Examination Standard
for
Polyvinyl Chloride (PVC) Pipe
and
Fittings for Underground Fire Protection Service

Class Number 1612

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Foreword

This standard is intended to verify that the products and services described will meet stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of this standard is to present the criteria for examination of various types of products and services.

Examination in accordance with this standard shall demonstrate compliance and verify that quality control in manufacturing shall ensure a consistent and reliable product.

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1. INTRODUCTION

1.1 Purpose

1.1.1 This standard states testing and certification requirements for polyvinyl chloride (PVC) pipe and fittings for underground fire service water mains.

1.1.2 Testing and certification criteria may include performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a surveillance program.

1.2 Scope

1.2.1 This standard encompasses the design and performance requirements for NPS (Nominal Pipe Size) 4 in. through 36 in. PVC pipe and fittings for use in underground fire service mains. Other sizes may be considered for certification on a case by case basis.

1.2.2 In cases where metric sized PVC pipe and fittings are to be examined for certification, test criteria comparable to the United States equivalent size shall be used.

1.2.4 The certification agency will consider PVC pipe and fittings which are designed in accordance to national or international standards. Only after verification is made that the products to be reviewed are in conformance to ANSI/AWWA C900, ANSI/AWWA C907, ANSI/AWWA C909 or other nationally or internationally recognized standards will certification testing commence. All certification testing is to be conducted on production samples.

1.3 Basis for Requirements

1.3.1 The requirements of this standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions and/or loss control specialists was also considered.

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of PVC pipe and fittings for the purpose of obtaining certification. PVC pipe and fittings having characteristics not anticipated by this standard may be certified if performance is equal, or superior, to that required by this standard is demonstrated.

1.4 Basis for Certification

Certification is based upon satisfactory evaluation of the product and the manufacturer in the following major areas:

1.4.1 Examination and tests on production samples shall be performed to evaluate:

- the suitability of the product;
- the performance of the product as specified by the manufacturer and required for certification;
- the durability and reliability of the product.

1.4.2 An examination of the manufacturing facilities and audit of quality control procedures may be conducted to evaluate the manufacturer's ability to consistently produce the product which is examined and tested, and the marking procedures used to identify the product. Subsequent surveillance may be required by the certification agency in accordance with the certification scheme to ensure ongoing compliance.

1.5 Basis for Continued Certification

The basis for continual certification may include the following based upon the certification scheme and requirements of the certification agency:

- production or availability of the product as currently certified;
- the continued use of acceptable quality assurance procedures;
- satisfactory field experience;
- compliance with the terms stipulated by the certification
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory surveillance audits conducted as part of the certification agency's surveillance program.

1.6 Effective Date

The effective date of this examination standard mandates that all products tested for certification after the effective date shall satisfy the requirements of this standard.

The effective date of this standard is eighteen (18) months after the publication date of the standard for compliance with all requirements.

1.7 System of Units

Units of measurement used in this standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Conversion of U.S. customary units is in accordance with ANSI/IEEE/ASTM SI 10.

Two units (liter and bar), outside of but recognized by SI, are commonly used in international fire protection and are used in this standard.

1.8 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the cited edition applies:

ANSI A21.1, *American National Standard for Thickness Design of Cast Iron Pipe*
ANSI/IEEE/ASTM SI 10 *American National Standard for Metric Practice*
ASTM D883, Standard *Terminology Relating to 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 of Plastic Pipe, Tubing, and Fittings*
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 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 D2837, *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Bases for Thermoplastic Pipe Products*
ASTM F412, *Standard Terminology Relating to Plastic Piping Systems*
ASTM F477, *Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe*

