gpd	Imp gps	Imp gpm	Imp gph	Imp gpd	liters/sec	liters/min	liters/hr	liters/day
US gal/sec (gps)	1	0.017	-	-	1.2	0.02	-	-	0.264	0.004	-	-
US gal/min (gpm)	60	1	0.017	0.001	72.06	1.2	0.02	0.001	15.85	0.264	0.004	-
US gal/hr (gph)	3,600	60	1	0.042	4,323	72.06	1.2	0.05	951.02	15.85	0.264	0.011
US gal/day (gpd)	86,400	1,440	24	1	103,762	1,729.40	28.82	1.2	22,824	380.41	6.34	0.264
Imperial gal/sec	0.833	0.014	-	-	1	0.017	-	-	0.22	0.004	-	-
Imperial gal/min	49.96	0.833	0.014	0.001	60	1	0.017	0.001	13.2	0.22	0.004	-
Imperial gal/hr	2,997.60	49.96	0.833	0.035	3,600	60	1	0.042	791.89	13.2	0.22	0.009
Imperial gal/day	71,943	1,199	19.98	0.833	86,400	1,440	24	1	19,005	316.76	5.279	0.22
Liters/sec	3.79	0.063	0.002	-	4.55	0.076	0.001	-	1	0.017	-	-
Liters/min	227.12	3.785	0.063	0.003	272.77	4.55	0.076	0.003	60	1	0.017	0.001
Liters/hr	13,627	227.12	3.785	0.158	16,366	272.77	4.55	0.189	3,600	60	1	0.042
Liters/day	327,060	5,451	90.85	3.785	392,782	6,546	109.11	4.55	86,400	1,440	24	1
Cubic ft/sec (cfs)	0.134	0.002	-	-	0.161	0.003	-	-	0.035	0.001	-	-
Cubic ft/min (cfm)	8.02	0.134	0.002	-	9.633	0.161	0.003	-	2.119	0.035	0.001	-
Cubic ft/hr (cfh)	481.25	8.02	0.134	0.006	577.96	9.63	0.161	0.007	127.13	2.119	0.035	0.001
Cubic ft/day (cfd)	11,550	192.5	3.21	0.134	13,871	231.18	3.853	0.161	3,051.20	50.85	0.848	0.001
Acre in/min	0.002	-	-	-	0.003	-	-	-	0.001	-	-	-
Acre in/hr	0.133	0.002	-	-	0.159	0.003	-	-	0.035	-	-	-
Acre in/day	3.182	0.053	0.001	-	3.821	0.064	0.001	-	0.841	0.001	-	-
Cubic m/sec	0.004	-	-	-	0.005	-	-	-	0.001	-	-	-
Cubic m/min	0.227	0.004	-	-	0.273	0.005	-	-	0.06	0.001	-	-
Cubic m/hr	13.628	0.227	0.004	-	16.366	0.273	0.005	-	3.6	0.06	0.001	-
Cubic m/day	327.06	5.451	0.091	0.004	392.78	6.546	0.109	0.005	86.4	1.44	0.024	0.001

Units of Flow Rate	ft^3/sec	ft^3/min	ft^3/hr	ft^3/day	Acre in/min	Acre in/hr	Acre in/day	m^3/sec	m^3/min	m^3/hr	m^3/day
US gal/sec (gps)	7.48	0.125	0.002	-	452.6	7.54	0.31	264.2	4.4	0.073	0.003
US gal/min (gpm)	448.8	7.48	0.125	0.005	27,154	452.6	18.86	15,850	264.2	4.403	0.183
US gal/hr (gph)	26,930	448.83	7.481	0.312	1.629E+06	27,154	1,131	951,019	15,850	264.17	11.007
US gal/day (gpd)	646,317	10,772	179.53	7.481	3.910E+07	651,703	27,154	2.282E+07	380,408	6,340	264.17
Imperial gal/sec	6.229	0.104	0.002	-	376.8	6.28	0.26	220	3.67	0.061	0.003
Imperial gal/min	373.73	6.229	0.104	0.004	22,611	376.8	15.7	13,198	220	3.666	0.153
Imperial gal/hr	22,424	373.73	6.229	0.259	1.357E+06	22,611	942.1	791,889	13,198	220	9.165
Imperial gal/day	538,171	8,970	149.49	6.229	3.256E+07	542,656	22,611	1.901E+07	316,756	5,279	220
Liters/sec	28.32	0.472	0.008	-	1,713	28.6	1.19	1,000	16.67	0.278	0.012
Liters/min	1,699	28.32	0.472	0.2	102,790	1,713	71.38	60,000	1,000	16.67	0.694
Liters/hr	101,941	1,669	28.32	1.18	6.167E+06	102,790	4,283	3.600E+06	60,000	1,000	42.67
Liters/day	2,446,575	40,776	679.6	28.32	1.480E+08	2.467E+06	102,790	8.640E+07	1.440E+06	24,000	1,000
Cubic ft/sec (cfs)	1	0.017	-	-	60.5	1.008	0.042	35.31	0.589	0.01	-
Cubic ft/min (cfm)	60	1	0.017	-	3,630	60.5	2.52	2,119	35.31	0.59	0.025
Cubic ft/hr (cfh)	3,600	60	1	0.042	217,800	3,630	151.25	127,133	2,119	35.31	1.471
Cubic ft/day (cfd)	86,400	1,440	24	1	5.227E+06	87,120	3,630	3,051,187	50,853	847.55	35.31
Acre in/min	0.017	-	-	-	1	0.017	0.001	0.584	0.01	-	-
Acre in/hr	0.992	0.001	-	-	60	1	0.042	35.02	0.584	0.01	-
Acre in/day	23.8	0.033	0.006	-	1,440	24	1	840.55	14.001	0.233	0.001
Cubic m/sec	0.028	-	-	-	1.71	0.029	0.001	1	0.017	-	-
Cubic m/min	1.7	0.028	-	-	102.8	1.71	0.071	60	1	0.017	0.001
Cubic m/hr	101.94	1.7	0.028	0.001	6,167	102.8	4.283	3,600	60	1	0.042
Cubic m/day	2446.6	40.78	0.68	0.028	148,018	2,467	102.79	86,400	1,400	24	1

Table E-7. Temperature Conversion

°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
-60	-51	22	-5.6	50	10.0	78	25.6	160	71
-50	-46	23	-5.0	51	10.6	79	26.1	170	77
-40	-40	24	-4.4	52	11.1	80	26.7	180	82
-30	-34	25	-3.9	53	11.7	81	27.2	190	88
-20	-29	26	-3.3	54	12.2	82	27.8	200	92
-10	-23.0	27	-2.8	55	12.8	83	28.3	210	99
0	-17.8	28	-2.2	56	13.3	84	28.9	212	100
1	-17.2	29	-1.7	57	13.9	85	29.4	220	104
2	-16.7	30	-1.1	58	14.4	86	30.0	230	110
3	-16.1	31	-0.6	59	15.0	87	30.6	240	116
4	-15.6	32	0.0	60	15.6	88	31.1	250	121
5	-15.0	33	0.6	61	16.1	89	31.7	260	127
6	-14.4	34	1.1	62	16.7	90	32.2	270	132
7	-13.9	35	1.7	63	17.2	91	32.8	280	138
8	-13.3	36	2.2	64	17.8	92	33.3	290	143
9	-12.8	37	2.8	65	18.3	93	33.9	300	149
10	-12.2	38	3.3	66	18.9	94	34.4	310	154
11	-11.7	39	3.9	67	19.4	95	35.0	320	160
12	-11.1	40	4.4	68	20.0	96	35.6	330	166
13	-10.6	41	5.0	69	20.6	97	36.1	340	171
14	-10.0	42	5.6	70	21.1	98	36.7	350	177
15	-9.4	43	6.1	71	21.7	99	37.2	360	182
16	-8.9	44	6.7	72	22.2	100	37.8	370	188
17	-8.3	45	7.2	73	22.8	110	43	380	193
18	-7.8	46	7.8	74	23.3	120	49	390	199
19	-7.2	47	8.3	75	23.9	130	54	400	204
20	-6.7	48	8.9	76	24.4	140	60		
21	-6.1	49	9.4	77	25.0	150	66		

Degrees Celsius $°C = \frac{5}{9}(°F - 32)$ Degrees Fahrenheit $°F = \frac{9}{5}°C + 32$

Degrees Kelvin $°T = °C + 273.2$ Degrees Rankine $°R = °F + 459.7$

Table E-8. Length Conversion

Units of Length	in.	ft.	yd.	mile	mm	cm	m	km
inch	1	0.0833	0.0278	-	25.4	2.54	0.0254	-
foot	12	1	0.3333	-	304.8	30.48	0.3048	-
yard	36	3	1	-	914.4	91.44	0.9144	-
mile	-	5280	1760	1	-	-	1609.3	1.609
millimeter	0.0394	0.0033	-	-	1	0.100	0.001	-
centimeter	0.3937	0.0328	0.0109	-	10	1	0.01	-
meter	39.37	3.281	1.094	-	1000	100	1	0.001
kilometer	-	3281	1094	0.6214	-	-	1000	1

(1 micron = 0.001 millimeter)

Table E-9. Area Conversion

Units of Area	in^2	ft^2	acre	sq mile	cm^2	m^2	sq hectare	km^2
sq inch	1	0.0069	-	-	6.452	-	-	-
sq foot	144	1	-	-	929.0	0.0929	-	-
acre	-	43,560	1	0.0016	-	4047	0.4047	0.004
sq mile	-	2.79E+6	640	1	-	2.59E+6	259.0	2.59
sq centimeter	0.155	0.001	-	-	1	0.0001	-	-
sq meter	1550	10.76	-	-	10,000	1	0.0001	-
hectare	-	1.076E+5	2.471	0.004	-	10,000	1	0.01
sq kilometre	-	1.076E+7	247	0.386	-	1.0E+6	100	1

Table E-10. Weight Conversion

Units of Weight	grain	oz	lb	ton	gram	kg	metric tonne
grain	1	-	-	-	0.0648	-	-
ounce	437.5	1	0.0625	-	28.35	0.0283	-
pound	7000	16	1	0.0005	453.6	0.4536	-
ton	-	32,000	2000	1	-	907.2	0.9072
gram	15.43	0.0353	-	-	1	0.001	-
kilogram	-	35.27	2.205	-	1000	1	0.001
metric tonne	-	35,274	2205	1.1023	-	1000	1

