SPRINKLER IRRIGATION

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Claude H. Pair, Editor-in-Chief
Agricultural Engineer
United States Department of Agriculture
Agricultural Research Service
Snake River Conservation Research Center
Kimberly, Idaho

Walter W. Hinz
Extension Agricultural Engineer
University of Arizona
Tucson, Arizona

Crawford Reid
Professional Engineer
South Laguna, California

Kenneth R. Frost
Professor, College of Agriculture
Department of Soil, Water and Engineering
University of Arizona
Tucson, Arizona

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Chapter IV

THERMOPLASTIC PIPE*

Pipelines for conducting water are one of the fundamental components of sprinkler irrigation systems. The materials used in the manufacture of irrigation pipe listed in Chapter II are steel, asbestos-cement, aluminum, and plastic. Plastic is the newest material being used and information on its capabilities and limitations is necessary for its proper use.

Plastic is a man-made organic polymer. There are numerous kinds of plastics, but four major ones are used in pipe manufacture. These are:

Poly(vinyl chloride) (PVC)
Polyethylene (PE)
Acrylonitrile-butadiene-styrene (ABS)
Polybutylene (PB)

Of these, only poly (vinyl chloride) (PVC) and polyethylene (PE) are presently used to any great extent in sprinkler irrigation.

History

Vinyl chloride was polymerized by sunlight in 1838 by H. V. Regnault[7]. Germany and England developed poly (vinyl chloride) (PVC) before World War II and occupation troops observed much PVC pipe used in Germany after World War II[10]. Rigid PVC pipe became commercially available in Europe about 1935, and in the U.S. A. about 1950, and its use has been increasing rapidly. PVC is a polymer consisting of three chemical elements: carbon (C), hydrogen (H_2), and chlorene (Cl_2)[5]. The carbon and hydrogen atoms in a polymer will burn, but the chlorine atoms will suppress combustion; for this reason, PVC is classified as a self-extinguishing material according to ASTM D-635. The PVC materials exhibit outstanding resistance to inorganic chemicals, and excellent resistance to most organic chemicals.

Polyethylene was produced in Great Britain about 1937. Commercial production began there in 1939[7]. Polyethylene is a polymer consisting of carbon (C) and hydrogen (H_2). It is a resinous substance produced by the chemical linking of molecules of ethylene gas into very long chains. Polyethylene is one of a group of partially crystalline lightweight thermoplastics ($-CH_2\ CH_2-$)$_n$ that has good resistance to chemicals, low moisture absorption, and good insulating properties. It has a surface that may range from soft to hard and from tough and flexible to rigid, according to the conditions of its manufacture and the type of catalyst.

*This Chapter written by: Claude H. Pair, Agricultural Engineer, Snake River Conservation Research Center, Kimberly, Idaho; Walter W. Hinz, Extension Specialist in Agricultural Engineering, University of Arizona, Tucson; Kenneth R. Frost, Professor, Department of Soils, Water and Engineering, University of Arizona, Tucson; and Crawford Reid, Consulting Engineer, South Laguna, California.

Manufacturing Methods

Plastic pipe is manufactured by the extrusion process, converting raw thermoplastics (PE, PVC, PB, ABS) granular or powdered material to continuous lengths of finished product. A single- or multiple-screw extruder accepts the raw material from a feed source, subjects the material to heat and pressure for complete melting and mixing, then forces the melted material continuously through extrusion dies to shape the pipe, which is then cooled to set the shape, and cut to length by haul-off and cutting units.

Standards and Specifications

A great deal of confusion regarding plastic pipe is caused by the variety of materials, working pressures, wall thicknesses, and pipe sizes available from the manufacturers. Much technical engineering effort has been devoted to the establishment of standards and specifications to aid design engineers in selecting the proper pipe.

Standards and/or recommendations for materials, manufacturing, testing, and installation of plastic pipe have been established by the American Society for Testing and Materials (ASTM), Plastic Pipe Institute (PPI), United States Department of Commerce Product Standards (PS), American Society of Mechanical Engineers (ASME), National Sanitation Foundation Testing Laboratory (NSF), International Association of Plumbing and Mechanical Officials (I.A.P.M.O.), Southern Building Code Congress (SBCC), Building Officials Conference of America (BOCA), Farmers' Home Administration, Federal Housing Administration, Soil Conservation Service, and other federal agencies. The ASTM publishes annually two bound volumes of specifications and tentative specifications concerning plastics and their products. These are designated as Part 26 and Part 27 of the Annual Book of ASTM Standards. Many specifications, test procedures, and recommended practices are listed in these two volumes. Table IV-1 lists some of the presently applicable ASTM specifications[1] and Plastic Pipe Institute publications[9] for PVC and PE pipe.

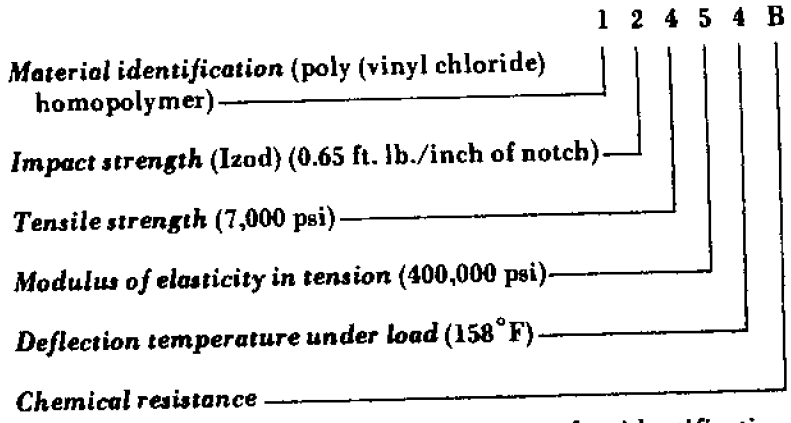
The quality of a plastic pipe is determined by the compounds used in its manufacture. ASTM, has published basic requirements for the classification of compounds. These standards provide symbols for identifying a thermoplastic piping material in a designated sequence to indicate the chemical formulation of plastic, the pipe grade of that

plastic, and the hydrostatic design stress rating of the material for water at 73°F (23°C) in units of 100 psi.

Plastic Pipe Class Systems

PVC

The current standard specifications for rigid poly (vinyl chloride) compounds are described in ASTM D-1784-69. This standard changed the method of specifying the class of pipe from the type and grade designation used in the past to the cell block classification. The cell block classification for each compound consists of five numbers and a letter which defines the following underlined pipe properties according to cell limits (see Tables IV-2 and IV-3). The values in brackets are valid only for a Class 1 2 4 5 4 - B compound.



This cell-type format provides the means for identification, close characterization, and specification of material properties, alone or in combination, for a broad range of plastic materials.

PE

Polyethylene pipe compounds are classified according to ASTM Standard D-1248-72 and on the basis of two characteristics, density and flow rate of the material used. The density of the material determines the type of pipe as shown in Table IV-4, and the flow rate determines the category as shown in Table IV-5. Other pipe attributes are covered by three general classes and by grades that specify a number of key characteristics not covered by the type, class, and category designations.

The class designation is determined by the composition and use, with Class A being natural color, Class B is white or black, Class C is weather resistant with carbon black.

Grade of pipe is shown in Table IV-6.

Pipe Rating

The *pressure rating of a plastic pipe* is the estimated maximum

pressure that the fluid in the pipe can exert continuously with a high degree of certainty that the pipe will not fail. Pressure rating is related to pipe working pressure in that the pressure rating should be high enough to prevent damage to a plastic pipe from the highest static pressure plus any pressure surges which may occur. Pressure surges occur in all systems, the amount of the pressure depends on the system design. See Sprinkler Irrigation Chapter VIII for surge information. The pressure rating of a plastic pipe depends upon the hydrostatic design stress of the compound used in its manufacture, pipe diameter, and pipe wall thickness. Pipe wall thicknesses are specified for the Standard Dimension Ratio (SDR) or Schedule Series of pipe sizes in the applicable ASTM Standards. Recommended pressure ratings for SDR and Schedule sizes of pipe made from the various plastic materials are included in the appendix of the applicable ASTM Standard.

Hydrostatic design stress is defined as the estimated maximum tensile stress in the wall of the pipe in the circumferential orientation due to the internal hydrostatic pressure that can be applied continuously with a high degree of certainty that the pipe will not fail. This stress value for a plastic pipe material is determined by tests made on pipe samples as outlined in ASTM Method D-1598 - "Time-to-failure of plastic pipe under long-term hydrostatic pressure" and analyzed in accordance with ASTM Method D-2837 - "Obtaining hydrostatic design basis for thermoplastic pipe materials." (Also, Plastic Pipe Institute Technical Report PPI-TR-2-Oct. 1969.) Table IV-7 shows PVC and PE compound designations and hydrostatic design stress for plastic pipe used in sprinkler systems.