ASTM F610-610M, *Standard Practice for Evaluating the Quality of Molded Poly(Vinyl Chloride) (PCV) Plastic Pipe Fittings by the Heat Reversion Technique*
ANSI/AWWA C900, *Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings*, *4 in. Through 60 in. (100 mm Through 1500 mm)*
ANSI/AWWA C907, Injection Molded *Polyvinyl Chloride (PVC) Pressure Fittings, 4 in. Through 12 in. (100 mm Through 300 mm) for Water, Wastewater, and Reclaimed Water Service*
ANSI/AWWA C909, *Molecularly Oriented Polyvinyl Chloride (PVCO) Pressure Pipe, 4 in. through 24 in. (100 mm Through 600 mm) For Water, Wastewater, and Reclaimed Water Service*
NSF/ANSI 61, *Drinking Water Systems Components - Health Effects*

1.9 Terms and Definitions

Generally, terminology relating to PVC pipe and fittings shall be in accordance with ASTM D883, *Standard Terminology Relating to Plastics* and ASTM F412, *Standard Terminology Relating to Plastic Piping Systems*, respectively. Any terminology not included within, or in contradiction to, those documents will be separately defined where used in the certification examination of PVC pipe and fittings. For purposes of this standard, the following terms apply:

Accepted

This term refers to installations acceptable to the authority enforcing the applicable installation rules (Authority Having Jurisdiction). Acceptance is based upon an overall evaluation of the installation. Acceptance is not a characteristic of a product. It is installation specific. A product accepted for one installation may not be acceptable elsewhere.

Design Factor (DF)

The factor that is used to reduce the Hydrostatic Design Basis (*HDB*) to arrive at the Hydrostatic Design Stress (*HDS*). The Design Factor is the inverse of the Factor of Safety.

Dimension Ratio (DR)

The ratio of the average outside diameter of outside diameter-controlled plastic pipe to the minimum specified wall thickness of the pipe, rounded to the nearest tenth (e.g. DR 13.5).

Factor of Safety (SF)

A number, typically greater than 2.0, by which the Hydrostatic Design Basis (HDB) is divided to obtain the Hydrostatic Design Stress (HDS). This SF is used to account for variations in conditions from those contemplated in the design of an installation, rough handling of piping, and manufacturing variations.

Hydrostatic Design Basis (HDB)

One of a series of established stress values specified in ASTM Test Method D2837 for a plastic compound obtained by categorizing the Long Term Hydrostatic Strength of the material as described in ASTM D2837, *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products*.

Hydrostatic Design Stress (HDS)

The recommended maximum allowable hoop stress used in the design of plastic pipe of a given material. It is obtained by dividing the Hydrostatic Design Basis (*HDB*) by a factor of safety.

$$HDS = \frac{HDB}{SF}$$

For water distribution and transmission pipe, nominal sizes 4 in. through 60 in., the minimum factor of safety is 2.0 as described in AWWA C900 and AWWA C909.

Long Term Hydrostatic Strength (LTHS)

Plastic materials exhibit a time-dependent response to stress. This occurs in a predictable fashion. If samples of plastic pipe are pressurized to various levels, they will fail after periods of time proportional to those pressures. The specific relationship is that the logarithm of the time to failure is negatively proportional to the logarithm of the stress.

$$\log T = a - b \log S$$

Where a and b are constants.

This stress, S, is the hoop stress in the material due to internal pressure at a constant temperature. ASTM D2837-13, *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products,* details test procedures for obtaining this relationship. The relationship is then used to determine a particular maximum S that should not cause failure until at least after a minimum desired life. That S is termed the Long Term Hydrostatic Stress (*LTHS*) for the material in question. For purposes of certification of PVC Pipe, T=50 years shall be used to determine the LTHS.

Molecularly Oriented Polyvinyl Chloride (PVCO) Pressure Pipe

PVCO pressure pipe is made through a manufacturing process which reorients the molecular structure of polyvinyl chloride (PVC) in the circumferential or hoop direction. The process starts by extruding a smaller outside diameter, heavier wall stock pipe. The stock pipe is reheated and then expanded with internal pressure to its final dimensions. The expansion causes the polymer molecules to orient in the hoop direction. The orientation is “locked in” by cooling the pipe. The result is PVCO pressure pipe characterized by its strong mechanical properties (HDB) and light weight for water pressure applications.