Table E-11. Density Conversion

Units of Density	lb/in^3	lb/ft^3	lb/gal	g/cm^3	g/l
pound/cubic in.	1	1728	231.0	27.68	27,680
pound/cubic ft.	-	1	0.1337	0.0160	16.019
pound/gal.	0.00433	7.481	1	0.1198	119.83
gram/cubic cm	0.0361	62.43	8.345	1	1000.0
gram/liter	-	0.0624	0.00835	0.001	1

Table E-12. Energy Conversion

Units of Energy	ft lb	BTU	g cal	Joule	kw hr	hp hr
foot-pound	1	0.001285	0.3240	1.3556	-	-
British Thermal Unit	778.2	1	252.16	1054.9	-	-
gram calorie	3.0860	0.003966	1	4.1833	-	-
Int. Joule	0.7377	0.000948	0.2390	1	-	-
Int. kilowatt-hour	2,655,656	3412.8	860,563	-	1	1.3412
horsepower-hour	1,980,000	2544.5	641,617	-	0.7456	1

Table E-13. Power Conversion

Units of Power	hp	watt	kw	BTU/sec	BTU/min	BTU/hr	ft lb/sec	ft lb/min	ft lb/hr	cal/sec	cal/min	cal/hr	j/sec	j/min	j/hr
horsepower (international)	1	0.001	1.34	1.41	0.24	-	0.002	-	-	0.006	-	-	0.001	-	-
watt	745.7	1	1,000	1,055	17.58	0.29	1.36	0.023	-	4.19	0.07	0.001	1	0.017	-
kilowatt	0.746	0.001	1	1.06	0.018	-	0.001	-	-	0.004	-	-	0.001	-	-
BTU per second	0.707	0.001	0.948	1	0.017	-	0.001	-	-	0.004	-	-	-	-	-
BTU per minute	42.41	0.057	56.87	60	1	0.017	0.077	0.001	-	0.238	0.004	-	0.057	-	-
BTU per hour	2,544	3.412	3,412	3,600	60	1	4.63	0.077	0.001	14.29	0.238	0.004	3.412	0.057	0.001
foot pound force per second	550	0.738	738	778	12.97	0.216	1	0.017	-	3.09	0.05	0.001	0.738	0.012	-
foot pound force per minute	33,000	44.25	44,254	46,690	778	12.97	60	1	0.017	185.3	3.09	0.05	44.25	0.738	0.012
foot pound force per hour	1.980E+06	2,655	2.655E+06	2.801E+06	46.69	778	3,600	60	1	11,117	185.28	3.09	2,655	44.25	0.738
calories per second	178	0.239	238.9	252	4.2	0.07	0.324	0.005	-	1	0.017	-	0.239	0.004	-
calories per minute	10,686	14.33	14,331	15,120	252	4.2	19.43	0.324	0.005	60	1	0.017	14.33	0.239	0.004
calories per hour	641,186	859.85	859,845	907,185	15,120	252	1,166	19.43	0.324	3,600	60	1	860	14.33	0.239
joules per second	746	1	1,000	1,055	17.58	0.29	1.36	0.023	-	4.19	0.07	0.001	1	0.017	-
joules per minute	44,742	60	60,000	63,303	1,055	17.58	81.35	1.36	0.023	251.2	4.19	0.07	60	1	0.017
joules per hour	2.685E+06	3,600	3.600E+06	3.798E+06	63,303	1,055	4,881	81.35	1.36	15,072	251.2	4.19	3,600	60	1

Table E-14. Dimensions, Weights, & Pressure Ratings for PVC Pipe

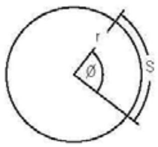
Schedule (DR) SDR	Nominal Pipe Size in	Nominal Pipe Size mm	Outside Diameter in	Outside Diameter mm	Max Working Pressure psi	Max Working Pressure kPa	Min Wall Thickness in	Min Wall Thickness mm	Avg Inside Diameter in	Avg Inside Diameter mm	Weight of pipe PVC lbs/ft	Weight of pipe PVC kg/m
Sch 80 (DR 4.5)	1/4	6	0.540	13.7	1130	7 790	0.119	3.02	.302	7.67	0.10	0.150
Sch 80 (DR 5.4)	3/8	10	0.675	17.1	920	6 340	0.126	3.20	.423	10.74	0.14	0.210
Sch 40 (DR 8)	1/2	12	0.840	21.3	600	4 140	0.109	2.76	.602	15.26	0.17	0.253
Sch 80 (DR 6)					850	5 860	0.147	3.72	.526	13.34	0.21	0.313
SDR 21					200	1 380	0.080	2.02	.660	16.74	0.13	0.193
Sch 40 (DR 10)	3/4	20	1.050	26.70	480	3 300	0.113	2.86	.804	20.46	0.22	0.327
Sch 80 (DR 7)					690	4 760	0.154	3.90	.722	18.38	0.28	0.417
SDR 21					200	1 380	0.060	2.02	.870	22.14	0.13	0.194
Sch 40 (DR 10)	1	25	1.315	33.40	450	3 100	0.133	3.38	1.029	26.14	0.33	0.491
Sch 80 (DR 8)					630	4 340	0.179	4.54	.936	23.78	0.41	0.610
SDR 21					200	1 380	0.080	2.02	1.135	28.84	0.21	0.313
Sch 40 (DR 12)	1 1/4	32	1.660	42.15	370	2 550	0.141	3.56	1.360	34.53	0.44	0.655
Sch 80 (DR 9)					520	3 590	0.191	4.84	1.255	31.87	0.57	0.848
SDR 21					200	1 380	0.080	2.02	1.480	37.59	0.27	0.402
Sch 40 (DR 13)	1 1/2	40	1.900	48.25	330	2 280	0.145	3.68	1.590	40.37	0.52	0.774
Sch 80 (DR 10)					470	3 240	0.200	5.08	1.476	37.49	0.69	1.026
SDR 21					200	1 380	0.090	2.28	1.700	43.17	0.35	0.521
SDR 26					160	1 100	0.080	2.02	1.720	43.69	0.32	0.476
Sch 40 (DR 16)	2	50	2.375	60.35	280	1 930	0.154	3.90	2.047	52.03	0.70	1.042
Sch 80 (DR 11)					400	2 760	0.218	5.54	1.913	48.61	0.96	1.429
SDR 21					200	1 380	0.113	2.86	2.129	54.11	0.54	0.804
SDR 26					160	1 100	0.091	2.30	2.173	55.23	0.45	0.670
Sch 40 (DR 14)	2 1/2	65	2.875	73.00	300	2 070	0.203	5.16	2.445	62.08	1.11	1.652
Sch 80 (DR 11)					420	2 900	0.276	7.00	2.290	58.16	1.46	2.173
SDR 21					200	1 380	0.137	3.48	2.581	65.54	0.78	1.161
SDR 26					160	1 100	0.110	2.78	2.635	66.92	0.64	0.952
Sch 40 (DR 16)	3	75	3.500	88.90	260	1 790	0.216	5.48	3.042	77.28	1.45	2.158
Sch 80 (DR 12)					370	2 550	0.300	7.62	2.864	72.74	1.96	2.917
SDR 21					200	1 380	0.167	4.24	3.146	79.92	1.14	1.697
SDR 26					160	1 100	0.135	3.42	3.210	81.54	0.94	1.399
SDR 32.5					125	860	0.108	2.74	3.264	82.90	0.77	1.146
SDR 41					100	690	0.085	2.16	3.310	84.08	0.63	0.938
Sch 40 (DR 19)	4	100	4.500	114.30	220	1 520	0.237	6.02	3.998	101.58	2.07	3.081
Sch 80 (DR 13)					320	2 210	0.337	8.56	3.786	96.16	2.87	4.271
SDR 21					200	1 380	0.214	5.44	4.046	102.76	1.88	2.798
SDR 26					160	1 100	0.173	4.38	4.133	105.00	1.54	2.292
SDR 32.5					125	860	0.138	3.50	4.204	106.78	1.25	1.860
SDR 41					100	690	0.110	2.78	4.260	108.22	1.02	1.518
Sch 40 (DR 22)	5	125	5.563	141.30	190	1 310	0.258	6.54	5.016	127.42	2.81	4.182
Sch 80 (DR 15)					290	2 000	0.375	9.52	4.768	121.12	4.02	5.982
SDR 21					200	1 380	0.265	6.72	5.001	127.04	2.88	4.286
SDR 26					160	1 100	0.214	5.44	5.107	129.74	2.35	3.497
SDR 32.5					125	860	0.171	4.34	5.199	132.08	1.89	2.813
SDR 41					100	690	0.136	3.44	5.271	133.90	1.53	2.277
Sch 40 (DR 24)	6	150	6.625	168.30	180	1 240	0.280	7.10	6.031	153.22	3.65	5.432
Sch 80 (DR 16)					280	1 930	0.432	10.96	5.709	145.04	5.48	8.155
SDR 21					200	1 380	0.315	8.02	5.955	151.28	4.09	6.087
SDR 26					160	1 100	0.255	6.48	6.084	154.56	3.33	4.956
SDR 32.5					125	860	0.204	5.18	6.193	157.32	2.69	4.003
SDR 41					100	690	0.161	4.12	6.281	159.56	2.15	3.200

psi @ 73°F
kPa @ 23°C
weight of pipe is for plain end

Table E-14. Dimensions, Weights, & Pressure Ratings for PVC Pipe (cont.)