Standard thermoplastic pipe dimension ratio (SDR) is the ratio of pipe diameter to wall thickness. For PVC pipe, and outside diameter controlled PE pipe, SDR is calculated by dividing the average outside diameter of the pipe in inches by the minimum wall thickness in inches. If the wall thickness calculated by this formula is less than 0.060 inch, it should be arbitrarily increased to 0.060 inch. For PE pipe (inside diameter controlled), the SDR is calculated by dividing the average inside diameter of the pipe in inches by the minimum wall thickness in inches. If the wall thickness calculated by this formula is less than 0.060 inch, it should be arbitrarily increased to 0.060 inch. SDR values should be rounded off to the nearest 0.5.

The relation between standard dimension ratio, hydrostatic design stress, and pressure rating is given in the following formulas for PVC and PE pipe:

For PVC and PE outside diameter controlled pipe

$$\frac{2S}{P} = SDR - 1 \quad \text{or} \quad \frac{2S}{P} = \frac{OD}{t} - 1$$

For PE inside diameter controlled pipe

$$\frac{2S}{P} = SDR + 1 \quad \text{or} \quad \frac{2S}{P} = \frac{ID}{t} + 1$$

where S = hydrostatic design stress, psi
P = pressure rating, psi
ID = average inside diameter, inches
OD = average outside diameter, inches
t = minimum wall thickness, inches
SDR = standard thermoplastic pipe dimension ratio

Pipes of one material having the same SDR rating have the same pressure rating, regardless of pipe diameter; only the wall thickness will vary.

Schedule 40, 80, and 120 method of plastic pipe sizing gives pressure ratings that vary with pipe size and schedule number. The larger the pipe diameter, the smaller the pressure rating for the same pipe material. As an example, a Schedule 40 pipe made of PVC 1120 material 1 inch in diameter has a pressure rating of 450 psi and a 6-inch diameter pipe has a pressure rating of 180 psi. In contrast, SDR 26 PVC pipe of a 1120 material has a pressure rating of 160 psi regardless of pipe diameter.

Poly (vinyl chloride) pipe used in sprinkler irrigation is usually manufactured in one of two size designations, iron pipe size (IPS) or plastic irrigation pipe (PIP)[2]. The IPS plastic pipe has the same outside diameter (OD) as iron pipe, but the PIP pipe that has the same size designation has a slightly smaller outside diameter. Both pipe sizes are available in SDR ratings. The IPS pipe is also manufactured in Schedule 40, 80, and 120 pipe ratings.

Polyethylene pipe used in sprinkler irrigation is manufactured to both inside pipe diameter and outside pipe diameter specifications. Both sizes are available in SDR or Schedule 40 and 80 presure ratings for most materials.

ASTM specifications for PVC and PE pipe diameters, wall thicknesses and tolerances, and water pressure ratings are given in the appendix tables:

Type	*ASTM Specification No.*	*Pipe Size Classification*		*Table No.*
PE	D-2239	ID	SDR*	IV- 8, IV- 9, IV-10
PE	D-2104	ID	Schedule 40	IV-11, IV-12, IV-13
PE	D-3035	OD	SDR	IV-14, IV-15, IV-16
PE	D-2447	OD	Schedule 40 & 80	IV-17, IV-18, IV-19
PVC	D-2241 IPS	OD	SDR	IV-20, IV-21, IV-22
PVC	D-1785 IPS	OD	Schedule 40, 80, and 120	IV-23, IV-24, IV-25
PVC	PIP SCS 432-D Specification	OD	SDR	IV-26, IV-27, IV-28

*Standard dimension ratio

In its manufacture, plastic pipe is marked at intervals of not more than 5 feet along its length with the following: nominal pipe size, type of plastic pipe material in accordance with the designation code, the standard thermoplastic pipe dimension ratio or the pressure rating in pounds per square inch for water at 23°C (73.4 F), the ASTM Designation or whatever standard with which the pipe complies, the manufacturer's name or trademark and code, and if the pipe is intended for transporting potable water, the seal (mark) of the qualifying laboratory. The material designation code consists of the letter abbreviation for the type of plastic as given in ASTM 1600-71a followed by four figures. The first and second figures are the type and grade as determined in the pertinent ASTM material specification given in Arabic numerals. The third and fourth figures are the recommended hydrostatic design stresses in psi for water at 73°F divided by 100 with any decimals that result dropped; when this number contains less than two figures, a zero is used before the number. Some manufacturers may delete the IPS marking.

A sample marking is "4 PVC 1220 D-2241, 160 psi, P.P.Co." which means "4-inch pipe made of poly (vinyl chloride) meeting the requirements of Type I, Grade II in ASTM specification D-1748 with a recommended long life hydrostatic design stress of 2,000 psi for water at 73°F (23°C), meeting the requirements of ASTM Product Specification D-2241, a pressure rating of 160 psi, and manufactured by the Plastic Pipe Company."

DESIGN

The design of sprinkler systems using plastic pipe follows the general procedure given in Chapters II, VII, and XII of Sprinkler Irrigation. The pipeline should be designed to meet all service requirements without the pressure at any point in the pipeline being greater than the pressure rating of the pipe used at that point. This includes operating or static pressure plus any possible surge pressures from any part of the pipeline system. To reduce surge pressures, the velocity of water in the pipe should be kept as low as possible and should not exceed 5 feet per second.

Pressure losses from friction for PVC and PE pipe can be computed by the Hazen-Williams formula using a roughness coefficient of 150:

$$f = 0.2083 \left(\frac{100}{C} \right)^{1.852} \times \frac{q^{1.852}}{d^{4.8655}}$$

where f = friction head in feet of water per 100 feet of pipe
d = inside diameter of pipe in inches
q = water flow in gallons per minute
C = coefficient of inside roughness of the pipe (C = 150 for plastic pipe)

A nomograph for computing friction loss and water velocity in plastic pipe is shown in Figure IV-1. The pipe dimension for the nomograph is inside diameter of the pipe. For ID pipe, this is given in the pipe size tables; for OD pipe, two times the minimum wall thickness must be deducted from the outside diameter (OD) given in the pipe size tables.

The nomograph is used by lining up values on the scales by means of a ruler or straight edge. Two independent variables must be set to obtain the other values. For example, line (1) indicates that 500 gallons per minute may be conveyed with an 8-inch inside diameter pipe at a head loss of 0.18 pound per square inch per 100-foot length of pipe at a velocity of 3.3 feet per second. Line (2) indicates that a pipe with a 2.0-inch inside diameter will convey a flow of about 47 gallons per minute at a loss in head of 2 pounds per square inch per 100 feet of pipe. Line (3) and dotted line (4) show that in changing from a pipe 3.0-inch inside diameter to one of 2.5 inches inside diameter, the head loss increases from 0.55 to 1.3 pounds per square inch when conveying a flow of 70 gallons per minute.

Outlets, check valves, pressure relief, vacuum release, and air release devices of adequate sizes should be installed when needed.[11] A check valve should be installed between the pump and the pipeline if detrimental backflow could occur. For details of safety in design and operation, check the latest issue of the Soil Conservation Service Engineering Standard 432-D.

A pressure relief valve must be installed between the pump discharge and the pipeline when excessive pressures can be developed by operating with all valves closed. Where the pipelines are protected from reversal of flow by check valves and excessive surge pressures could result, a surge chamber or pressure relief valve must be installed. Pressure relief valves or surge chambers should be installed at the end of the pipeline when needed to relieve pressure rise there. Pressure relief valves should be no smaller than 1/4-inch for each inch diameter of the pipeline, and should be set to open at a pressure no greater than 5 psi above the pressure rating of the pipe[11].

Air release and vacuum release valves should be placed at all summits in the pipeline, and also at the end of the line when needed to provide a positive means for air escape or air entrance. The size of these valves varies with the inside diameter of the pipe. The Soil Conservation Service recommends 1/2-inch diameter outlets for pipelines 4 inches or less in diameter, 1-inch outlets for 5- to 8-inch pipelines, and 2-inch outlets for 10- to 12-inch pipelines[11].

Provisions must be made for draining a pipeline completely where a hazard is imposed by freezing temperatures, or drainage is recommended by the manufacturer of the pipe, or if drainage of the line is specified for the job. Where drainage is necessary, drainage outlets should be located at all low places in the line and air inlets provided at summits to prevent the development of partial vacuums. These outlets may drain into dry wells or to points of lower elevation. If drainage cannot be provided by gravity, provisions can be made to empty the line by pumping or by using compressed air. Where provisions are needed to flush sediment from the line, a suitable valve should be installed at the distal end of the pipeline[11].

