**ANSI/ASAE S376.3 FEB2016**
**Design, Installation and Performance of Underground, Thermoplastic Irrigation Pipelines**

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# Design, Installation and Performance of Underground, Thermoplastic Irrigation Pipelines

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**Keywords:** HDPE, Irrigation, Pipe, Plastic, PVC

## 1 Purpose and Scope

**1.1 Purpose.** Thermoplastic pipe is manufactured in several size classifications from different materials of various grades, types and formulations involving many different specifications. It is used for applications other than irrigation where certain requirements often apply to pipe used for a specific purpose. This Standard pertains to thermoplastic pipe used underground for irrigation and is intended to:

**1.1.1** Provide minimum guidelines for engineers and others in planning, designing and specifying thermoplastic pipe commonly used for irrigation. It is not intended as a complete specification or to replace the judgment of personnel familiar with site conditions or other controlling factors.

**1.1.2** Provide information from referenced standards to promote uniformity in the design and installation of thermoplastic pipe in underground irrigation systems.

**1.1.3** Establish minimum requirements for the design, installation and testing of pipelines which are necessary for the satisfactory performance and safe operation of the irrigation system and to prevent damage to the system

**1.2 Scope.** This Standard applies to underground, thermoplastic pipelines used in the conveyance of irrigation water to the point of distribution and may or may not apply to potable water systems.

**1.2.1** Polyvinyl chloride (PVC) plastic pipe, standard dimension ratio - pressure rated (SDR-PR). This Standard applies to underground thermoplastic PVC (SDR-PR) pipelines 4 to 1500 mm (0.125 to 60 in.) nominal diameter with a pressure rating of 2170 kPa (315 psi) or less.

NOTE: Nominal pipe size in millimeters is the actual outside pipe diameter to the nearest millimeter for OD controlled pipe and the actual inside diameter to the nearest millimeter for ID controlled pipe.

**1.2.2** Polyethylene (PE) plastic pipe, (SDR-PR). This standard applies to underground thermoplastic PE pipelines 13 to 1651 mm (0.5 to 65 in.) nominal diameter with a pressure rating of 2308 kPa (335 psi) or less.



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## 2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies unless noted. For undated references, the latest approved edition of the referenced document (including any amendments) applies.

### 2.1 General Standards

ASTM D638, Standard Test Method for Tensile Properties of Plastics

ASTM D1598, Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure

ASTM D1599, Standard Test Method for Resistance to Short-Time Hydraulic Pressure Failure of Plastic Pipe, Tubing, and Fittings

ASTM D2122, Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

ASTM D2321, Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications

ASTM D2412, Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading

ASTM D2444, Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)

ASTM D2774, Standard Practice for Underground Installation of Thermoplastic Pressure Piping

ASTM D2837, Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials

ASTM D3139, Standard Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals

ASTM F477, Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

ASTM F1668, Standard Guide for Construction Procedures for Buried Plastic Pipe

ISO 161-1:1996, Thermoplastics pipes for the conveyance of fluids — Nominal outside diameters and nominal pressures — Part 1: Metric series

PPI TR-3 Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Materials

PPI TR-4 HDB/HDS/SDB/MRS Listed Materials

### 2.2 HDPE Standards

ASTM D1603, Standard Test Method for Carbon Black Content in Olefin Plastics

ASTM D2609, Standard Specification for Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe

ASTM D3035, Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter

ASTM D3261, Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing

ASTM D3350, Standard Specification for Polyethylene Plastics Pipe and Fittings Materials



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ASTM D4218 Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle Furnace Method

ASTM F714, Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter

ASTM F1055, Standard Specification for Electrofusion Type Polyethylene Plastic Fittings for Outside Dimension Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing

ASTM F2164 Standard Practice for Field Leak Testing of Polyethylene (PE) and Crosslinked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure

ASTM F2620 Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings

AWWA C 906, Polyethylene (PE) Pressure Pipe and Fittings, 4 in. (100 mm) Through 63 in. (1,600 mm), for Water Distribution and Transmission

AWWA Manual M 55 PE Pipe Design and Installation

PPI Handbook of Polyethylene Pipe, Second Edition, Irving, TX 2009

### 2.3 PVC Standards

ASTM D1784, Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds

ASTM D2152, Standard Test Method for Adequacy of Fusion of Extruded Poly (Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion

ASTM D2241, Standard Specification for Poly (Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)

ASTM D2466, Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40

ASTM D2467, Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80

ASTM D2564, Standard Specification for Solvent Cements for Poly (Vinyl Chloride) (PVC) Plastic Piping Systems

ASTM D2672, Standard Specification for Joints for IPS PVC Pipe Using Solvent Cement

AWWA C905, Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 14 in. thru 48 in. (350 mm thru 1,200 mm) for Water Transmission and Distribution

AWWA C605, Underground Installation of Polyvinyl Chloride (PVC) Pressure Pipe and Fittings for Water

ASTM F402, Standard Recommended Practice for Safe Handling of Solvent Cements, Primers, and Cleaners Used for Joining Thermoplastic Pipe and Fittings

## 3 Definitions

**3.1 design area:** The specific land area in which pipelines are planned and located to serve as integral parts of an irrigation water distribution or conveyance system, designed to facilitate conservation, use and management of water and soil resources, and which the supplier or designer and purchaser mutually understand to be irrigated.

**3.2 irrigation system:** All equipment required to convey water to or within the design area.

**3.3 irrigation pipelines:** Includes the underground, thermoplastic pipelines and appurtenances installed in an irrigation system.



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**3.3.1 high pressure pipelines:** This term applies to underground, thermoplastic pipelines that are closed to the atmosphere, and are subject to internal pressures, including surge pressures of 550 kPa (80 psi) or greater.

**3.3.2 low pressure pipelines:** This term applies to underground thermoplastic pipelines that are used in systems subject to pressures of less than 550 kPa (less than 80 psi.

**3.4 outlets:** Appurtenances required to deliver water from the pipeline to an individual sprinkler or to a lateral of sprinklers, to surface pipe located on the ground, to distribution pipe or laterals containing surface or subsurface emitters or tricklers, to surface valves, or to open ditches.

**3.5 hydrostatic design basis (HDB):** The HDB is derived from ASTM D 2837, Standard Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials, where constant hydrostatic stress loading is extrapolated for 100,000 hours and 50 years at 73.4°F (23°C).

**3.6 hydrostatic design stress (HDS):** The estimated maximum tensile stress the material is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur. This stress is circumferential when internal hydrostatic water pressure is applied. It is the HDB with a safety factor (SF). (That is HDS = HDB/SF).

**3.7 pressure rating (PR):** The estimated maximum pressure that water in the pipe can exert continuously with a high degree of certainty that the pipe will not fail.

**3.8 dimensional ratio (DR):** The average specified diameter of a pipe or tubing divided by the minimum specified wall thickness.

**3.8.1 standard dimension ratio (SDR):** The ratio of the average outside pipe diameter to the minimum wall thickness for outside diameter-controlled plastic pipe. Typical SDRs are: 6.0, 7.3, 9.0, 11.0, 13.5, 17, 21, 26, 32.5, 41.0, 51, and 64.

**3.8.2 standard inside diameter ratio (SIDR):** A specific ratio of the average inside pipe diameter to the average specified wall thickness (Di/t) for inside diameter-controlled plastic pipe.

**3.9 relation between standard dimension ratio, hydrostatic design stress and pressure rating:** The following expression, commonly known as the ISO equation (from ISO 161-1-1996), is used to relate standard dimension ratio, hydrostatic design stress, and pressure rating:

**3.9.1 For PVC OD based pipe:**

$$2\ S/P = R - 1$$

or

$$2\ S/P = (D_o/t) - 1$$

where:

$S$ is hydrostatic design stress (HDS), kPa (psi); where HDS = HDB / 2

$P$ is pressure rating (PR), kPa (psi)

$D_o$ is average outside diameter, mm (in.)