Schedule	Nominal Pipe Size		Outside Diameter		Max Working Pressure		Min Wall Thickness		Avg Inside Diameter		Weight of pipe PVC	
(DR) SDR	in	mm	in	mm	psi	kPa	in	mm	in	mm	lbs/ft	kg/m
Sch 40 (DR 27)	8	200	8.625	219.05	160	1 100	0.322	8.18	7.941	201.71	5.50	8.185
Sch 80 (DR 17)					250	1 720	0.500	12.70	7.565	192.13	8.32	12.382
SDR 21					200	1 380	0.411	10.40	7.756	196.99	6.91	10.283
SDR 26					160	1 100	0.332	8.42	7.921	201.79	5.65	8.408
SDR 32.5					125	860	0.266	6.72	8.063	204.79	4.55	6.771
SDR 41					100	690	0.210	5.32	8.180	207.77	3.63	5.402
Sch 40 (DR 30)	10	250	10.750	273.05	140	970	0.365	9.26	9.976	253.41	7.78	11.578
Sch 80 (DR 18)					230	1 590	0.593	15.06	9.493	241.13	11.81	17.576
SDR 21					200	1 380	0.512	12.98	9.667	245.55	10.73	15.968
SDR 26					160	1 100	0.413	10.48	9.874	250.81	8.76	13.036
SDR 32.5					125	860	0.331	8.40	10.048	255.23	7.08	10.536
SDR 41					100	690	0.262	6.66	10.195	258.95	5.64	8.393
Sch 40 (DR 32)	12	300	12.750	323.90	130	900	0.406	10.30	11.888	302.04	10.30	15.328
Sch 80 (DR 19)					230	1 590	0.687	17.44	11.294	286.92	16.98	25.269
SDR 21					200	1 380	0.607	15.38	11.465	291.28	15.10	22.471
SDR 26					160	1 100	0.490	12.44	11.711	297.52	12.35	18.379
SDR 32.5					125	860	0.392	9.96	11.919	302.78	9.94	14.792
SDR 41					100	690	0.311	7.90	12.091	307.16	7.94	11.816
Sch 40 (DR 32)	14	350	14.000	355.60	130	910	0.438	11.13	13.072	332.03	12.18	18.130
Sch 80 (DR 19)					220	1 540	0.750	19.05	12.412	315.22	20.34	30.270
SDR 21					200	1 380	0.665	16.88	12.590	319.80	18.18	27.065
SDR 26					160	1 100	0.538	13.66	12.859	326.62	14.88	22.144
SDR 32.5					125	860	0.431	10.76	13.100	332.78	11.83	17.615
SDR 41					100	690	0.342	8.66	13.277	337.24	9.58	14.260
Sch 40 (DR 32)	16	400	16.000	406.40	130	910	0.500	12.70	14.936	379.38	15.96	23.75
Sch 80 (DR 19)					220	1 540	0.843	21.41	14.224	361.29	26.03	38.74
SDR 21					200	1 380	0.760	19.30	14.388	365.48	23.76	35.36
SDR 26					160	1 100	0.615	15.62	14.696	373.28	19.41	28.89
SDR 32.5					125	860	0.492	12.32	14.970	380.24	15.47	22.99
SDR 41					100	690	0.391	9.90	15.172	385.38	12.52	18.63
Sch 40 (DR 32)	18	450	18.000	457.20	130	910	0.562	14.27	16.809	429.46	20.11	29.93
Sch 80 (DR 19)					220	1 540	0.937	23.80	16.014	406.76	32.76	48.75
SDR 21					200	1 380	0.857	21.72	16.182	411.14	30.11	44.81
SDR 26					160	1 100	0.693	17.60	16.531	419.88	24.62	36.64
SDR 32.5					125	860	0.554	14.06	16.825	427.36	19.86	29.55
SDR 41					100	690	0.440	11.14	17.065	433.46	15.92	23.69
Sch 40 (DR 34)	20	500	20.000	508.00	120	840	0.593	15.06	18.743	476.07	23.62	35.15
Sch 80 (DR 19)					220	1 450	1.031	26.19	17.814	452.48	40.09	59.66
SDR 21					200	1 380	0.952	24.12	17.982	456.86	37.17	55.32
SDR 26					160	1 100	0.770	19.56	18.368	466.54	30.37	45.20
SDR 32.5					125	860	0.615	15.62	18.696	474.88	24.47	36.42
SDR 41					100	690	0.489	12.42	18.963	481.66	19.61	29.18
Sch 40 (DR 35)	24	600	24.000	609.60	120	840	0.687	17.45	22.544	572.62	32.87	48.92
Sch 80 (DR 20)					210	1 470	1.218	30.94	21.418	544.02	56.88	84.65
SDR 21					200	1 380	1.143	28.96	21.576	548.20	53.54	79.68
SDR 26					160	1 100	0.924	23.46	22.041	559.86	43.77	65.14
SDR 32.5					125	860	0.740	18.80	22.431	569.74	35.35	52.61
SDR 41					100	690	0.585	14.86	22.760	578.10	28.12	41.84

Formulas



Circle

Diameter = 2R

Circumference = $\pi D = 2\pi R$

Area = πR^2

Length of Circular Arc

$S = Ø \times \left(\frac{\pi}{180}\right) \times r$ Ø in degrees

$S = Ø \times r$ Ø in radians

Area of Circle Sector

$A = \times \left(\frac{Ø}{360}\right) \times \pi \times r^2$ Ø in degrees

$A = \times \left(\frac{Ø}{2}\right) \times r^2$ Ø in radians

Equation of a Circle (cartesian co-ordinates)
- for a circle with center (j, k) and radius (r)

$(x - j)^2 + (y - k)^2 = r^2$

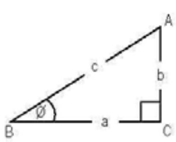
Equation of a line (quadratic formula)

$ax + by + c = 0$

or

$ax^2 + bx + c = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$



Trigonometry

$\sin Ø = \frac{b}{c}$

$\cos Ø = \frac{a}{c}$

$\tan Ø = \frac{b}{a}$

Sine Law

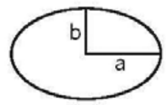
$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} = 2R$$

Cosine Law

$c^2 = a^2 + b^2 - 2ab \cos C$

$b^2 = a^2 + c^2 - 2ac \cos B$

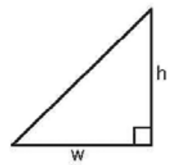
$a^2 = b^2 + c^2 - 2bc \cos A$



Ellipse

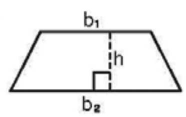
Area = $\pi \times a \times b$

Circumference = $\frac{1 + 4(a-b)^2}{((3a + 5b)(5a + 3b))}$



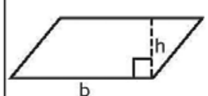
Triangle

Area = $\frac{w \times h}{2}$



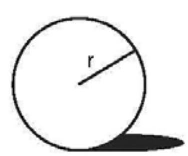
Trapezoid

Area = $\frac{1}{2}(b_1 + b_2) \times h$



Parallelogram

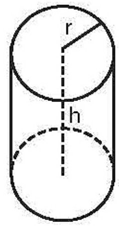
Area = $b \times h$



Sphere

Surface Area = $4 \pi r^2$

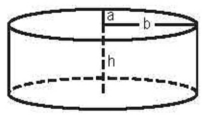
Volume = $\frac{4}{3} \pi r^3$



Cylinder

Surface Area = $(2 \pi r^2) + (2 \pi r h)$

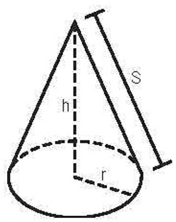
Volume = $\pi r^2 h$



Elliptical Tank

Surface Area = $2 \pi \left(\sqrt{\frac{a^2 + b^2}{2}} \right) h + (2\pi ab)$

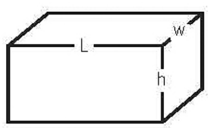
Volume = πabh



Cone

Surface Area = $\pi r S$

Volume = $\pi r^2 \times \frac{h}{3}$



Rectangular Solid

Surface Area = $2 (Lw + Lh + wh)$

Volume = $L \times w \times h$

Glossary of Plastic and Piping Terminology

Definitions shown are from industry literature sources including the Plastic Pipe and Fittings Association, "Plastic Piping Systems" authored by David A. Chasis and others.

Abrasion: Wear or scour by hydraulic traffic.

Abutment: A wall supporting the end of a bridge or span, and sustaining the pressure of the abutting earth.

Acceptance test: An investigation performed on an individual lot of a previously qualified product, by or under the observation of, the purchaser to establish conformity with a purchase agreement.

Acid vent: A pipe venting an acid waste system.

Acid waste: A pipe that conveys liquid waste matter having a pH of 6.9 or less.

Acme Thread: A screw thread, the profile of which is between the square and V threads, used extensively for feed screws. The included angle between the flanks of the thread is 29° as compared to 60° for the unified thread.

Acrylonitrile- butadiene-styrene (ABS) pipe and fitting plastics: Plastics containing polymers and/or blends of polymers, in which the minimum butadiene content is 6%, the minimum acrylonitrile content is 15%, the minimum styrene and/or substituted styrene content is 15%, and the maximum content of all other monomers is not more than 5%: they also contain lubricants, stabilizers, and colorants.

Adapter fitting: (1) Any of various fittings designed to mate or to fit to each other two pipes or fittings that are different in design, when connecting the two together would otherwise not be possible. (2) A fitting that serves to connect two different tubes or pipes to each other, such as copper tube to iron pipe.

Additive: A substance added in a small amount for a special purpose such as to reduce friction, corrosion, and the like.

Adhesive: A substance capable of holding materials together by surface attachment.

Aerial sewer: An unburied sewer (generally sanitary type) supported on pedestals or bents to provide a suitable grade line.

Aging: The effect of exposing plastics to the environment for a length of time. The specific effect and degree of aging depend on the moisture, temperature, and composition of the environment in addition to the length of exposure.

Air vent: Small outlets for preventing gas entrapment.

Ambient temperature: The prevailing temperature in the immediate vicinity, or the temperature of the medium surrounding an object.

Anchor: A device used to fasten or secure pipes to the building or structure.

Angle of bend: In a pipe, the angle between radial lines from the beginning and end of the bend to the center.

Angle of Repose: The angle which the sloping face of a bank of loose earth, gravel, or other material, makes with the horizontal.

Anhydrous: Free of water, especially water of crystallization.

Annulus or Annuli: The gap between the penetrating item and the outside edge of the hole (fire stops).

Antioxidant: A compounding ingredient added to a plastic composition to retard the degradation of the plastics' properties caused by contact with oxygen (aid), particularly at or exposure to high temperatures.