If fittings such as couplings, reducers, bends, tees, crossings, inserts, and flared or compression types are used in connecting the plastic pipes in a sprinkler system, they should meet the appropriate material, dimensional, and quality requirements given in the following ASTM Specifications:

ASTM D-2464	Threaded poly (vinyl chloride) (PVC) plastic pipe fittings, Schedule 80
ASTM D-2466	Socket-type poly (vinyl chloride) (PVC) plastic pipe fittings, Schedule 40
ASTM D-2467	Socket-type poly (vinyl chloride) (PVC) plastic pipe fittings, Schedule 80
ASTM D-2609	Plastic insert fittings for polyethylene (PE) plastic pipe
ASTM D-2610	Butt fusion polyethylene (PE) plastic pipe fittings, Schedule 40
ASTM D-2611	Butt fashion polyethylene (PE) plastic pipe fittings, Schedule 80
ASTM D-2672	Bell-end poly (vinyl chloride) PVC pipe
ASTM D-2683	Socket-type polyethylene fittings for SDR 11.0 polyethylene (PE) pipe
ASTM D-3036	Poly (vinyl chloride) (PVC) plastic line couplings, socket type

All fittings should be made of material recommended for use with the particular pipe and installed in accordance with the recommendations of the pipe manufacturer.

INSTALLATION

Installation is the assembling of pipe, fittings, and other sprinkler equipment into a complete irrigation system. All joints and connections should be made so as to withstand the design maximum working pressure for the pipeline without leakage and without obstructing the inside of the pipeline in a manner that would reduce its capacity below the design requirements.

Chapter X in Sprinkler Irrigation gives the general instructions for assembling pipe into a sprinkler system. Additional suggestions here on the installation of plastic pipe will supplement them. PVC pipe is joined by using solvent-welded joints, gasketed couplers, or clamps. The manufacturer's recommendations should be followed for joining each type of pipe and fittings.

Solvent-welded connections require closer tolerances, both in fabrication and installation practices. To minimize any problems for this

type of connection, the following recommendations and requirements are suggested[6]:

1. The dry fit of the connection must be snug. Improper fit should necessitate rejection of the pipe or coupling.
2. Building up the joint with multiple layers of solvent to overcome a loose fit should not be permitted.
3. Shaving of the pipe to decrease the outside diameter to form a joint should not be permitted.
4. Fittings must be of the same material and ratings as the pipe.
5. Solvents should be supplied by the pipe manufacturer to assure proper formulation for the pipe delivered.
6. Solvents should be compounded for weather conditions during the season of installation.
7. All dirt, dust, and moisture should be removed from the surfaces to be solvent welded.
8. The glaze of the pipe should be broken for proper bonding of the materials.
9. Extra caution should be exercised with solvent welds if the temperature is below 25°F or above 90°F.
10. The manufacturer's recommendations concerning curing time for solvents should be followed.
11. Male ends of pipe should be slightly beveled to prevent excessive removal or wiping of the solvent during insertion.
12. Excessive solvent is detrimental to the joint and should be removed.
13. Cutting the pipe should be done in a neat workmanlike manner with the use of a fine-tooth saw, tubing cutter, etc. The cut should be square and a file or cutting tool used to remove ragged edges. If possible, the use of a miter box is recommended.
14. Another important note to remember is that solvents are toxic and inflammable, so exercise caution when handling these materials.

Adherence to these techniques will produce a consistently high quality solvent-weld joint.

Gasket connections are the most dependable and most economical from the contractor's viewpoint, but require an awareness of the following potential trouble spots during installation[6].

1. An improper fit should be cause for rejection of the pipe or coupling.
2. The gasket recess in the coupling should be clean and smooth to assure a watertight joint.
3. The male end of the pipe should be inserted into the coupling to a depth indicated by the manufacturer's marking.
4. Gaskets should be supplied by the pipe manufacturer to assure proper tolerances.
5. Male end of the pipe should be slightly beveled to prevent rolling out the gasket during insertion.

6. To meet National Sanitation Foundation approval, all areas of the gasket pocket must meet or exceed the rating of the pipe.

These are a few of the items that should be constantly kept in mind concerning gasket joints. Recommended guidelines when installing PVC must be followed. Installation shortcuts should be avoided. Polyethylene (PE) pipe may be joined by butt-fusion of pipe, by butt-fusion of pipe and fittings, by socket-fusion or insert-fusion of pipe and fittings, by flaring of pipe ends and use of suitable metal fittings, or by the use of plastic-insert or metal-insert fittings and clamps, flanges, and metal backup rings, mechanically tightened compression fittings and companion pipe-stiffener inserts, or self-restraining mechanical couplings with hydraulic sealing gaskets. Where heat fusion of pipe and components is contemplated, the manufacturer's recommendations should be strictly followed. Materials to be so joined should be the same grade of PE compound, and trained personnel with the proper equipment are needed for making a leakproof connection.

After the pipe is placed in a trench, it should be allowed to come within a few degrees of the lowest possible temperature before the trench is backfilled. The pipeline should be installed deep enough below the ground surface to provide protection from hazards imposed by traffic crossing, farming operations, freezing temperatures, or soil cracking. Soil Conservation Service recommends a minimum depth of:

1. 18 inches for pipes 1/2 to 2-1/2 inches in diameter.
2. 24 inches for pipes over 2-1/2 and up to 4 inches in diameter.
3. 30 inches for pipes over 4 inches in diameter

At low places on the ground surface, extra fill may be placed over the pipeline to provide the minimum depth of cover. In such cases, the top width of the fill should be no less than 10 feet and the side slopes no steeper than 6 horizontal to 1 vertical.

Where rock, hardpan, boulders, or any other material that might damage the pipe are encountered, the trench should be undercut a minimum of 4 inches below final grade and backfilled to grade. The material used to establish final grade can be sand or fine-graded stable soil.

The pipeline should be thoroughly and completely tested for pressure strength and leakage before backfilling is begun. The line should be filled very slowly with water, taking care to bleed all entrapped air in the process. The pressure should be slowly raised to the maximum design working pressure. The line should be thoroughly inspected while the maximum working pressure is maintained. Leaks should be repaired and the line retested. Sometimes it may be necessary to partially backfill the trench before pipe testing so as to hold the pipe in place. If such is the case, only the body of the pipe sections should be covered and all joints and connections should be left uncovered to enable inspection.

Testing should show that the pipeline will function properly at design capacity. There should be no objectionable surge or water hammer.

Backfilling

The pipe must be uniformly and continuously supported. Blocking or mounding should not be used to bring the pipe to final grade. The initial backfill should be of selected fine-grained material free from rocks or stones larger than 1 inch in diameter, and earth clods larger than about 2 inches in diameter. The initial fill should be placed under, around, and over the pipe so as to comply with Section 8 of ASTM D-2321 Underground Installation of Flexible Thermoplastic Sewer Pipe where low- or high-head pipe is used. Care should be taken to avoid deformation or displacement of the pipe during this phase of the operation.

When water packing is used, the pipeline first must be filled with water. The initial backfill, before wetting, should be deep enough to insure complete coverage of the pipe after consolidation has taken place. Water packing is accomplished by adding water in such quantity as to thoroughly saturate the initial backfill without inundation. After saturation, the pipeline should remain full until final backfilling is finished.

The remainder of the backfill should be placed in approximately uniform layers in a manner to fill the trench and leave no unfilled spaces. Final backfill material should be free from rocks larger than 3 inches in diameter and should be added and compacted in a manner that will leave the fill at ground level after it has settled. Rolling equipment should not be used until a minimum of 18 inches of backfill material has been placed over the top of the pipe.

Special backfilling requirements of the pipe manufacturer should be observed.

Miscellaneous

The thermal properties of plastic pipe make it necessary to reduce the pressure ratings when the temperature of the water increases above the standard test temperature of 73°F (23°C). Both PVC and PE pipe pressure rating reductions should be obtained from the manufacturer. Table IV-29 gives one manufacturer's suggested derating multiplier for temperatures up to 120°.

Both PVC and PE pipe expand and contract with temperature changes. The amount of change in length with temperature varies among the different specific kinds of PVC and PE pipe. Under non-restrained conditions, linear expansion or contraction per 100 feet of pipe for each 10°F of temperature change ranges from 1/3 to 2/3 of an inch for PVC materials, and from 7/8 to 1-1/4 inches for PE materials. Table IV-30 shows the allowance for changes in length for PVC pipe made from Type 1, Grades 1 or 2 materials as recommended in ASTM Specification D-2665. Some method for compensating for the expansion and contraction of the pipe with temperature change must

be a part of the system design. One method is to snake plastic pipe along the bottom of the trench. This allows extra length for contraction. Allowance is provided for expansion and contraction in PVC pipe by using fittings with gasketed seals at intervals along the pipe.

Thrust blocks should be used at all changes in direction at tees and bends, changes in pipe size, dead ends, and valves for gasketed pipe systems. The size and type of thrust block depends upon operating pressure, pipe size, and kind of soil. A thrust block can be constructed by pouring low slump concrete between the pipe and the undisturbed bearing wall of the trench. The stiff concrete can then be shaped into a wedge with its widest side against the bearing wall.