$t$ is minimum wall thickness, mm (in.)

$R$ is dimension ratio, DR or SDR (equals $D_o/t$)



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### 3.9.2 For HDPE OD based pipe:

$$PR = HDB \times (\text{design factor, } D_f) \times (F_T) / (DR - 1)$$

where:

HDB = hydrostatic design basis (1600 psi for HDPE pipe materials listed in tables included in this standard)

$D_f$ = design factor

= 0.50 for PE3408/3608 pipe materials

= 0.63 for PE4710 pipe materials

$F_T$ = service temperature design factor

= 1.0 for service temperatures up to 80°F

DR = dimension ratio

= outside diameter/minimum wall thickness

### 3.9.3 For ID based pipe:

$$2\ S/P = R + 1$$

or

$$2\ S/P = (D_i / t) + 1$$

where $R$ is dimension ratio, DR or SIDR (equals $D_i / t$ for ID based plastic pipe).

# 4 Pipeline Design Criteria

## 4.1 Working pressure

**4.1.1 Working Pressure — PVC.** The PVC pipeline shall have a pressure rating (see Table 1) greater than the static or working pressure, plus surge pressure at any point in the system. If surge pressures are not known, pipe velocities should be maintained to 1.5 m/s (5 ft/s) or less and the working pressure shall not exceed 72% of the pressure rating for the particular pipe and SDR or DR used. Table 1 also provides other pressure information for a particular pipe and SDR or DR used. The pipe pressure rating may be used when a detailed hydraulic and water hammer analysis is performed. Maximum allowable surge pressures for a particular pipe and SDR or DR used is presented in Table 1 . For other SDR or DR, the surge pressure is determined by:

$$\text{Metric: } P = 1440 V [Et / (Et + 2\ 070\ 000 D_i)]^{1/2}$$

$$\text{Inch-Pound: } P = 63.5 V [Et / (Et + 300\ 000 D_i)]^{1/2}$$

where:

$P$ is surge pressure, kPa (psi)

$V$ is sudden change in velocity, m/s (ft/s)

$E$ is modulus of elasticity of pipe material, kPa (psi); 2 800 000 kPa (400 000 psi) for most PVC

$t$ is pipe wall thickness, mm (in.)

$D_i$ is pipe inside diameter (ID), mm (in.)



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**TABLE 1 – Pressure Ratings of Poly (Vinyl Chloride) (PVC) in psi at 73.4° F. (23 C)**
**Cell Classification — 12454**
**HDB 4 000 (HDS 2 000)**

| DR or SDR | Pressure Rating psi | Quick Burst psi | Sustained Pressure psi | Surge @1 ft/sec[1] psi |
|---|---|---|---|---|
| 50' hd | 22 | 70 | 83 | |
| 93.5 | 43 | 135 | 90 | 7.5 |
| 81 | 50 | 160 | 105 | 8.1 |
| 64 | 63 | 200 | 130 | 9.1 |
| 51 | 80 | 260 | 168 | 10.2 |
| 41 | 100 | 315 | 210 | 11.4 |
| 32.5 | 125 | 400 | 270 | 12.9 |
| 26 | 160 | 500 | 340 | 14.4 |
| 25 | 165 | 535 | 350 | 14.6 |
| 21 | 200 | 630 | 420 | 16.1 |
| 18 | 235 | 755 | 500 | 17.4 |
| 17 | 250 | 800 | 530 | 18.0 |
| 14 | 305 | 985 | 650 | 19.8 |
| 13.5 | 315 | 1 000 | 670 | 20.3 |

[1] Surge per 1 ft/s sudden velocity change

**4.1.1.1 Service factor — PVC.** All pressure ratings are determined in a water environment of 23 ± 3°C (73.4 ± 5.4°F), which is generally not exceeded by irrigation water. Where water temperature exceeds this limit, the pressure rating must be decreased to allow for safe operation of the pipe and fittings. Appropriate ASTM and AWWA standards and manufacturer literature should be consulted for recommended service factors.