Polyvinyl Chloride (PVC)

A polymer prepared by the polymerization of vinyl chloride as the sole monomer.

Pressure Class

The pressure class is the design capacity to resist working pressure up to 73.4°F (23°C) maximum service temperature. Pressure Class is defined as:

$$PC = \left[\frac{2}{DR-1}\right]\left[\frac{HDB}{SF}\right]$$

Where:

- *PC* - Pressure Class
- *DR* - Dimension Ratio = D_o/t
- D_o - Average outside diameter
- *t* - Minimum pipe wall thickness
- *HDB* - Hydrostatic Design Basis, as determined in AWWA C-900 / C909-.
- *SF* - 2.0; Safety factor; provides for degree of safety and accounts for installation and operation variables, including limited surge effects.

Pressure Pipe for Water Distribution and Transmission

Underground pipe used to carry water from a source of supply and distribute it throughout a distribution system or a service area. For the purposes of this Standard, transmission pipe is limited to nominal sizes 14 inches through 36 inches; other sizes will be evaluated on a case-by-case basis. Water distribution and transmission pipe pressure classes are typically based on a factor of safety of 2.

Surge Allowance (P_s)

Surge pressure allowance, in pounds per square inch, based on an instantaneous velocity change of 2 ft/s (0.61 m/s).

Tup B

A cylindrical weight with a 2 in. (55 mm) radius nose, as defined in ASTM D2444.

Working Pressure (WP)

The maximum anticipated, sustained operating pressure applied to the pipe exclusive of hydraulic transient pressures.

2. GENERAL INFORMATION

2.1 Product Information

2.1.1 PVC pipe and fittings encompassed by this standard are used in underground fire protection systems. Within this Standard a distinction is made between pipe designed as water distribution pipe and that designed as water transmission pipe. For the purposes of this standard, distribution pipe is limited to nominal sizes 4 in. through 12 in., while transmission pipe is limited to nominal sizes 14 in. through 36 in. Other sizes shall be evaluated on a case-by-case basis.

2.1.2 PVC pipe and fittings are manufactured from materials with specific properties. They are thermoplastic compounds prepared by combining PVC resin with modifiers to attain desirable properties, and with stabilizers, lubricants, and pigments for processing, property control, and coloring.

2.1.3 PVC compound is usually either extruded (pipes) or injection molded (fittings) of specific thermoplastic formulations, in conformance to nationally or internationally recognized standards.

2.1.4 In order to meet the intent of this standard, PVC pipe and fittings components must be examined on a model-by model, type-by-type, manufacturer-by-manufacturer, and plant-by-plant basis. This is predicated on the basis that identical designs, fabricated using identical materials by different manufacturers, or even by different plants of the same manufacturer, have been seen to perform differently in testing. Sample PVC pipe and fittings, selected in conformance to this criterion, shall satisfy all of the requirements of this standard.

2.2 Certification Application Requirements

The manufacturer shall provide the following preliminary information with any request for certification consideration:

- a complete list of all models, types, sizes, end connections, and options for the products being submitted for certification consideration,
- general assembly drawings, one complete set of manufacturing drawings, hydrostatic design basis (HDB) calculations, anticipated marking format, brochures, sales literature, specification sheets, installation, operation and maintenance procedures, and
- the number and location(s) of manufacturing facilities making the products submitted for certification.

All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All documents shall be provided with English translation.

2.3 Requirements for Samples for Examination

2.3.1 Following authorization of a certification examination, the manufacturer shall submit samples for examination and testing based on the following:

- Sample requirements to be determined by the certification agency

2.3.2 Requirements for samples may vary depending on design features, results of prior or similar testing, and results of any foregoing tests.

2.3.3 The manufacturer shall submit samples representative of production. Any decision to use data generated using prototypes is at the discretion of the certification agency

2.3.4 It is the manufacturer's responsibility to provide any special test fixtures which may be required to evaluate the PVC pipe and fittings.

2.3.5 If there are failures encountered during the examination testing, the certification agency will provide the manufacturer with information regarding what testing will need to be repeated and any additional sample requirements.