Artificial weathering: The exposure of plastics to cyclic laboratory conditions involving changed in temperature, relative humidity, and ultraviolet radiant energy, with or without direct water spray, in an attempt to produce changes in the material similar to those observed after long-term continuous outdoor exposure. (Note: The laboratory exposure conditions are usually intensified beyond those encountered in actual out-door exposure in an attempt to achieve an accelerated effect. This definition does not involve exposure to special conditions such as ozone, salt spray, industrial gages, and the like.)

Backer Rod: A cylindrical polyurethane or polyethylene foam material used to provide support and set the proper depth of material for gunned or troweled in place sealant (fire stops).

Backfill: That portion of the trench excavation that is replaced after the buried pipe line has been laid with the material above the pipe (up to the original earth line).

Backfill Density: Percent compaction for pipe backfill (required or expected).

Backing Material: Combustible or noncombustible material used to provide support for gunned or troweled in sealant or caulk.

Ball check valve: A device used to stop the flow of media in one direction while allowing flow in the opposite direction. The closure member used is spherical or ball shaped.

Ball valve: A valve with a ball-shaped disk with a hole through the center of the ball, providing straight-through flow. A quarter-turn of the handle fully opens or closed the valve for quick shut off.

Base (course): A layer of specified or selected material of planned thickness, constructed on the subgrade (natural foundation) or subbase for the purpose of distributing load, providing drainage or upon which a wearing surface or a drainage structure is placed.

Baume gravity: Arbitrary scale for measuring the density of liquids: the unit used is the "Baume" (Be) degree. The scale uses an inverse ration of the specific gravity (sp. Fr.) scale:

$$\text{sp. gr.} = \frac{140}{130 + \text{Be degree}}$$

(for liquids *lighter* than water)

$$\text{sp. gr.} = \frac{145}{145 - \text{Be degree}}$$

(for liquids *heavier* than water)

This permits the translation of Baume gravity to specific gravity. For instance, when floated in pure water, the Baume hydrometer indicated 10° Be, while the specific gravity scale reads 1.00. The Baume scale is employed by the U.S. National Bureau of Standards for all liquids except oils.

Beam loading: The application of a load to a pipe between two points of support; it is usually expressed in pounds and the distance between the centers of supports.

Bedding: The earth or other material on which a pipe or conduit is supported.

Bell and spigot joints: One side of the fitting or pipe is belled or socket; the other end is plain-ended pipe.

Bell end: The enlarged portion of a pipe that resembles the socket portion of a fitting and that is intended to make a joint by inserting a piece of pipe into it. Joining may be accomplished by solvent cements, adhesives, or mechanical techniques.

Berm: The space between the toe of a slope and excavation made for Bedding – The earth or other material on which a pipe or conduit is supported.

Binder: The part of adhesive composition responsible for adhesive forces.

Biological Corrosion: Corrosion that results from a reaction between the Pipe material and organisms such as bacterial, algae, and fungi.

Blister: The elevated part of the surface of a plastic caused by trapped air, moisture, solvent; it can be caused by insufficient adhesive, inadequate curing time, or excessive temperature or pressure.

Bond: The attachment at the interface or exposed surfaces between an adhesive and an adherent; to attach materials together with adhesives.

Branch: Any part of a piping system other than a main, riser, or stack.

Branch interval: A length of soil or waste stack corresponding in general to a story height- but in no case less than 8 ft (2.4 m) – within which the horizontal branches from one floor or story of a building are connected to the stack.

Branch tee: A tee having one side branch.

Branch vent: A vent connecting one or more individual vents with a vent stack or stack vent.

British thermal unit (Btu): The quantity of energy needed to heat one pound of water from 59° F to 60° F at a standard barometric pressure: 1 Btu = 0.252 kcal = 0.000293 kWh.

Brittleness Temperature: Temperature at which 50% of the tested specimens will fail when subjected to an impact blow.

Bubble tight: The condition of a valve seat that, when closed, prohibits the leakage of visible bubbles.

Building Sewer: The conduit that connects building wastewater sources to the public or street sewer, including lines serving homes, public buildings, commercial establishments, and industrial structures. The building sewer is referred to in two sections: (1) the section between the building line and the property line, frequently specified and supervised by plumbing or housing officials; and (2) the section between the property line and the street sewer, including the connection thereto frequently specified and supervised by sewer, public works, or engineering officials (Referred to also as "house sewer," "building connection,)' "service connection," or "lateral connection").

Bulk density: Density of a molding material in loose form, such as granular of nodular, in units of g/cm^3 or lb/ft^3.

Bulkhead fitting: A fitting fixed to a vessel wall that allows fluids to flow through the wall and adapts pipe or tubing to the vessel. One end is usually smooth (inside vessel), and the other end is usually threaded.

Bull head tee: A tee, the branch of which is larger than the run.

Burst pressure: The pressure that can be applied slowly to a valve, fitting, or pipe at room temperature for 30 sec without causing rupture.

Burst strength: The internal pressure required to break a pipe or fitting. This pressure will vary with the rate of buildup of the pressure and the time during which the pressure is maintained.

Bushing: A fitting used to connect a pipe to a female fitting of a larger size.

Butt Fusion: A method of joining thermoplastic pipes wherein the ends of the two pieces to be joined are heated to the molten state and then quickly pressed together.

Butt weld joint: A welded pipe joint made with the ends of the two pipes butting each other.

Butterfly valve: A device deriving its name from the winglike action of the disk, which operates at right angles to the flow. The disk impinges on the resilient seal with low operating torque.

By-pass: An auxiliary loop in a pipeline that divers flow around a valve or other piece of equipment.

By-pass valve: Valve by which the flow or liquid or gas in a system may be directed past some part of the system through which it normally flows (e.g., an oil filter in a lubrication system).

Caisson: A watertight box or cylinder used in excavating for foundations or tunnel pits to hold out water so concreting or other construction can be carried on.

Camber: Rise or crown of the center of a bridge, or Bowline through a culvert, above a straight line through its ends.

Capacity: The maximum or minimum flow obtainable under given conditions of media, temperature, pressure, velocity, and the like. Also, the volume of media that may be stored in a container or receptacle.

Capillary: The action by which the surface of a liquid, where it is in contact with a solid, is elevated or depressed depending on the relative attraction of the molecules of the liquid for each other and for those of the solid.

Cathode: The electrode of an electrolytic cell at which reduction is the principal reaction (Electrons flow toward the cathode in the external circuit). Typical cathodic processes are cations taking up electron and being discharged, oxygen being reduced, and the reduction of an element or group of elements from a higher to a lower valence state.

Cathodic Corrosion: An unusual condition (especially with Al, Zn, Pb) in which corrosion is accelerated at the cathode because the cathodic reaction creates an alkaline condition that is corrosive to certain metals.

Cathodic Protection: Preventing corrosion of a pipeline by using special cathodes (and anodes) to circumvent corrosive damage by electric current. Also a function of zinc coatings on iron and steel drainage products - galvanic action.

Cavitation: Formulation and sudden collapse of vapor bubbles in a liquid; usually resulting from local low pressures - as on the trailing edge of a propeller; this develops momentary high local pressure.

Cell Classification: Method of identifying thermoplastic materials, such as Polyvinyl Chloride, as specified by ASTM, where the Cell Classification is based on these six properties for PVC are: Density, Melt Index, Flexural Modulus, Tensile Strength at Yield, Environmental Stress Crack Resistance, and Hydrostatic Design Basis.

Cement: A dispersion of "solution" of unvulcanized rubber or a plastic in a volatile solvent. This meaning is peculiar to the plastics and rubber industries and may or may not be an adhesive composition. (*See also* Adhesive and Solvent cement.)

Centipoise: Unit of absolute viscosity; it equals one hundredth of a poise.

Centistoke: Unit of kinematic viscosity; it equals one hundredth of a stoke. Kinematic viscosity in centistokes multiplied by the specific gravity equals absolute viscosity in centipoises.

Char: A grayish black, crusty material formed by burning organic type sealants (fire stops).

Chase: A recess in a wall in which pipes can be run.

Check valve: Device that permits flow in only one direction in pipeline.

Chemical waste system: Piping that conveys corrosive or harmful industrial, chemical, or processed wastes to the drainage system.

Chemical resistance: (1) The effect of specific chemicals on the properties of plastic piping with respect to concentration, temperature, and time of exposure. (2) The ability of a specific plastic pipe to render service for a useful period in the transport of a specific chemical at a specified concentration and temperature.

Circuit vent: A branch vent that serves two or more traps and extends from in front of the last fixture connection of a horizontal branch to the vent stack.

Classification: A series of procedures, usually administered by an independent testing laboratory, by which the consumer is protected and assured that the product that was tested is the same as the product purchased.

Cleaner: Medium strength organic solvent such as methylethyl ketone used to remove foreign matter from plastic pipe and fitting joint surfaces.

Cleanout: A plug or cover joined to an opening in a pipe that can be removed to clean or examine the interior of the pipe.

Close nipple: A nipple twice as long as a standard pipe thread.

Closed System: A piping system that is sealed, typically carrying fluids under pressure, such as hot and cold water distribution.

Coefficient of expansion: The increase in unit length, area, or volume for a unit rise in temperature.

Cohesion: The molecular attraction that holds the body of a sealant or adhesive together. The internal strength of an adhesive or sealant (fire stops).

Cohesive Failure: Failure characterized by rupture within the sealant adhesive or coating (fire stops).

Cold Bend: To force the pipe into a curvature without damage, using no special tools, equipment or elevated temperatures.

Cold flow (*see* Creep).

Collector Sewer: A sewer located in the public way collects the wastewater's discharged through building sewers and conducts such flows into larger interceptor sewers and treatment works. (Referred to also as "street sewer.")

Combined Sewer: A sewer intended to serve as both a sanitary sewer and a storm sewer, or as both an industrial sewer and a storm sewer.

Combined waste and vent system: A specially designed system of waste piping, embodying the horizontal wet venting of one or more floor sinks or floor drains by means of a common waste and vent pipe, adequately sized to provide free movement of air above the flow line of the drain.

Combustion: Burning or rapid oxidation.