**4.1.2 Working Pressure — HDPE.** The working pressure rating is the design capacity to resist working pressure at the anticipated operating temperature with sufficient capacity against the actual anticipated positive pressure surges above working pressure. Table 2, Pressure Rating and Surge for PE 3408/3608 and PE 4710 PE Pipe provides the allowable pressure surges for different velocities and dimensional ratios.

**Table 2 – Pressure Rating and Surge for PE3408/3608 and PE4710 PE Pipe**

| Dimension Ratio, DR | Pressure Rating, psi | | Surge Pressures (psi) at Specific Flow Velocities, psi | | | | | |
|---|---|---|---|---|---|---|---|---|
| | PE3408 / 3608 | PE4710 | 1.0 ft/sec | 2.0 ft/sec | 3.0 ft/sec | 4.0 ft/sec | 5.0 ft/sec | 7.0 ft/sec |
| 32.5 | 50 | 63 | 8.0 | 16.0 | 24.0 | 32.0 | 40.0 | 56.0 |
| 26 | 63 | 80 | 8.9 | 17.8 | 26.7 | 35.6 | 44.5 | 62.3 |
| 21 | 80 | 100 | 10.0 | 20.0 | 30.0 | 40.0 | 50.0 | 70.0 |
| 17 | 100 | 125 | 11.3 | 22.1 | 33.9 | 45.2 | 56.5 | 79.1 |
| 15.5 | 110 | 138 | 11.8 | 23.6 | 35.4 | 47.2 | 59.0 | 82.6 |
| 13.5 | 125 | 160 | 12.8 | 25.6 | 38.4 | 51.2 | 64.0 | 89.6 |
| 11 | 160 | 200 | 14.4 | 28.8 | 43.2 | 57.6 | 72.0 | 100.8 |
| 9 | 200 | 250 | 16.2 | 32.4 | 48.6 | 64.8 | 81.0 | 113.4 |



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To determine surge pressures for other SDRs and flow rates not shown in section 4.1 use the following equations for polyethylene pipe:

$$a = 4\,660/[1 + (K_{bulk}/E_d)(DR - 2)]^{1/2}$$

where:

$a$ = wave velocity in fps

$K_{bulk}$ = bulk modulus of water at 80ºF and lower

= 300 000 psi

$E_d$ = dynamic instantaneous effective modulus of PE pipe

= 150 000 psi

DR = pipe dimension ratio

$$P_S = a\,(\Delta V/2.31 \times g)$$

where:

$P_S$ = surge pressure, psi

a = wave velocity, fps

$\Delta V$ = sudden velocity change, fps

$g$ = gravitational acceleration constant

= 32.2 ft/sec$^2$

**4.2 Pipeline capacity.** The design capacity of the pipeline shall be sufficient to provide an adequate flow of water for all methods of irrigation planned.

**4.3 Friction losses.** For design purposes, friction head losses shall be no less than those computed by the Hazen-Williams equation using a coefficient (C) equal to 150.

**4.4 Flow velocity.** The design water velocity in a pipeline when operating at system capacity should not exceed 1.5 m/s (5 ft/s) unless special considerations are given to the control of surge or water hammer and adequate protection from these pressures is provided (see section 5.1.1 and Table 1 and 2). Adequate pressure and/or air relief valves shall be used with all velocities.

**4.5 Outlets.** Outlets shall have adequate capacity at the pipeline working pressure to deliver the design flow to the distribution system at the design operating pressure of the respective systems, i.e., sprinklers, surface pipe, emitters, tricklers, etc.