A buried plastic pipeline is not as easy to find as steel pipe. A wire is sometimes buried along with the pipe during installation to enable metal detectors to locate the pipe.

Plastic pipe used to carry water for human consumption is required to carry the National Sanitation Foundation (NSF) approval marking on the pipe. In many areas, this also applies to pipe carrying water for livestock use.

At high altitudes there will be ultraviolet deterioration if PVC pipe is exposed to the sunlight, resulting in changes in color of white pipe to yellow and brittleness[2]. It is the general feeling in the plastic pipe industry that PVC should be buried for longer life of the pipe.

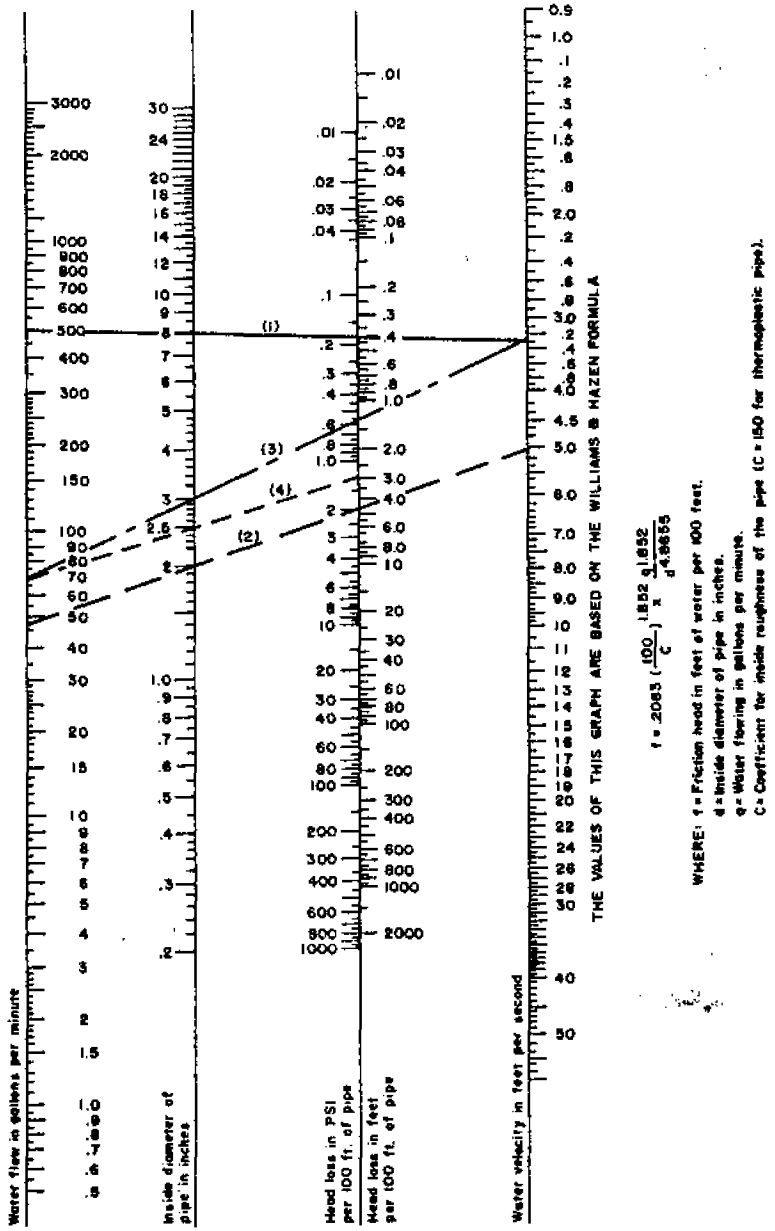


FIGURE IV-1.
Flow loss characteristics of water flow through rigid plastic pipe.[3]

TABLE IV-1
Reference standards for poly (vinyl chloride) and polyethylene pipes[8]

ASTM	American Society for Testing and Materials 1916 Race Street Philadelphia, Pennsylvania 19103
D-883	Nomenclature relating to plastics
D-1180	Test for bursting strength of round rigid plastic tubing
D-1248	Specifications for polyethylene plastics molding and extrusion materials
D-1598	Test for time-to-failure of plastic pipe under long-term hydrostatic pressure
D-1599	Test for short-time rupture strength of plastic pipe, tubing, and fittings
D-1600	Abbreviations of terms relating to plastics
D-1603	Test for carbon black in ethylene plastics
D-1784	Specification for rigid poly (vinyl chloride) compounds and chlorinated poly (vinyl chloride) compounds
D-1785	Specifications for poly (vinyl chloride) plastic pipe Schedules 40, 80, and 120
D-2104	Specification for polyethylene plastic pipe, Schedule 40, (ID base)
D-2122	Determining dimensions of thermoplastic pipe and fittings
D-2153	Recommended practice for calculating stress in plastic pipe under internal pressure
D-2239	Specification for polyethylene (PE) plastic pipe (SDR-PR) (ID base)
D-2241	Standard specifications for poly (vinyl chloride) (PVC) plastic pipe (SDR-PR and Class T)
D-2321	Recommended practice for underground installation of flexible thermoplastic sewer pipe
D-2412	Test for external loading properties of plastic pipe by parallel-plate loading
D-2444	Test for impact resistance of thermoplastic pipe and fittings by means of a tup (falling weight)
D-2447	Specification for polyethylene plastic pipe, Schedules 40 and 80 based on outside diameter
D-2464	Specifications for threaded poly (vinyl chloride) (PVC) plastic pipe fittings, Schedule 80
D-2466	Specifications for socket-type poly (vinyl chloride) (PVC) plastic pipe fittings, Schedule 40
D-2467	Specifications for socket-type poly (vinyl chloride) (PVC) plastic pipe fittings, Schedule 80

TABLE IV-1—con...ed

D-2564	Specifications for solvent cements for poly (vinyl chloride) (PVC) plastic pipe and fittings
D-2609	Specification for plastic insert fittings for polyethylene (PE) plastic pipe (insert-clamp type)
D-2610	Specification for butt-fusion polyethylene (PE) plastic pipe fittings, Schedule 40
D-2611	Specification for butt-fusion polyethylene (PE) plastic pipe fittings, Schedule 80
D-2657	Recommended practice for heat joining of thermoplastic pipe and fittings
D-2683	Specification for socket-type polyethylene fittings for SDR 11.0 polyethylene pipe
D-2737	Specification for polyethylene (PE) plastic tubing
D-2749	Symbols for dimensions of plastic pipe fittings
D-2774	Recommended practice for underground installation of thermoplastic pressure piping
D-2837	Obtaining hydrostatic design basis for thermoplastic pipe materials
D-2855	Making solvent cemented joints with PVC pipe and fittings
D-3035	Specification for polyethylene plastic pipe (SDR-PR) based on controlled outside diameter

PPI (Technical Reports) Plastics Pipe Institute, Division of
The Society of the Plastics Industry, Inc.
250 Park Avenue
New York, New York 10017

TR-1	A glossary of plastics piping terms
TR-2	Recommended method for obtaining hydrostatic design basis for thermoplastic pipe
TR-3	Policies and procedures for developing recommended hydrostatic design stresses for thermoplastic pipe
TR-4	Recommended hydrostatic design stresses for thermoplastic pipe compounds for water
TR-5	Standards for plastics piping
TR-6	Recommended standard dimensional terminology for plastic pipe fittings
TR-7	Recommended method for calculation of nominal weight of plastic pipe
TR-8	Installation procedures for polyethylene plastic pipe
TR-9	Recommended service (design) factors for pressure applications of thermoplastic pipe materials
TR-13	Poly (vinyl chloride) (PVC) plastic piping design and installation
TR-14	Water flow characteristics of thermoplastic type

D 1784

TABLE IV-2 Class Requirements for Rigid Poly (Vinyl Chloride) Compounds[1]

NOTE—The minimum property value will determine the cell number although the maximum expected value may fall within a higher cell

Designation Order No.	Property and Unit	Cell Limits								
		0	1	2	3	4	5	6	7	8
1	Base resin	unspecified	poly(vinyl chloride) homopolymer	chlorinated poly(vinyl chloride)	ethylene vinyl chloride copolymer	propylene vinyl chloride copolymer	vinyl acetate-vinyl chloride copolymer	alkyl vinyl ether-vinyl chloride copolymer		
2	Impact strength (Izod) min:									
	cm·kgf/cm of notch	unspecified	<3.55	3.55	8.2	27.0	54.0	81.0		
	ft·lb/in. of notch		<0.65	0.65	1.5	5.0	10.0	15.0		
3	Tensile strength, min:									
	kgf/mm²	unspecified	<3.5	3.5	4.2	4.9	5.6			
	psi		<5 000	5 000	6 000	7 000	8 000			
4	Modulus of elasticity in tension, min:									
	kgf/mm²	unspecified	<197	197	225	253	281	309		
	psi		<280 000	280 000	320 000	360 000	400 000	440 000		
5	Deflection temperature under load, min, 0.1856 kgf/mm² (264 psi):									
	deg C	unspecified	<55	55	60	70	80	90	100	110
	deg F		<131	131	140	158	176	194	212	230
	Flammability	All compounds covered by this specification shall be self-extinguishing according to ASTM Method D 635.								