Common vent: A vent that connects at the junction of two fixture drains and serves as a vent for both fixtures. Also, known as a dual vent.

Compaction: The densification of a soil by means of mechanical manipulation.

Companion flange: A pipe flange used to connect with another pipe flange or with a flanged valve or fitting. It is attached to the pipe by threads, welding, or other methods and differs from a flange that is an integral part of a pipe or fitting.

Compatibility: The capability of two or more materials when placed in contact or close proximity with one another to maintain their usual physical or chemical properties, or both.

Composite Pipe: Pipe consisting of two or more different materials arranged with specific functional purpose to serve as pipe.

Compound: The admixture of a polymer or polymers with other ingredients such as fillers, softeners, plasticizers, catalysts, pigments, dyes, curing agents, stabilizers, or antioxidants.

Compression fitting: A fitting designed to join a pipe or tube by means of pressure or friction.

Compression joint: A multipiece joint with cup-shaped threaded nuts, which, when tightened, compress tapered sleeves so that they form a tight joint on the periphery of the tubing they connect.

Compression strength: The crushing load at failure of an item divided by the number of square inches of resisting surface. (Figures are given in thousands of pounds.)

Concentric: Having a common center; a pipe centered in the middle of a through-penetration hole results in a concentric annulus (fire stops).

Condensate: Water that has liquefied from steam.

Conductivity: A measure of the ability of a solution to carry an electrical current. Conductivity varies both with the number and type of ions the solution carries.

Continuous vent: A vent that is a continuation of the drain to which it connects.

Continuous waste: A drain from two or three fixtures connected to a single trap.

Control valve: Variable opening valve used with a control instrument to maintain a predetermined flow rate, pressure, temperature, or level. The valve can be electric, electrohydraulic, or air operated.

Copolymer: Formed form two or more monomers. (*See also* Polymer).

Corrosion: The destruction of a material or its properties because of a reaction with its (environment) surroundings.

Corrosion Rate: The speed (usually an average) with which corrosion progresses (it may be linear for a while); often expressed as though it was linear, in units of mdd (milligrams per square decimeter per day) for weight change, or mpy (milligrams per year) for thickness changes.

Corrosion-erosion: Corrosion which is increased because of the abrasive action of a moving stream; the presence of suspended particles greatly accelerates abrasive action.

Collar: A galvanized sheet metal restricting device used in conjunction with plastic pipe. Its function is to direct and control the intumescent action of the fires stopping material (fire stops).

Corrosion: Deterioration in metals caused by oxidation or chemical action.

Creep: The dimensional change, with time, of a material under continuously applied stress after the initial elastic deformation. The time dependent part of strain due to a constant stress.

Cross: A pipe fitting with four branches in pairs, each pair on one axis, and the axes at right angles.

Cross-linking: Generation of chemical linkages between long-chain molecules; cross-linking can be compared to two straight chains joined together by links. The rigidity of the material increases with the number of links. The function of a monomer is to provide these links.

Cross-over: A fitting with a double offset-shaped like the letter "U" with the ends turned out-used to pass the flow of one pipe past another when the pipes are in the same plane.

Crown: That part of the trap in which the direction of flow is changed from upward to downward.

Crown vent: A vent pipe connected at the topmost point in the crown of a trap.

Dead end: A branch leading from a soil, waste, or vent pipe; building (house) drain; or building (house) sewer that is terminated at a developed distance of 2 ft (0.6 m) or more by means of a plug or other closed fitting.

Deflection temperature: The temperature at which a specimen will deflect a given distance at a given load under prescribed conditions of test (formerly called heat distortion).

Degradation: Deleterious change in a plastic's chemical structure.

Destiny: Mass of a fluid per unit volume.

Deterioration: Permanent adverse change in the physical properties of a plastic.

Developed length: The length along the center line of the pipe and fittings.

Dew point: The temperature at which liquid first condenses when a vapor is cooled.

Diameter: Unless specifically stated, the nominal diameter as designated commercially.

Diaphragm: A flexible disk used to separate the control medium form the controlled medium; it actuates the valve stem.

Diaphragm valve: A valve used for controlling flow by a flexible elastometric disk.

Diffusion: The movement of a material, such as a gas or liquid, in the body of a plastic. If the gas or liquid is absorbed on one side of a piece of plastic and given off on the other side, the phenomenon is called permeability. Diffusion and permeability are not due to holes or pores in the plastic, but are caused and controlled by chemical mechanisms.

Dimension ratio: The diameter of a pipe divided by the wall thickness. Each pipe can have two dimension ratios depending on whether the pipe's outside or inside diameter is used. In practice, the outside diameter is used if the standards requirement and manufacturing control are based on this diameter. The inside diameter is used when this measurement is the controlling one.

Disk: The part of a valve that actually closes off the flow.

Dispersion: Heterogeneous mixture in which finely divided material is suspended in the matrix of another material; as in the distribution of finely divided solids in a liquid or a solid (e.g., pigments or fillers).

Displacement: The volume or weight of a fluid, such as water, displaced by a floating body.

Double offset: Two changes of direction installed in succession or series in continuous pipe.

Double ported valve: A valve having tow ports to overcome line pressure imbalance.

Double sweep tee: A tee made with "easy" (long-radius) curves between body and branch.

Drain: Any pipe that carries wastewater or water-borne wastes in a building drainage system.

Drainage fitting: A type of fitting used for draining fluid from pipes. The fitting makes a smooth and continuous interior surface for the piping system.

Dry bulb temperature: The temperature of air as measured by an ordinary thermometer.

Dual vent (*see* Common vent).

Ductile Failure: A failure mode that exhibits material deformation (stretching, elongation, or necking down) in the area of the break.

Durometer hardness: A material's hardness as measured by the Shore Durometer.

Eccentric: Off center; an eccentric annulus results when a pipe is not centered in the hole (fire stops)

Effluent: Outflow or discharge from a sewer us sewage treatment equipment.

Elastic Modulus: A measure of the stress buildup associated with a given strain.

Elasticity: Property of materials that tends to retain or recover their original shape and size after undergoing deformation.

Elastomer: A material under ambient conditions that can be stretched and, upon release of the applied stress, returns with force to approximately its original size and shape.

Elevated temperature testing: Tests on plastic pipe above 23^{O}C (73^{O} F).

Elbow (Ell): A fitting that makes an angle between adjacent pipes. The angle is 90^{O}, unless another angle is specified.

Elongation: (strain) The increase in length of a material stressed in tension.

Elongation: Extension produced by a tensile stress.

Embankment (or fill): A bank of earth, rock or other material constructed above the natural ground surface.

Embrittlement: Loss of ductility of a material resulting from a chemical or physical change.

End connection: A reference to the method of connecting the parts of a piping system (i.e., threaded, flanged, butt-weld, socket weld).

Environmental stress cracking: Cracks that develop when the material is subjected to stress in the presence of specific chemicals.

Erosion: The gradual destruction of a material by the abrasive action of liquids, gases, solids, or mixtures of these materials.

Exfiltration: The leakage or discharge of flows being carried by sewers out into the ground through leaks in pipes, joints, manholes, or other sewer system structures; the reverse of "infiltration."

Expansion joint: Joint used in the connection of long lines of pipe; the expansion joint contains a bellows or telescopelike section to absorb the thrust or stress resulting from linear expansion or contraction of the line owing to changes in temperature or to accidental forces.

Expansion loop: A large radius bend in a pipe line to absorb longitudinal thermal expansion in the line.

Extrusion: Method of processing plastic in a continuous or extended form by forcing the heat-softened plastic through an opening shaped like the cross section of the finished product.

F Rating: A firestop shall be considered as meeting the requirements for an F rating when it remains in the opening during the fire test and hose stream test within the following limitations: The firestop shall have withstood the fire test for the rating period without permitting the passage of flame through openings, or the occurrence of flaming on any element of the unexposed side of the firestop. During the hose stream test, the firestop shall not develop any opening the would permit a projection of water from the stream beyond the unexposed side (ASTM E 814) (fires stops).

Fabricate: Method of forming a plastic into a finished article by machining, drawing, and similar operations.

Face-to-face dimensions: The dimensions from the face of the inlet port to the face of the outlet port of a valve or fitting.

Fatigue Strength: The stress to which a material can be subjected for a specified number of fatigue cycles.

Female thread: Internal thread in pipe fittings, valves, and the like, for making screwed connections.

Filler: A relatively inert material added to a plastic to modify its strength, permanence, working properties, or other qualities, or to lower costs.

Filter: A device through which fluid is passed to separate contaminates.

Filter element: A porous device that performs filtration.

Finishing: Removal of any defects from the surfaces of plastic products.

Fire Endurance: A measure of the elapsed time during which a material or assembly continues to exhibit fire resistance under specified conditions of test and performance. As applied to elements of building, it shall be measured by the methods and criteria defined in ASTM E 119 Fire Tests of Building Construction and Materials (fire stops).

Fire Rated or Fire Resistance: (1) A system which has been tested by a qualified laboratory in accordance with the appropriate ASTM test standard and has met the mechanical and endurance requirements of that standard. (2) The property of a material or assembly to withstand fire or give protection from it. As applied to elements of buildings, it is characterized by the ability to confine a fire or to continue to perform a given structural function, or both. Systems are rated for 1, 2, 3 or 4 hours, based on the results of the fire test (fire stops).

Fire Resistance Classification: A standard rating of fire-resistance and protective characteristics of a building construction or assembly (ASTM E 119) (fire stops).

Firestop: A through-penetration firestop is a specific combination of components or materials that fill the opening around wall, floor or ceiling penetrating pipes and their means of support for the purpose of preventing the spread of fire (fire stops).

Fire Test Standard: Fire test standards are procedures intended to measure and describe the response of material, products, and systems to sources of heat or flame under controlled conditions. These tests are intended to provide information useful for such purposes as product development, quality control, and specification description. They are not intended to be used alone to provide a measure of the fire hazard of materials, products or systems. Fire test standards are separate and distinct from fire hazard standards, which are used to describe, measure, assess or control the behavior of materials, products and systems in the relevant environment (fire stops).

Fitting: A device or connection that allows a pipe to change direction or size.