**4.6 Check valves.** A check valve shall be installed between the pump discharge and the pipeline where detrimental back flow may occur. It shall be designed to close, without slamming shut, at the point of zero velocity before damaging reversal of flow can occur.

**4.7 Pressure relief valves.** These shall be installed between the pump discharge and the pipeline when excessive pressures can develop by operating with all valves closed. Pressure relief valves or surge chambers shall be installed on the discharge side of the check valve where back flow may occur and at the end of the pipeline when needed to relieve surge.

**4.7.1 Low pressure systems.** Pressure relief valves may be used as alternatives to serve the pressure relief functions of vents and stands open to the atmosphere. They do not function as air release valves and should not be substituted for such valves where release of entrapped air is required.

**4.7.1.1** Pressure relief valves shall have enough capacity to pass the full pipe discharge with a pipeline pressure no greater than 50% above the pressure rating of the pipe.



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**4.7.1.2** Pressure relief valves shall be marked with the pressure at which the valve starts to open. Adjustable valves shall be installed in such a manner to prevent changing of the adjustment marked on the valve.

**4.7.2 High pressure systems.** The ratio of nominal size pressure relief valves to pipeline diameter shall be no less than 0.25. Pressure relief valves shall be set to open at a pressure no greater than 34.5 kPa (5 psi) above the pressure rating of the pipe or the lowest pressure rated component in the system.

**4.8 Air release and vacuum relief valves.** Air release and vacuum relief valves shall be installed at all summits, at the ends, and at the entrance of pipelines to provide for air escape and entrance. Combination air-vacuum release valves which provide both functions may be used.

**4.8.1 Air flow capacity.** Valves having large orifices to exhaust large quantities of air from pipelines when filling and to allow air to enter to prevent a vacuum when draining are required at the end and entrance of all pipelines. Valves intended to release entrapped air only may have smaller orifices and are required at all summits.

**4.8.2 Low pressure systems (not open to the atmosphere)**

**4.8.2.1** Air-vacuum release valves shall be provided at each of the locations described in section 5.6.

**4.8.2.2** The size of valve outlet for low pressure systems shall be as specified in section 5.6.2.

**4.8.3 High pressure systems.** The ratio of air release valve diameter to pipe diameter for valves intended to release air when filling the pipe should not be less than 0.1. However, smaller diameter valves may be used as a means of limiting water hammer pressures by controlling air release where filling velocities cannot be controlled. Equivalent valve outlet diameters of less than 0.1 are permitted for continuously acting air release valves. Adequate vacuum relief must still be provided. It is very important to select the correct air release or vacuum breaker valve and to properly locate where needed. Air vacuum release valves shall be used as follows (all valve diameters refer to the total cross-sectional flow area of the vent or port outlet):

| Pipe diameter, mm (in.) | Minimum air-vacuum, release valve outlet, diameter, mm (in.) |
|---|---|
| 102 (4) or less | 13 (0.5) |
| 127-203 (5-8) | 25 (1) |
| 254-500 (10-20) | 51 (2) |
| 530 (21) or larger | 0.1 × pipe diameter |

**4.9 Draining.** Provisions shall be made for draining the pipeline completely where a hazard is imposed by freezing temperatures, drainage is recommended by the manufacturer of the pipe, or drainage of the line is specified for any reason. Where provisions for drainage are required, drainage outlets shall be located at all low places in the line. The outlets may drain into dry wells or to points of low elevation. If drainage cannot be provided by gravity, provisions shall be made to empty the line by pumping.

**4.10 Flushing.** Where provision is needed to flush the line of sediment, a suitable valve shall be installed at the distal end of the pipeline. Intermediate valves may be required at changes in pipe diameters in order to achieve proper flushing velocities in all clauses of the pipeline.

**4.11 Gate stands and float valve stands.** When these are used in low pressure pipelines not open to the atmosphere, refer to the criteria in sections 5.4.1 and 5.4.2.



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