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TABLE IV-3 Suffix Designation for Chemical Resistance[c]

Solution	A	B	C	D
H_2SO_4 (93 percent)—14 days immersion at 55 ± 2 C:				
Change in weight:				
Increase, max, percent	1.0[a]	5.0[a]	25.0	NA[b]
Decrease, max, percent	0.1[a]	0.1[a]	0.1	NA
Change in flexural yield strength:				
Increase, max, percent	5.0[a]	5.0[a]	5.0	NA
Decrease, max, percent	5.0[a]	25.0[a]	50.0	NA
H_2SO_4 (80 percent)—30 days immersion at 60 ± 2 C:				
Change in weight:				
Increase, max, percent	NA	NA	5.0	15.0
Decrease, max, percent	NA	NA	5.0	0.1
Change in flexural yield strength:				
Increase, max, percent	NA	NA	15.0	25.0
Decrease, max, percent	NA	NA	15.0	25.0
ASTM Oil No. 3—30 days immersion at 23 C:				
Change in weight:				
Increase, max, percent	0.5	1.0	1.0	10.0
Decrease, max, percent	0.5	1.0	1.0	0.1

[a] Specimens washed in running water and dried by an air blast or other mechanical means shall show no sweating within 2 h after removal from the acid bath.
[b] NA = not applicable.

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TABLE IV-4 Classification of Polyethylene Plastics Molding and Extrusion Materials According to Type[c]

Type	Nominal Density,[a] g/cm[3]
I	0.910 to 0.925
II	0.926 to 0.940
III	0.941 to 0.959
IV	0.960 and higher

[a] Uncolored, unfilled material (see Note 9).

TABLE IV-5 Classification of Polyethylene Plastics Molding and Extrusion Materials According to Category[c]

Category	Nominal Flow Rate, g/10 min (190 C, 2160-g load)
1	>25
2	>10 to 25
3	>1.0 to 10
4	>0.4 to 1.0
5	0.4 max

[3] *Annual Book of ASTM Standards*, Part 28.

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TABLE IV-6 Detail Requirements for Molded Test Specimens[a]

Property and Unit	Grade[b] P14	P23	P33	P34
Tensile strength, min:[c]				
kgf/cm²	125	125	225	225
(psi)[b]	(1800)	(1800)	(3200)	(3200)
Elongation, min, percent	500	400	100	500
Brittleness temperature, max, deg C	−70	−60	−70	−75
Environmental stress-crack resistance,[c,d] min, F_{50} h	...	...	...	192
Thermal stress-crack resistance, h without cracking, min	...	...	...	...
Dissipation factor,[e] max:				
Class A				
Before milling	...	...	...	...
After milling	...	...	...	...
Class B	...	...	...	...
Class C	...	...	...	...
Dielectric constant,[f] max increase over nominal[f]				
Class A	...	...	...	...
Class B	...	...	...	...
Class C	...	...	...	...

[a] P—Pipe.
Further, the numbers associated with the pipe materials identify them in terms of the types and grades previously given in Specification D 1248 – 63 T; for example P14 signifies a Type I, Grade 4 material under that specification. Grade P34 is an exception since it identifies a Type III material of a grade not previously specified (very high molecular weight). As indicated by Note 6, other grades may be added by revision of this specification as the need arises.

[b] Both metric and U.S. customary units have been rounded off for simplicity and, therefore, are not equivalent. In borderline cases, the exact equivalent of the metric value shall apply.

[c] F_{50} is the time required for failure of 50 percent of the samples tested in accordance with Method D 1693 as further directed by 10.1.8.1, 10.1.8.2 and 10.1.8.3 of this specification.

[d] Requirements for environmental stress-crack resistance apply only to Class C (weather resistant compounds) unless otherwise specified (see 4.2.6).

[e] At any frequency from 1 KHz through 1 MHz. (see also 10.1.10.1, 10.1.10.2, and 10.1.10.3).

[f] Dielectric constant is a function of density; hence, the nominal value will be different for each type. Based on published information, the nominal values for the four types covered by this specification are as follows: Type I—2.28, Type II—2.31, Types III and IV—2.35 (Lanza, V. L., and Herrmann, D. B., *Journal of Polymer Science*, JP SCA, Vol 28, 1958, p. 622). To illustrate the manner in which the maximum limit for the dielectric constant of a particular, grade is determined, assume that a Type I, Class A material is to be supplied under Grade E2, then its maximum limit for dielectric constant will be 2.28 + 0.01 = 2.29.

[g] Dissipation factor and dielectric constant must not exceed the limits specified above after immersion of the test specimens in water as described in 10.1.11. However, because this test is lengthy, it need not be performed on every lot of material. Rather, the material is to be checked initially for compliance with this requirement and, after that, as often as necessary to assure continued compliance. This requirement is not applicable to weather resistant (Class C) compounds (see Note 13).

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TABLE IV-7
Designation and Hydrostatic Design Stress—Plastic Pipe

Compound	Compound designation Former Type	Grade	New*	Standard code designation of compound	Class	Hydrostatic design stress for water at 73 F psi
PVC	I	1	12454-B	PVC 1120		2000
PVC	I	2	12454-C	PVC 1220		2000
PVC	II	1	14333-D	PVC 2110		1000
PVC	II	1	14333-D	PVC 2112		1250
PVC	II	1	14333-D	PVC 2116		1600
PVC	II	1	14333-D	PVC 2120		2000
PE	I	4	P14	PE 1404	C	400
PE	II	3	P23	PE 2305	C	500
PE	II	3	P23	PE 2306	C	630
PE	III	3	P33	PE 3306	C	630
PE	III	3	P34	PE 3406	C	630

*The 1972 ASTM Specifications D-1784 and D-1248 specify the pipe compound designation in the new cell-block designation system rather than in the previous type and grade system.

[1] From: Soil Conservation Service Engineering Standard 432-D, 1971, p. 14.

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TABLE IV-8 Inside Diameters and Tolerances for SDR-PR PE Plastic Pipe, in.[1]

Nominal Pipe Size	Average Inside Diameter	Tolerances
½	0.622	+0.010 −0.010
¾	0.824	+0.010 −0.015
1	1.049	+0.010 −0.020
1¼	1.380	+0.010 −0.020
1½	1.610	+0.015 −0.020
2	2.067	+0.015 −0.020
2½	2.469	+0.015 −0.025
3	3.068	+0.015 −0.030
4	4.026	+0.015 −0.035
6	6.065	+0.020 −0.035

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TABLE IV-9 Wall Thicknesses and Tolerances for SDR-PR PE Plastic Pipe, in.[1]

Nominal Pipe Size	Wall Thickness[a] SDR 15 Minimum	SDR 15 Tolerance[c]	SDR 11.5[b] Minimum	SDR 11.5 Tolerance[c]	SDR 9 Minimum	SDR 9 Tolerance[c]	SDR 7 Minimum	SDR 7 Tolerance[c]	SDR 5.3 Minimum	SDR 5.3 Tolerance[c]
½	0.060	+0.020	0.060	+0.020	0.069	+0.020	0.089	+0.020	0.117	+0.020
¾	0.060	+0.020	0.072	+0.020	0.092	+0.020	0.118	+0.020	0.155	+0.020
1	0.070	+0.020	0.091	+0.020	0.117	+0.020	0.150	+0.020	0.198	+0.024
1¼	0.092	+0.020	0.120	+0.020	0.153	+0.020	0.197	+0.024	0.260	+0.031
1½	0.107	+0.020	0.140	+0.020	0.179	+0.020	0.230	+0.028	0.304	+0.036
2	0.138	+0.020	0.180	+0.022	0.230	+0.028	0.295	+0.035	0.390	+0.047
2½	0.165	+0.020	0.215	+0.025	...	...	...	...	...	...
3	0.205	+0.020	0.267	+0.032	...	...	...	...	...	...
4	0.268	+0.032	0.350	+0.042	...	...	...	...	...	...
6	0.404	+0.048	0.527	+0.063	...	...	...	...	...	...