Fixture: A device or appliance at the end of a water supply distribution pipe line.

Flammability: The time a specimen will support a flame after having been exposed to it for a given period of time.

Flange: In pipe work, a ring plate on the end of a pipe at right angles to the end of the pipe and provided with holes for bolts to allow fastening the pipe to a similarly equipped adjoining pipe. The resulting joint is called a flanged joint.

Flanged ends: A valve of fitting having flanges for joining to other piping elements. Flanged ends can be plain faced, raised face, large male and female, large tongue and groove, small tongue and groove, or ring joint.

Flange faces: Pipe flanges that have the entire surface of the flange faced straight across and use either a full face or ring gasket.

Flash point: Temperature at which enough of a material is vaporized to produce a flash f burning vapor.

Flexural Modulus: The ratio, within the elastic limit, of the applied stress in the outermost fibers of a test specimen in three point static flexure, to the calculated strain in those outermost fibers (ASTM D 790).

Flexural strength: The pressure in pounds necessary to break a given sample when the pressure is applied to the center of the sample that has been supported at its ends.

Flow coefficient or C: Valve coefficient of flow representing the flow rate of water in gallons per minute that will produce a 1 psi pressure drop through the valve.

Fluorocarbon resins: Material made by the polymerization of monomers composed only of carbon and fluorine.

Foot valve: Check valve located at the inlet end of the suction line at a pump that allows the pump to remain full of liquid when not in service.

Forming: A process in which the shape of plastic pieces such as sheets, rods, or tubes is changed to a desired configuration. (*Note*: The use of the term "forming" in plastics technology does not include such operations as molding, casting, or extrusion, in which shapes or pieces are made from molding materials or liquids.)

Fouling: An accumulation of deposits. This term includes accumulation and growth of marine organisms on a submerged metal surface and also includes the accumulation of deposits (usually inorganic) on heat exchanger tubing.

Full port valve: A valve in which the resistance to flow, in the open position, is equal to an equivalent length of pipe.

Fungi resistance: The ability of plastic pipe to withstand fungi growth or their metabolic products or both under normal conditions of service or laboratory tests simulating such conditions.

Fusion point: Temperature at which solid and liquid states of a substance can exist together in equilibrium (also called melting or freezing points).

Galvanic Cell: A cell consisting of two dissimilar metals in contact with each other and with a common electrolyte (sometimes refers to two similar metals in contact with each other but with dissimilar electrolytes; differences can be small and more specifically defined as a concentration cell).

Gate valve: Valve with a sliding blank that opens to the complete cross section of the line; used for complete opening or complete shutoff of the flow in pipes. It is not used for throttling or control.

Glass transition temperature: The range of temperatures in which a plastic changes from a rigid to a soft state. (*Note*: values will depend on the method of test. It is sometimes referred to as softening point.)

Glass Transition Temperature: The temperature below which a plastic is more brittle and glassy.

Globe valve: Valve used for throttling that does not have a straight-through opening.

Grade: The slope or fall of a line of pipe in reference to a horizontal plane. In drainage, it is expressed as the fall in a fraction of an inch or percentage slope per foot (mm/m) length of pipe.

Ground Water Table (or level): Upper surface of the zone of saturation in permeable rock or soil. (When the upper surface is confined by impermeable rock, the water table is absent.)

Haunch: That portion of the pipe barrel extending below the pipe springline.

Haunching: Area from the bedding to the spring line of pipe. Provides the majority of load carrying of underground pipe and also provides side support for flexible and rigid pipe.

Head (Static): The height of water above any plane or point of references (the energy possessed by each unit of weight of a liquid, expressed as the vertical height through which a unit of weight would have to fall to release the average energy posed). The standard inch-pound unit of measure is feet of water. The relation between pressure in psi and feet of head at 68°F is 1 psi = 2.310 ft of head.

Heat capacity: The quantity of heat required to raise the temperature of a given mass by 1°. This quantity is based on either 1 mole or a unit mass of material.

Heat of fusion: Heat needed to change a quantity of solid to a liquid, without a change in temperature.

Heat joining: Making a pipe joint by heating the edges of the parts to be joined so that they fuse and become essentially one piece with or without additional material.

Home-run: A plumbing design that utilizes a central manifold and distribution piping to each hot and cold water fixture.

Hoop stress: The tensile stress, usually expressed in pounds per square inch (psi), in the circumferential orientation in the wall of the pipe when the pipe contains a gas or liquid under pressure.

Hot soils: Soils having a resistivity of less than 1000 ohm-cm; they are generally very corrosive to base steel.

Hydraulic gradient: The amount of inclination of a drainage line between the trap outlet and the vent connection, not exceeding one pipe diameter in this total length.

Hydrostatic Design Basis (HDB): One of a series of established stress values specified in Test Method D 2837 "Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials" for a plastic compound obtained by categorizing the LTHS determined in accordance with Test Method D 2837. HDB refers to the categorized LTHS in the circumferential, or hoop direction, for a given set of end use conditions. Established HDBs are listed in PPI TR-4.

Hydrostatic design stress: The estimated maximum tensile stress in the wall of the pipe in the circumferential orientation owing to internal hydrostatic pressure that can be applied continuously with a high degree of certainty that failure of the pipe will not occur.

Hydrostatic strength (quick): The hoop stress calculated by means of the ISO equation at which the pipe breaks due to an internal pressure buildup, usually within 60-70 sec. (*See also* ISO equation).

Ignition Temperature: Temperature at which the vapors emitted from a material will ignite either without exposure to a flame (self-ignition) or when a flame is introduced (flash ignition).

Impact, Izod: A specific type of impact test made with a pendulum-type machine. The specimens are molded or extruded, with a machined notch in the center. (*See also* Izod impact strength.)

Impact strength: Resistance, or mechanical energy absorbed by plastic part, to shocks such as dropping and hard blows.

Impact, tup: A falling weight (tup) impact test developed specifically for pipe and fittings. There are several variables that can be selected.

Intumesce: To swell, enlarge inflate or expand as with heat. Intumescent fire stopping sealants swell to close gaps or voids in through-penetration openings when exposed to high heat conditions (fire stops).

Infiltration: The water entering a sewer system, including building sewers, from the ground, through such means as defective pipes, pipe joints, connections, or manhole walls. Infiltration does not include, and is distinguished from inflow.

Inhibitor: Material that retards chemical reaction or curing.

Injection Molding: The process of forming a material by melting it and forcing it, under pressure, into the cavity of a closed mold.

Interceptor Sewer: A sewer which receives the flow of collector sewers and conveys the wastewaters to treatment facilities.

ISO equation: An equation showing the relations among stress, pressure, and dimensions in pipe, namely,

$$S = \frac{P(ID + t)}{2t}$$

or

$$\frac{P(OD - t)}{2t}$$

where
S = stress
P = pressure
ID = average inside diameter
OD = average outside diameter
t = minimum wall thickness

Isobaric process: A constant-pressure process.

Isometric process: A constant-volume process.

Isothermal process: A constant-temperature process.

Izod impact strength: The resistance a notched test specimen has to a sharp blow from a pendulum hammer. (*See also* Impact, Izod.)

Joint: The location at which two pieces of pipe or a pipe and a fitting are connected. The joint may be made by a mechanical device, such as threads or ring seals, or by heat fusion and cementing.

Load factor: The percentage of the total connected fixture unit flow that is likely to occur at any point in the drainage system. Load factor represents the ratio of the probable load to the potential load and is determined by the average rates of flow of the various kinds of fixtures, the average frequency of use, the duration of flow during one use, and the number of fixtures installed.

Long-term burst: The internal pressure at which a pipe or fitting will break due to a constant internal pressure held for 100,000 hr (11.43 years).

Long –term hydrostatic strength: The estimated tensile stress in the wall of the pipe on the circumferential orientation (hoop stress) that when applied continuously will cause failure of the pipe at 100,000 hr (11.43 years). These strengths are usually obtained by extrapolation of log-log regression equations or plots.

Lubricant: A substance used to decrease the friction between solid faces, and sometimes used to improve processing characteristics of rubber or plastic compositions.

Manifold: A device having a series of ports that are used to connect distribution lines for several fixtures.

Manning's Formula: An equation for the value of coefficient c in the Chezy Formula, the factors of which are the hydraulic radius and a coefficient of roughness: an equation itself used to calculate flows in gravity channels and conduits.

Material Safety Data Sheet (MSDS): A document required by law describing the health and safety aspects of a material as it pertains to its properties, health effects, hazards, handling and disposal.

Melting Point: That temperature at which the plastic transitions to a completely amorphous state.

Mineral Fiber: A noncombustible insulation material made from mineral fibers. It is also known as mineral wool or safing material. It is typically used as a backing and filler material in through-penetrations (fire stops).

Modulus: The ration of stress to strain. Also, the tensile strength at a given elongation.

Modulus of Elasticity (E): ASTM D 638 The ratio of stress (nominal) to corresponding strain below the proportional limit of a material.

Moment, Bending: The moment that produces bending in a beam or other structure. It is measured by the algebraic sum of the products of all the forces multiplied by their respective lever arms.

Modulus: The load in pounds per square inch, kilograms (force) per square centimeter, or, in SI, the modern metric system, megapascals (Mpa) of initial cross-section area necessary to produce a stated percentage elongation; this value is used in the physical testing of rubber or plastics. It is a measure of stiffness, and is influenced by pigmentation, state of cure, quality of raw rubber, and other factors. The modulus at any given elongation is shown by stress-strain curve.

Molding, blow: Method of forming plastic articles by inflating masses of plastic material with compressed gas.

Molding compression: Process of shaping plastic articles by placing material in a confining mold cavity and applying pressure and usually heat.

Molding, high pressure: Molding or laminating with pressures in excess of 200 psi.

Molding, injection: Process of making plastic articles from powdered or granular plastics by fusing the material in a chamber under pressure with heat and forcing part of the mass into a cooler cavity where it solidifies; used primarily with thermoplastics.

Molding, low pressure: Molding or laminating with pressures below 200 psi.

Molding, transfer: Process of molding plastic articles from powered, granular, or performed plastics by fusing the material in a chamber with heat and forcing the mass into a hot chamber for solidification. Used primarily with thermosetting plastics.

Monomer: Reactive material that is compatible with the basic resin. Tends to lower the viscosity of the resin. Simplest repeating structural unit of polymer.

Needle valve: Valve with a cone seat and needle-point plug to control small and accurate flows.

Non-Pressure Pipe: Pipe designed for gravity-conveyed medium that must resist only intermittent static pressures and does not have a pressure rating.

Non-Sag Sealant: A compound that exhibits little or no flow when applied in vertical or inverted joints (fire stops).

Nonrigid plastic: Plastic whose apparent modulus of elasticity is not greater than 10,000 psi at room temperature in accordance with the Standard Method of Test for Stiffness in Flexure of Plastics.

Notch Sensitivity: The extent to which an inclination to fracture is increased by a notch, crack, scratch, or sudden change in cross-section.

Nylon plastics: Group of plastics comprised of resins that are primarily long-chain synthetic polymeric amides. These resins have recurring amide groups as an integral part of the principle polymer chain.

Offset: A combination of pipe, pipes, and/or fittings that join two approximately parallel sections of the line of pipe.

Olefin plastics: Plastics based on resins made by the polymerization of olefins or copolymerization of olefins with other unsaturated compounds, the olefins being in greatest amount by weight. Polyethylene, polypropylene, and polybutylene are the most common olefin plastics encountered as pipe.

Open System: An open system or sometimes referred to as a vented system is a piping system which allows air flow to the exterior of the building to prevent back flow or vacuum.

Out-of-Roundness: The allowed difference between the maximum measured diameter and the minimum measured diameter (stated as an absolute deviation).

Outdoor exposure: Plastic pipe placed in service or stored so that it is not protected from the elements of normal weather conditions, i.e., the sun's rays, rain, air, and wind. Exposure to industrial and waste gases, chemicals, engine exhausts, and the like, are not considered normal "outdoor exposure."

Permanence: The property of a plastic that describes its resistance to appreciable changes in characteristics with time and environment.

Permeability (*see* Diffusion).

pH: A scale ranging from 0 to 14 that ranks how acidic or alkaline a liquid is; fluids with a pH below 7 is considered acidic and fluids with a pH above 7 is consider alkaline.

Pitch: The amount of slope or grade given to horizontal piping and expressed in inches of vertically projected drop per foot (or mm/m) on a horizontally projected run of pipe.

Pitting: Highly localized corrosion resulting in deep penetration at only a few spots.

Pipe stiffness: A measure of how a flexible conduit will behave under burial conditions.

Plastic (n): A material that contains as an essential ingredient an organic substance of large molecular weight, is solid in its finished state, and, at some state in its manufacture or in it's processing into finished articles, can be shaped by flow.

Plastic (adj.): The adjective plastic indicates that the noun modified is made of, consists of, or pertains to plastic. (*Note 1*: This definition may be used as a separate meaning to the definitions contained in the dictionary for the adjective "plastic." *Note 2*: The plural form may be used to refer to two or more plastic materials, for example, plastics industry. However, when the intent is to distinguish "plastic products" from "wood products" or "glass products," the singular form should be used. As a general rule, if the adjective is to restrict the noun modified with respect to type of material, "plastic" should be used; if the adjective is to indicate that more than one type of plastic material is or may be involved, "plastics" is permissible.)

Plastic conduit: Plastic pipe or tubing used as an enclosure for electrical wiring.

Plastic pipe: A hollow cylinder of plastic material in which the wall thickness is usually small compared to the diameter and in which the inside and outside walls are essentially concentric. (*See also* Plastic tubing.)

Plastic, semirigid: Plastic having apparent modulus of elasticity in the range of 10,000-100,000 psi at 23°C, as determined by the Stanford Method of Test for Stiffness in Flexure Plastics.

Plastic tubing: A particular size of plastic in which the outside diameter is essentially the same as that of copper tubing. (See also Plastic pipe.)

Plastic welding: Joining of finished plastic components by fusing materials either with or without the addition of plastic from another source.

Plasticate: Softening by heating or kneading.

Plasticity: Property of plastics that permits the material to undergo deformation permanently and continuously without rupture from a force that exceeds the yield value of the material.

Plasticize: Softening by adding a plasticizer.

Plasticizer: Material added to a plastic to increase workability and flexibility. Plasticizers tend to lower the melt viscosity, the glass transition temperature, and or the elastic modulus.

Plough-in Piping: Installation procedure that splits the earth and pulls the pipe into position.

Plug valve: Valve mainly used in gas service; consisting of a rotating cylindrical plug in a cylindrical housing with an opening running through the plug.

Polybutylene: A polymer prepared by the polymerization of butane-1 as the sole monomer. (See also Polybutylene plastics.)

Polybutylene plastics: Plastics based on polymers made with butane-1 as essentially the sole monomer.

Polyethylene: A polymer prepared by the polymerization of ethylene as the sole monomer. (*See also* Polyethylene plastics.)

Polyethylene plastics: Plastics based on polymers made with ethylene as essentially the sole monomer. (*Note:* In common usage for this plastic, polyethylene plastics essentially means no less than 85% ethylene and no less than 95% total olefins.)

Polymer: A compound formed by the reaction of simple molecules having functional groups that permit the combination to proceed to high molecular weights under suitable conditions. Polymers may be formed by polymerization (addition polymer) or polycondensation (condensation polymer). When two or more monomers are involved, the product is called a copolymer.

Polymerization: A chemical reaction in which the molecules of a monomer are linked together to form large molecules whose molecular weight is a multiple of the original substance. When two or more monomers are involved, the process is called copolymerization heteropolymerization.

Polyolefin: A polymer prepared by the polymerization of an olefin(s) as the sole monomer(s). See also Polyolefin plastics and Olefin plastics.)

Polyolefin plastics: Plastics based on the polymers made with an olefin(s) as essentially the sole monomer(s).

Polypropylene: A polymer prepared by the polymerization of propylene as the sole monomer. (See also Polypropylene plastics and Propylene plastics.)

Polypropylene plastics: Plastics based on polymers made with propylene as essentially the sole monomer.

Polystyrene: A plastic based on a resin made by polymerization of styrene as the sole monomer. (*See also* Styrene plastics.) (*Note*: Polystyrene may contain minor proportions of lubricants, stabilizers, fillers, pigments, and dyes.)

Polyvinyl chloride: A resin prepared by the polymerization of vinyl chloride with or without the addition of small amounts of other monomers.

Polyvinyl chloride plastics: Plastics made by combining polyvinyl chloride with colorants, fillers, plasticizers, stabilizers, lubricants, other polymers, and other compounding ingredients, other polymers, and other compounding ingredients. Not all of these modifiers are used in pipe compounds.

Powder blend (*See* Dry-blend).

Pressure: When expressed with reference to pipe, the force per unit area exerted by the medium in the pipe.

Pressure rating: The estimated maximum pressure that the medium in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.

Pressure tubing: Tubing used to convey fluids at elevated temperatures and/or pressures. Suitable for head applications, it is fabricated to exact outside diameter and decimal wall thickness in sizes ranging from ½ to 6 in. outside diameter inclusive and to ASTM specifications.

Primer: Coating that is applied to a surface before application of an adhesive, enamel, and the like; its purpose is to improve bonding.

Propylene plastics: Plastics based on resins made by the polymerization of propylene or copolymerization of propylene with one or more unsaturated compounds, the propylene being in greatest amount by weight.

Pump: Mechanical device for transporting liquids in pipelines; major types are centrifugal, reciprocating, turbine, rotary, and proportioning.

Qualification test: An investigation, independent of a procurement action, performed on a product to determine whether or not the product conforms to all requirements of the applicable specification. (*Note*: The examination is usually conducted by the agency responsible for the specification, the purchaser, or facility approved by the purchaser, at the request of the supplier seeking inclusion of his or her product on a qualified products list.)

Quick burst: The internal pressure required to burst a pipe or fitting due to an internal pressure buildup, usually within 60-90 sec.

Quick Burst Test: (ASTM D 1599) An internal pressure test designed to produce rupture (bursting) of a piping component in 60-70 seconds determined in accordance with ASTM D 1599.

Reinforced plastic: According to ASTM, those plastics having superior properties over those consisting of the base resin, owing to the presence of high-strength fillers embedded in the composition. Reinforced fillers are usually fibers, fabrics, beads, or mats made of fibers.

Relief valve: Safety device for automatic release of fluid at a predetermined pressure.

Resin: A solid, semisolid, or pseudosolid organic material that has an indefinite and often high molecular weight, exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures conchoidally (radially).

Reworked material (thermoplastic): A plastic material that has been reprocessed, after having been previously processed by molding, extrusion, and the like, in a fabricator's plant.

Reworked Plastic: A plastic from a manufacturer's own production that has been reground or pelletized for reuse by that same manufacturer.

Riser: A water supply pipe that extends vertically one or more stories to transport water to fixtures or branches.

Roughness Coefficient: A factor in the Kutter, Manning, and other flow formulas representing the effect of channel (or conduit) roughness upon energy tosses in the fl owing water.

Rubber: A material that is capable of recovering from large deformations quickly and forcibly. (*See also* Elastomer.)

Saddle Fitting: A fitting used to make lateral connection to a pipe in which a portion of the fitting is contoured to match the OD of the pipe to which it is attached.

Sample: A small part or portion of a plastic material or product intended to be representative of the whole.

Sanitary Sewer: A sewer intended to carry only sanitary and industrial wastewaters from residences, commercial buildings, industrial parks, and institutions.

Schedule: A pipe size system (outside diameters and wall thickness) originated by the Iron Pipe Industry.

Sealant: A material that has the adhesive and cohesive properties to form a seal (fire stops).

Sealant Backing: A compressible material placed in a joint before applying a sealant (fire stops).

Self-extinguishing: The ability of a plastic to resist burning when the source of heat or flame that ignited it is removed.

Self-Leveling Sealant: A compound that exhibits flow sufficient to seek gravitational leveling (fire stops).

Service factor: A factor that is used to reduce a strength value to obtain an engineering design stress. The factor may vary depending on the service desired and the properties of the pipe.

Shelf life: Period of time over which a material will remain usable during storage under specified conditions such as temperature and humidity.