[a] The minimum is the lowest wall thickness of the pipe at any cross section. All tolerances are on the plus side of the minimum requirement.
[b] The 2½ to 6-in. pipe with a pressure rating of 0.69 MPa (100 psi) is not included.
[c] This is limited by the eccentricity requirement (see 5.2.3).
MPa is Mega Pascals = Mega Newtons/m²

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TABLE IV-10 Standard Thermoplastic Pipe Dimension Ratios (SDR) and Water Pressure Ratings (PR) at 23 C (73.4 F) for SDR-PR PE Plastic Pipe[1]

Standard Dimension Ratio	PE Pipe Materials*			
	PE3306 PE3406	PE2306	PE2305	PE1404
	Pressure Rating MPa (psi)			
5.3	1.38 (200)	1.38 (200)	1.10 (160)	0.86 (125)
7	1.10 (160)	1.10 (160)	0.86 (125)	0.69 (100)
9	0.86 (125)	0.86 (125)	0.69 (100)	0.55 (80)
11.5	0.69 (100)	0.69 (100)	0.55 (80)	
15	0.55 (80)	0.55 (80)		

Pressure Rating, MPa (psi)				
1.38 (200)	5.3	5.3		
1.10 (160)	7	7	5.3	
0.86 (125)	9	9	7	5.3
0.69 (100)	11.5	11.5	9	7
0.55 (80)	15	15	11.5	9

* See 2.6 and 3.4 for code designation.

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TABLE IV-11 Inside Diameters and Tolerances for PE Plastic Pipe, Schedule 40, in.[1]

Nominal Pipe Size,	Average Inside Diameter	Tolerances
½	0.622	+0.010 −0.010
¾	0.824	+0.010 −0.015
1	1.049	+0.010 −0.020
1¼	1.380	+0.010 −0.020
1½	1.610	+0.015 −0.020
2	2.067	+0.015 −0.020
2½	2.469	+0.015 −0.025
3	3.068	+0.015 −0.030
4	4.026	+0.015 −0.035
6	6.065	+0.020 −0.035

TABLE IV-12 Wall Thicknesses and Tolerances for PE Plastic Pipe, Schedule 40, in.[1]

Nominal Pipe Size	Wall Thickness*	
	Minimum	Tolerance†
½	0.109	+0.020
¾	0.113	+0.020
1	0.133	+0.020
1¼	0.140	+0.020
1½	0.145	+0.020
2	0.154	+0.020
2½	0.203	+0.024
3	0.216	+0.026
4	0.237	+0.028
6	0.280	+0.034

* The minimum is the least wall thickness of the pipe at any cross section. All tolerances are on the plus side of the minimum requirement.
† This is limited by the eccentricity requirements, see 5.2.3.

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TABLE IV-13 Water Pressure Ratings at 23 C (73.4 F) for Schedule 40 PE Plastic Pipe[1]

Nominal Pipe Size, in.	Pressure Ratings, psi*		
	PE2306† PE3306 PE3406	PE2305†	PE1404†
½	190	150	120
¾	150	120	100
1	140	110	90
1¼	120	90	70
1½	100	80	70
2	90	70	60
2½	100	80	60
3	80	70	50
4	70	60	NPR
6	60	NPR‡	NPR

* These pressure ratings apply only to unthreaded pipe. The industry does not recommend threading PE plastic pipe.
† See code designation.
‡ NPR = not pressure rated.

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TABLE IV-14 Outside Diameters and Tolerances for SDR-PR PE Plastic Pipe[1]

Nominal Pipe Size, in.	Outside Diameter, in. (mm)	Tolerances, in.
½	0.840 (21.34)	±0.004
¾	1.050 (26.7)	±0.004
1	1.315 (33.4)	±0.005
1¼	1.660 (42.2)	±0.005
1½	1.900 (48.3)	±0.006
2	2.375 (60.3)	±0.006
3	3.500 (88.9)	±0.008
4	4.500 (114.3)	±0.009
6	6.625 (168.28)	±0.011

TABLE IV-15 Wall Thicknesses and Tolerances for SDR-PR PE Plastic Pipe[1]

Nominal Pipe Size, in.	SDR 17		SDR 13.5		SDR 11	
	Minimum,* in.	Tolerance, in.	Minimum,* in.	Tolerance, in.	Minimum,* in.	Tolerance, in.
½	0.062	+0.020	0.062	+0.020	0.076	+0.020
¾	0.062	+0.020	0.078	+0.020	0.095	+0.021
1	0.077	+0.020	0.097	+0.020	0.119	+0.026
1¼	0.098	+0.020	0.123	+0.020	0.151	+0.026
1½	0.112	+0.020	0.141	+0.020	0.173	+0.026
2	0.140	+0.020	0.176	+0.021	0.216	+0.026
3	0.206	+0.025	0.259	+0.031	0.318	+0.038
4	0.264	+0.032	0.333	+0.040	0.409	+0.049
6	0.390	+0.047	0.491	+0.059	0.602	+0.072

* The minimum is the lowest wall thickness of the pipe allowable at any cross-section.

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TABLE IV-16 Standard Thermoplastic Pipe Dimension Ratios (SDR) and Water Pressure Ratings (PR) at 23 C (73.4 F) for SDR-PR PE Plastic Pipe[1]

Standard Dimension Ratio	PE Pipe Materials[a]			
	PE3406 & PE3306	PE2306	PE2305	PE1404
	Pressure Rating psi (MPa)			
11	125 (0.86)	125 (0.86)	100 (0.69)	80 (0.55)
13.5	100 (0.69)	100 (0.69)	80 (0.55)	
17	80 (0.55)	80 (0.55)		

Pressure Rating psi (MPa)	Standard Dimension Ratio			
125 (0.86)	11	11	...	...
100 (0.69)	13.5	13.5	11	...
80 (0.55)	17	17	13.5	11

[a] See 2.6 and 3.4 for code designations.

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TABLE IV-17 Outside Diameters and Tolerances for PE Plastic Pipe, Schedules 40 and 80, in.[1]

Nominal Pipe Size	Average Outside Diameter	Tolerance	
		For Average Diameter	For Maximum and Minimum Diameter (Out-of-Roundness)
½	0.840	±0.004	±0.015
¾	1.050	±0.004	±0.020
1	1.315	±0.005	±0.025
1¼	1.660	±0.005	±0.025
1½	1.900	±0.006	±0.030
2	2.375	±0.006	±0.035
2½	2.875	±0.007	±0.035
3	3.500	±0.008	±0.040
3½	4.000	±0.008	±0.050
4	4.500	±0.009	±0.050
5	5.563	±0.010	±0.050
6	6.625	±0.011	±0.050
8	8.625	±0.015	±0.075
10	10.750	±0.015	±0.075
12	12.750	±0.015	±0.075

TABLE IV-18 Wall Thickness and Tolerances for PE Plastic Pipe, Schedules 40 and 80,[a] in.[1]

Nominal Pipe Size	Wall Thickness			
	Schedule 40		Schedule 80	
	Minimum	Tolerance	Minimum	Tolerance
½	0.109	+0.020	0.147	+0.020
¾	0.113	+0.020	0.154	+0.020
1	0.133	+0.020	0.179	+0.021
1¼	0.140	+0.020	0.191	+0.023
1½	0.145	+0.020	0.200	+0.024
2	0.154	+0.020	0.218	+0.026
2½	0.203	+0.024	0.276	+0.033
3	0.216	+0.026	0.300	+0.036
3½	0.226	+0.027	0.318	+0.038
4	0.237	+0.028	0.337	+0.040
5	0.258	+0.031	0.375	+0.045
6	0.280	+0.034	0.432	+0.052
8	0.322	+0.039	...	...
10	0.365	+0.044	...	...
12	0.406	+0.049	...	...

[a] The minimum is the lowest wall thickness of the pipe at any cross section. All tolerances are on the plus side of the minimum requirement.

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TABLE IV-19 Water Pressure Ratings at 23 C (73.4 F) for PE Plastic Pipe, Schedules 40 and 80[1]

Nominal Pipe Size, in.	Pressure Rating[a]					
	PE2306, PE3306 PE3406		PE2305[a]		PE1404[a]	
	Sch 80	Sch 40	Sch 80†	Sch 40	Sch 80†	Sch 40†
	psi					
½	188	267	149	212	119	170
¾	152	217	120	172	96	137
1	142	199	113	158	90	126
1¼	116	164	92	130	74	104
1½	104	148	83	118	66	94
2	87	127	69	101	55	81
2½	96	134	76	106	61	85
3	83	118	66	94	53	75
3½	75	109	60	86	50	69
4	70	102	55	81	NPR	65
5	61	91	50	72	NPR	58
6	55	88	NPR	70	NPR	56
8	50	...	NPR	...	NPR	...
10	NPR[c]	...	NPR	...	NPR	...
12	NPR	...	NPR	...	NPR	...

[a] These pressure ratings apply only to unthreaded pipe. The industry does not recommend threading PE plastic pipe.
[b] See code designation.
[c] NPR = not pressure rated. The industry does not recommend pressure ratings less than 0.34 MPa (50 psi).
†Corrected editorially.

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TABLE IV-20 Outside Diameters and Tolerances for PVC Plastic Pipe[1]

Nominal Pipe Size, in.	Average Outside Diameter, in.	Tolerances, in.		
		For Average	For Maximum and Minimum (Out-of-Roundness)	
			SDR64 SDR41 SDR32.5 SDR26 SDR21	SDR17 SDR13.5
⅜	0.405	±0.004	±0.015	±0.008
½	0.540	±0.004	±0.015	±0.008
⅝	0.675	±0.004	±0.015	±0.008
¾	0.840	±0.004	±0.015	±0.008
⅞	1.050	±0.004	±0.015	±0.010
1	1.315	±0.005	±0.015	±0.010
1¼	1.660	±0.005	±0.015	±0.012
1½	1.900	±0.006	±0.030	±0.012
2	2.375	±0.006	±0.030	±0.012
2½	2.875	±0.007	±0.030	±0.015
3	3.500	±0.008	±0.030	±0.015
3½	4.000	±0.008	±0.050	±0.015
4	4.500	±0.009	±0.050	±0.015
5	5.563	±0.010	±0.050	±0.030
6	6.625	±0.011	±0.050	±0.035
8	8.625	±0.015	±0.075	±0.045
10	10.750	±0.015	±0.075	±0.050
12	12.750	±0.015	±0.075	±0.060

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TABLE IV-21 Wall Thicknesses and Tolerances for PVC Plastic Pipe[a]

Nominal Pipe Size, in.	SDR64 Minimum	SDR64 Tolerance	SDR41 Minimum	SDR41 Tolerance	SDR32.5 Minimum	SDR32.5 Tolerance	SDR26 Minimum	SDR26 Tolerance	SDR21 Minimum	SDR21 Tolerance	SDR17 Minimum	SDR17 Tolerance	SDR13.5 Minimum	SDR13.5 Tolerance
	Wall Thickness[a], in.													
1/8	...	...	...	...	...	...	...	...	...	...	...	...	0.060	+0.020
1/4	...	...	...	...	...	...	...	...	...	...	...	...	0.060	+0.020
3/8	...	...	...	...	...	...	...	...	...	...	...	...	0.060	+0.020
1/2	...	...	...	...	...	...	...	...	...	...	...	...	0.062	+0.020
3/4	...	...	...	...	...	...	...	...	0.060	+0.020	0.062	+0.020	0.078	+0.020
1	...	...	...	...	...	...	0.060	+0.020	0.063	+0.020	0.077	+0.020	0.097	+0.020
1¼	...	...	...	...	...	...	0.064	+0.020	0.079	+0.020	0.098	+0.020	0.123	+0.020
1½	...	...	...	...	...	...	0.073	+0.020	0.090	+0.020	0.112	+0.020	0.141	+0.020
2	...	...	...	...	...	...	0.091	+0.020	0.113	+0.020	0.140	+0.020	0.176	+0.021
2½	...	...	...	...	...	...	0.110	+0.020	0.137	+0.020	0.169	+0.020	0.213	+0.026
3	...	...	...	...	0.108	+0.020	0.135	+0.020	0.167	+0.020	0.206	+0.025	0.259	+0.031
3½	...	...	0.098	+0.020	0.123	+0.020	0.154	+0.020	0.190	+0.023	0.235	+0.028	0.296	+0.036
4	...	...	0.110	+0.020	0.138	+0.020	0.173	+0.021	0.214	+0.026	0.265	+0.032	0.333	+0.040
5	...	...	0.136	+0.020	0.171	+0.021	0.214	+0.027	0.265	+0.032	0.327	+0.039	0.412	+0.049
6	0.104	+0.020	0.162	+0.020	0.204	+0.024	0.255	+0.031	0.316	+0.038	0.390	+0.047	0.491	+0.059
8	0.135	+0.020	0.210	+0.025	0.265	+0.032	0.332	+0.040	0.410	+0.049	0.508	+0.061	...	...
10	0.168	+0.020	0.262	+0.031	0.331	+0.040	0.413	+0.050	0.511	+0.061	0.632	+0.076	...	...
12	0.199	+0.024	0.311	+0.037	0.392	+0.047	0.490	+0.059	0.606	+0.073	0.750	+0.090	...	...

[a] The minimum is the lowest wall thickness of the pipe at any cross section. All tolerances are on the plus side of the minimum requirement.

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TABLE IV-22 Standard Thermoplastic Pipe Dimension Ratios (SDR) and Water Pressure Ratings (PR) at 23 C (73.4 F) for Nonthreaded[a] PVC Plastic Pipe[1]

SDR	PVC 1120 / PVC 1220 MN/m²	PVC 1120 / PVC 1220 psi	PVC 2116 / CPVC 4116 MN/m²	PVC 2116 / CPVC 4116 psi	PVC 2112 MN/m²	PVC 2112 psi	PVC 2110 MN/m²	PVC 2110 psi
	PVC Pipe Materials[b] — Pressure Rating							
13.5	2.17	315	1.72	250	1.38	200	1.10	160
17	1.72	250	1.38	200	1.10	160	0.86	125
21	1.38	200	1.10	160	0.86	125	0.69	100
26	1.10	160	0.86	125	0.69	100	0.55	80
32.5[c]	0.86	125	0.69	100	0.55	80	0.43	63
41[d]	0.69	100	0.55	80	0.43	63	0.34	50
64[e]	0.43	63	0.34	50	NPR[f]	NPR[f]	NPR[f]	NPR[f]

Pressure Rating MN/m²	Pressure Rating psi	Standard Dimension Ratio			
2.17	315	13.5	...	...	...
1.72	250	17	13.5	...	...
1.38	200	21	17	13.5	...
1.10	160	26	21	17	13.5
0.86	125	32.5	26	21	17
0.69	100	41	32.5	26	21
0.55	80	...	41	32.5	26
0.43	63	64	...	41	32.5
0.34	50	...	64	...	41

[a] These pressure ratings do not apply for threaded pipe.
[b] See 2.6 and 3.4 for code designation.
[c] Available only in nominal pipe size diameters of 3 to 12 in.
[d] Available only in nominal pipe size diameters of 3½ to 12 in.
[e] Available only in nominal pipe size diameters of 6 to 12 in.
[f] NPR = not pressure rated.

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TABLE IV-23 Outside Diameters and Tolerances for PVC Plastic Pipe, Schedules 40, 80, and 120, in.*

Nominal Pipe Size	Outside Diameter	Tolerances		
		Average	For Maximum and Minimum Diameter (Out-of-Roundness)	
			Schedule 40 sizes 8.89 cm (3½ in.) and over; Schedule 80 sizes 20.32 cm (8 in.) and over	Schedule 40 sizes 7.62 cm (3 in.) and less; Schedule 80 sizes 15.24 cm (6 in.) and less; Schedule 120 sizes all
⅛	0.405	±0.004	...	±0.008
¼	0.540	±0.004	...	±0.008
⅜	0.675	±0.004	...	±0.008
½	0.840	±0.004	...	±0.008
¾	1.050	±0.004	...	±0.010
1	1.315	±0.005	...	±0.010
1¼	1.660	±0.005	...	±0.012
1½	1.900	±0.006	...	±0.012
2	2.375	±0.006	...	±0.012
2½	2.875	±0.007	...	±0.015
3	3.500	±0.008	...	±0.015
3½	4.000	±0.008	±0.050	±0.015
4	4.500	±0.009	±0.050	±0.015
5	5.563	±0.010	±0.050	±0.030
6	6.625	±0.011	±0.050	±0.035
8	8.625	±0.015	±0.075	±0.045
10	10.750	±0.015	±0.075	±0.050
12	12.750	±0.015	±0.075	±0.060

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TABLE IV-24 Wall Thicknesses and Tolerances for PVC Plastic Pipe, Schedules 40, 80, and 120,*† in.*

Nominal Pipe Size	Wall Thickness[a]					
	Schedule 40		Schedule 80		Schedule 120	
	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
⅛	0.068	+0.020	0.095	+0.020	...	...
¼	0.088	+0.020	0.119	+0.020	...	...
⅜	0.091	+0.020	0.126	+0.020	...	...
½	0.109	+0.020	0.147	+0.020	0.170	+0.020
¾	0.113	+0.020	0.154	+0.020	0.170	+0.020
1	0.133	+0.020	0.179	+0.021	0.200	+0.024
1¼	0.140	+0.020	0.191	+0.023	0.215	+0.026
1½	0.145	+0.020	0.200	+0.024	0.225	+0.027
2	0.154	+0.020	0.218	+0.026	0.250	+0.030
2½	0.203	+0.024	0.276	+0.033	0.300	+0.036
3	0.216	+0.026	0.300	+0.036	0.350	+0.042
3½	0.226	+0.027	0.318	+0.038	0.350	+0.042
4	0.237	+0.028	0.337	+0.040	0.437	+0.052
5	0.258	+0.031	0.375	+0.045	0.500	+0.060
6	0.280	+0.034	0.432	+0.052	0.562	+0.067
8	0.322	+0.039	0.500	+0.060	0.718	+0.086
10	0.365	+0.044	0.593	+0.071	0.843	+0.101
12	0.406	+0.049	0.687	+0.082	1.000	+0.120

[a] The minimum is the lowest wall thickness of the pipe at any cross section. All tolerances are on the plus side of the minimum requirement.