Socket Fusion Joint: A joint in which the joining surfaces of the components are heated, and the joint is made by inserting one component into the other.

Softening range: The range of temperature in which a plastic changes from a rigid to a soft state. (*Note*: Actual values will depend on the method of test. It is sometimes referred to as softening point.)

Solvent cement: In the plastic piping field, an adhesive that contains a solvent which dissolves or softens the surfaces being bonded so that the bonded assembly becomes essentially one piece of the same type of plastic.

Specific gravity: Weight of a unit of fluid volume.

Specimen: An individual piece or portion of a sample used to make a specific test. Specific tests usually require specimens of specific shape and dimensions.

Spool piece: A measured length of piping usually flanged on both ends.

Stabilizer: A compounding ingredient added to a plastic composition to retard possible degradation on exposure to high temperatures, particularly in processing. An antioxidant, for example, is a specific kind of stabilizer.

Stack: The vertical main of a system of soil, waste, or vent piping extending through one or more stories.

Standard dimension ratio (SDR): A selected series of numbers in which the dimension ratios are constants for all sizes of pipe.

Standard Time/Temperature Curve: A graphical representation derived from prescribed time-temperature relationships and used to control burn test furnace temperatures with progressing time (fire stops).

Steel Sleeve: A form used when pouring concreted to provide space for a penetrating item. Also may be used inside hollow construction walls to prevent firestopping materials from entering wall cavities unnecessarily (fire stops).

Stiffness factor: A physical property of plastic pipe that indicates the degree of flexibility of the pipe when subjected to external loads.

Strain: The ratio of the amount of deformation to the length being deformed caused by the application of a load on piece of material.

Stress crack: An internal or external crack in a plastic caused by tensile or shear stresses less than the short term tensile strength of the material. The development of such cracks is frequently related to, and accelerated by the environment to which the material is exposed. More often than not, the environment does not visibly attack, soften or dissolve the surface. The stresses may be internal, external, or a combination of both.

Strength: The stress required to break, rupture, or cause a failure.

Street elbow: Pipe fitting with a male thread on one end and a female thread on the other end.

Structural Sealant: A sealant capable of transferring dynamic or static loads, or both across joint members exposed to service environments typical for the structure involved (fire stops).

Styrene plastics: Plastics based on resins made by the polymerization of styrene or copolymerization of styrene with other unsaturated compounds, the styrene being in greatest amount by weight.

Styrene-rubber (SR) plastics: Compositions based on rubbers and styrene plastics, the styrene plastics being in greatest amount by weight.

Styrene-rubber (SR) pipe and fitting plastics: Plastics containing at least 50% styrene plastics combined with rubbers and other compounding materials, but not more than 15% acrylonitrile.

Substrate: A material upon which film, treatments, adhesives, sealants, membranes, and coatings are applied (fire stops).

Sustained pressure test: A constant internal pressure test for 1000 hr.

T Rating: A firestop shall be considered as meeting the requirements for a T rating when it remains in the opening during the fire test and hose stream test within the following limitations: The transmission of heat through the fires during the rating period hall not have been such as to raise the temperature of any thermocouple on the unexposed surface of the fires or on any penetrating item more than 325°F above its initial temperature. Also, the firestop shall have withstood the fire test for the rating period without permitting the passage of flame through openings, or the occurrence of flaming on any element of the unexposed side of the fires. During the hose stream test, the firestop shall not develop any opening that would permit a projection of water from the stream beyond the unexposed side (fire stops).

Tank adapter (*See* Bulkhead fitting).

Temperature: A measure of the degree of hotness of a material detected most commonly with a liquid-in-glass thermometer.

Tensile strength: The capacity of a material to resist a force tending to stretch it. Ordinarily, the term is used to denote the force required to stretch a material to rupture, and is known variously as "breaking load", "breaking stress," "ultimate tensile strength," and sometimes erroneously as "breaking strain." In rubber and plastics testing, it is the load in pounds per square inch, kilograms per square centimeter, or newtons per square millimeter in modern SI metric, of original cross-sectional area, supported at the moment of rupture by a piece of test sample on being elongated.

Thermal conductance: Also called "conductance," it is the amount of heat transmitted by a material divided by the difference in temperature of the surfaces of the material. Where heat is transferred by several mechanisms through a structure of mean cross-sectional area Am, conductance equals the gross rate of heat transfer divided by the temperature drop between its faces.

Thermal conductivity: Measure of the ability of a material to conduct heat; measured in flow of Btus per hour through a unit cross section or unit thickness with 1°F of temperature difference across this thickness. For refractory and insulation materials, typical units are Btu-in./ft^2-hr-°F. Other acceptable units are Btu-ft2-°F.

Thermal expansion: An increase in volume of linear dimensions caused by heating the material.

Thermal shock: Denotes a sudden temperature change.

Thermal Stabilizers: Compounds added to the plastic resins when compounded that prevent degradation of properties due to elevated temperatures.

Thermoelasticity: Rubberlike elasticity that a rigid plastic displays; it is caused by elevated temperatures.

Thermoplastic (n): A plastic that repeatedly can be softened by heating and hardened by cooling through a temperature range characteristic of the plastic, and that in the softened state can be shaped by flow into articles by molding or extrusion.

Thermoplastic (adj.): Capable of being repeatedly softened by heating and hardened by cooling through a temperature range characteristic of the plastic, and that in the softened state can be shaped by flow into articles by molding or extrusion. (*Note*: Thermoplastic applies to those materials whose change upon heating is substantially physical.)

Thermoset (n): A plastic that, when cured by application of heat or by chemical means, changes into a substantially infusible and insoluble product.

Thermoset (adj.): Pertaining to the state of a resin in which it is relatively infusible.

Thermosetting: Capable of being changed into a substantially infusible or insoluble product when cured by application of heat or by chemical means.

Tolerance: The total range of variation permitted; the upper and lower limits between which a dimension must be maintained.

Tooling: The act of compacting and contouring a sealant in a joint (fire stops).

Tooling Time: The time interval after application of a one-component sealant or after mixing and application of multi-component sealant during which tooling is possible (fire stops).

Trap: A fitting or device designed and constructed to provide, when properly vented, a liquid seal that will prevent the back passage of air without materially affecting the flow of sewage or waste water through it.

Through Penetration: Consist of three items: 1) wall or floor construction, 2) penetrating item or absence thereof, 3) the hold or void (fire stops).

Tuberculation: Localized corrosion at scattered locations resulting in knob-like mounds.

Tubing (plastic): A particular size of plastic pipe in which the outside diameter is essentially the same as that of copper tubing.

Ultraviolet Stabilizers: Compounds that when mixed with thermoplastic resins selectively absorb ultraviolet rays protecting the resins from ultraviolet attack.

Urethane plastics: Group of plastics composed of resins derived from the condensation of organic isocyanates with compounds containing hydroxyl groups.

UV Degradation: Sunlight contains a significant amount of ultraviolet radiation. The ultraviolet radiation that is absorbed by a thermoplastic material may result in actinic degradation (i.e., a radiation promoted chemical reaction) and the formation of heat. The energy may be sufficient to cause the breakdown of the unstabilized polymer and, after a period of time, changes in compounding ingredients. Thermoplastic materials that are to be exposed to ultraviolet radiation for long periods of time should be made from plastic compounds that are properly stabilized for such conditions.

Vacuum: Any pressure less than that exerted by the atmosphere; it may be termed a negative pressure.

Vacuum forming: Fabrication process in which plastic sheets are transformed to desired shapes by inducing flow; accomplished by reducing the air pressure on one side of the sheet.

Valve: A device that regulates the flow of fluids through piping by opening, closing, or obstructing ports or passageways.

Valve positioner: Auxiliary servo device that allows precision positioning of a control valve stem. It is used in conjunction with a standard valve operator (e.g., a diaphragm motor). Its purpose is to overcome stuffing box friction and stem thrust caused by fluid pressure.

Van Stone flange: A fitting flange whose drilled back plate turns 360° in order to facilitate the joining of one flange to another flange.

Velocity: Time rate of motion in a given direction.

Velocity head: Velocity pressure expressed in feet of column of the flowing of the flowing fluid.

Vinyl chloride plastics: Plastics based on resins made by the polymerization of vinyl chloride and copolymerization of vinyl chloride with other unsaturated compounds, the vinyl chloride being in greatest amount by weight.

Vinyl Plastics: Compositions of polymers and ingredients that are based on polymers of vinyl chloride, or copolymers of vinyl chloride with other monomers, the vinyl chloride being in the greatest amount by mass.

Virgin material: A plastic material in the form of pellets, granules, powder, floc, or liquid that has not been subjected to use or processing other than that required for its original manufacture.

Viscosity: A measure of the tendency of a fluid to resist shear. The unit of viscosity is the poise, which is defined as the resistance (in dynes per square centimeter of its surface) of one layer of fluid to the motion of a parallel layer one centimeter away and with a relative velocity of one centimeter per second.

Water absorption: The percentage of water absorbed by an immersed specimen in a given time.

Waterhammer: The forces, pounding noises, and vibration that develop in a piping system when a column of incompressible liquid flowing through a pipe line at a given pressure and velocity is stopped abruptly.

Waterhammer arrester: A device, other than an air chamber, designed to provide protection against excessive surge pressure.

Weathering: Exposure of a plastic to outdoor conditions.

Weld-or knit-line: A mark on a molded plastic formed by the union of two or more streams of plastic flowing together.

Wire Mesh: Galvanized steel hardware cloth used to support backing material in gypsum wallboard and hollow concrete block construction (fire stops).

Working ("pot") Life: The time interval after opening a container of a single component sealant or after mixing the components of a multi-component sealant, during which application and tooling is possible (fire stops).

Working Pressure (WP): The maximum anticipated, sustained operating pressure applied to the pipe exclusive of transient pressures.

Yield value: Also called yield stress; force necessary to initiate flow in a plastic.

Young's modulus of elasticity: The modulus of elasticity in tension. The ratio of stress in a material subjected to deformation.

The Plastic Pipe and Fittings Association
800 Roosevelt Road • Building C, Suite 312
Glen Ellyn, IL 60137-5833
Phone 630.858.6540 • Fax 630.790.3095
www.ppfahome.org