† These dimensions conform to nominal IPS dimensions, with the exception that Schedule 120 wall thickness for pipe sizes ½ to 3½ in., inclusive, are special PVC plastic pipe sizes.

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TABLE IV-25 Water Pressure Ratings at 23 C (73.4 F) for Schedule 40 PVC Plastic Pipe[1]

Nominal Pipe Size	Pressure Ratings			
	PVC1120[a] PVC1220	PVC2116 PVC4116	PVC2110[a]	PVC2112[a]
Inches	Pounds per Square Inch[a]			
⅛	810	650	400	500
¼	780	620	390	490
⅜	620	500	310	390
½	600	480	300	370
¾	480	390	240	300
1	450	360	220	280
1 ¼	370	290	180	230
1 ½	330	260	170	210
2	280	220	140	170
2 ½	300	240	150	190
3	260	210	130	160
3 ½	240	190	120	150
4	220	180	110	140
5	190	160	100	120
6	180	140	90	110
8	160	120	80	100
10	140	110	70	90
12	130	110	70	80

[a] These pressure ratings apply only to unthreaded pipe. The industry does not recommend threading PVC plastic pipe in Schedule 40 dimensions in nominal pipe sizes 150 mm (6 in.) and smaller.

[b] See 2.5 and Appendix for code designation.

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TABLE IV-25 Water Pressure Ratings at 23 C (73.4 F) for Schedule 80 PVC Plastic Pipe[1]

Nominal Pipe Size, in.	Pressure Ratings, psi							
	PVC1120, PVC1220		PVC2116, CPVC4116		PVC2110		PVC2112	
	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded
⅛	1230	610	980	490	610	310	770	380
¼	1130	570	900	450	570	280	710	350
⅜	920	460	730	370	460	230	570	290
½	850	420	680	340	420	210	530	260
¾	690	340	550	280	340	170	430	210
1	630	320	500	250	320	160	390	200
1 ¼	520	260	420	210	260	130	320	160
1 ½	470	240	380	190	240	120	290	150
2	400	200	320	160	200	100	250	130
2 ½	420	210	340	170	210	110	260	130
3	370	190	300	150	190	90	230	120
3 ½	350	170	280	140	170	90	220	110
4	320	160	260	130	160	80	200	100
5	290	140	230	120	140	70	180	90
6	280	140	220	110	140	70	170	90
8	250	120	200	100	120	60	150	80
10	230	120	190	90	120	60	150	70
12	230	110	180	90	110	60	140	70

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TABLE IV-25 Water Pressure Ratings at 23 C(73.4 F) for Schedule 120 PVC Plastic Pipe[4]

Nominal Pipe Size, in.	Pressure Ratings, psi							
	PVC1120, PVC1220		PVC2116, CPVC4116		PVC2110		PVC2112	
	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded
½	1010	510	810	410	510	250	630	320
¾	770	390	620	310	390	190	480	240
1	720	360	570	290	360	180	450	220
1¼	600	300	480	240	300	150	370	190
1½	540	270	430	210	270	130	340	170
2	470	240	380	190	240	120	290	150
2½	470	230	370	190	230	120	290	150
3	440	220	360	180	220	110	280	140
3½	380	190	310	150	190	100	240	120
4	430	220	340	170	220	110	270	130
5	400	200	320	160	200	100	250	120
6	370	190	300	150	190	90	230	120
8	380	180	290	140	180	90	230	110
10	370	180	290	140	180	90	230	110
12	340	170	270	140	170	80	210	110

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TABLE IV-26
Outside Diameters for Plastic Irrigation Pipe (PIP) PVC[5]

PIP size	Outside diameter	Tolerance: For average measurements	For maximum and minimum: SDR 51, 41, 32.5, 26, and 21	For maximum and minimum: SDR 17 and 13.5
	inches			
4	4.130	±0.009	±0.050	±0.015
6	6.140	±0.011	±0.050	±0.030
8	8.160	±0.015	±0.070	±0.042
10	10.200	±0.015	±0.075	±0.050
12	12.240	±0.015	±0.075	±0.060

[5]From: Soil Conservation Service Engineering Standard 432-D, 1971, p. 15.

TABLE IV-27
Wall Thickness* of Plastic Irrigation Pipe (PIP)[7]

PIP size	SDR 51 Min.	SDR 51 Tol.	SDR 21 Min.	SDR 21 Tol.	SDR 32.5 Min.	SDR 32.5 Tol.	SDR 26 Min.	SDR 26 Tol.	SDR 21 Min.	SDR 21 Tol.	SDR 17 Min.	SDR 17 Tol.	SDR 13.5 Min.	SDR 13.5 Tol.
	inches													
4	—	—	0.101	+0.020	0.127	+0.020	0.159	+0.020	0.197	+0.024	0.243	+0.029	0.306	+0.037
6	0.120	+0.020	0.150	+0.020	0.189	+0.023	0.236	+0.028	0.292	+0.035	0.361	+0.043	0.455	+0.054
8	0.160	+0.020	0.199	+0.024	0.251	+0.031	0.314	+0.038	0.389	+0.047	0.480	+0.058	0.604	+0.072
10	0.200	+0.024	0.249	+0.030	0.314	+0.038	0.392	+0.047	0.486	+0.058	0.600	+0.072	0.756	+0.091
12	0.240	+0.029	0.299	+0.036	0.377	+0.045	0.471	+0.056	0.583	+0.070	0.720	+0.086	0.907	+0.109

*The minimum is the least wall thickness of the pipe at any cross section. All tolerances are on the plus side of the minimum requirement.

[7]From: Soil Conservation Service Engineering Standard 432-D, 1971, p. 16.

TABLE IV-28

Water Pressure Rating in psi by Types, Grades, and Standard Dimension Ratios (SDR) of Non-threaded Pipes[5]

	PVC Materials			
SDR	PVC 1120, 1220, 2120	PVC 2116	PVC 2112	PVC 2110
7.0				
9.0				
11.5				
13.5	315	250	200	160
17.0	250	200	160	125
21.0	200	160	125	100
26.0	160	125	100	80
32.5	125	100	80	63
41.0	100	80	63	50
51.0	80	63	50	

[5]From: Soil Conservation Service Engineering Standard 432-D, 1971, p. 12.

TABLE IV-29

Working Pressure Versus Temperature Derating Table for PVC

Temperature (°F)	PVC Factor
73	1.00
80	.88
90	.75
100	.62
110	.50
120	.40
130	.30
140	.22

HOW TO USE:

Determine the highest temperature the PVC pipe will encounter.

Find the corresponding derating multiplier for that temperature.

Multiply the maximum working pressure rating for the particular pipe to be used by the derating multiplier. Your answer is the actual working pressure limit for that particular pipe and temperature.

TABLE IV-30

Thermal Expansion Table for PVC Plastic Pipe and Fittings* (reference - ASTM D-2665).

	Temperature change, degrees F						
Length, ft.	40	50	60	70	80	90	100
	Length change, inches						
100	1.39	1.74	2.09	2.44	2.78	3.13	3.48

*For PVC Type 1, Grades 1 and 2 materials

BIBLIOGRAPHY

1. American Society for Testing Materials. 1972. Plastics—Specifications, methods of testing pipe, film, reinforced and cellular plastics; fiber composites. Annual Book of ASTM Standards, Part 26, 1110 pages.
2. Clubb, C. C. 1972. Material aspects of plastic irrigation pipe. Amer. Soc. Agric. Eng. Paper No. 72-757.
3. Encyclopedia Britannica. 1969. Volume 18, page 2.
4. Encyclopedia International. 1964. Volume 14, page 416.
5. Giuffre, Joe. 1968. Understanding plastic pipe standards. Sprinkler Irrig. Assn. Ann. Tech. Conf. Proc., February 25-27, p. 36-47.
6. Lively, Robert M., and Don Jennings. 1972. Plastic pipe installation techniques from a contractor's viewpoint. Amer. Soc. Agric. Eng. Paper No. 72-759.
7. Plastic Pipe Institute. 1971. Water flow characteristics of thermoplastic pipe. Tech. Report PPI-TR-14, March.
8. Plastic Pipe Institute. 1972. Thermoplastic water piping systems. Tech. Report PPI-TR-16, June.
9. Plastic Pipe Institute. 1972. Standards for plastic piping. Tech. Report PPI-TR-5, January.
10. Soil Conservation Service, USDA. 1971. Irrigation pipeline—high pressure underground plastic. Engineering Standard 432-D, April.

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