3. GENERAL REQUIREMENTS

3.1 Review of Documentation

3.1.1 During the initial investigation and prior to physical testing, the manufacturer's specifications, technical data sheets, and design details shall be reviewed to assess the ease and practicality of installation and use. The certification examination results may further define the limits of the final certification.

3.1.2 The manufacturer's dimensional specifications and/or design drawings shall fully describe the product. All critical dimensions shall be indicated with allowed upper and lower tolerance limits clearly shown.

3.2 Physical or Structural Features

3.2.1 PVC Pipe and fittings shall be designed for a minimum rated working pressure of 150 psi (1035 kPa).

3.2.2 Nominal sizes of PVC pipe and fittings shall be 4 inches through 36 inches, other sizes may be evaluated on a case-by-case basis. In any case the minimum nominal pipe size for all PVC pipe and fittings shall be 4 inches.

3.2.3 PVC pipe shall be formed of homogeneous material. Material shall be assigned a hydrostatic design basis (HDB) for water at 73.4°F ± 3.6°F (23°C ± 2°C). This value shall be derived from sustained pressure tests conducted per ASTM D1598 and evaluated per ASTM D2837.

The testing shall have been performed on pipe made of the same raw material as that of the pipe submitted for certification and produced on equipment and under conditions equivalent to those to be used in its commercial production. The hydrostatic design stress (HDS) shall then be determined in accordance with ASTM D1598 and ASTM D2837. The actual factor of safety used shall be adjusted, if necessary, to provide at least a projected 50 year life at the rated pressures and temperature.

The manufacturer shall submit the long term hydrostatic test data used to calculate the HDS. The certification agency will verify the calculations and the suitability of the data per the applicable ASTM standard.

If the PPI has certified the material in question to have an HDS meeting these requirements, even if that certification is based upon a documented equivalency to other pipe rather than on direct testing to the pipe submitted for certification, that HDS shall be acceptable.

3.2.4 PVC pipe and fitting materials shall be Class 12454 as defined in ASTM D1784. When other materials are submitted, special tests may be necessary to verify their suitability.

3.2.5 All pipe and fittings shall be designed and manufactured in accordance with the dimensional and other requirements of the recognized national or international standard for the products in question. Where such a standard does not exist, the manufacturer shall be prepared to submit detailed documentation, including dimensional drawing and HDB/HDS calculations. A special investigation by the certification agency will determine if the products may be considered for certification.

3.2.6 The maximum pressure rating for PVC pipe shall be determined using procedures outlined in AWWA C900 or C909, as applicable. A manufacturer need not take full advantage of the properties of his material in establishing pressure ratings. That is, more conservative ratings than those derived from this calculation may be assigned.

3.2.7 Pressure ratings for PVC fittings cannot be easily determined. Fittings submitted for use with a given pipe must be of compatible material characteristics and must not fail before the pipe when tested to meet the requirements described in Section 4.4 (Hydrostatic Strength).

3.2.8 Testing shall use production pipe and fittings assembled according to the manufacturer's published instructions. All joining techniques submitted shall be tested in all sizes submitted. However, all fitting configurations need not be tested for qualification of a given line. The certification agency will designate those items to be tested which, in its judgement, adequately sample the products submitted for certification.

3.2.9 All gaskets, submitted for certification, shall be in accordance with ASTM F477, or equivalent. Each gasket shall be individually evaluated to the requirements of Section 4 (Performance Requirements).

3.2.10 All performance tests described in Section 4, unless otherwise noted, shall be run at an ambient temperature of 73.4°F ± 3.6°F (23°C ± 2°C). When tests are conducted at temperatures above 80°F (27°C) required pressure values may be adjusted downwards according to the thermal de-rating factors shown in Table 3.2.10

Table 3.2.10 Thermal De-Rating Factors for PVC Pipes and Fittings

Pipe Surface Temperature		**Multiply the Pressure Rating or Pressure Class at 73.4°F (23°C) by These Factors**
°F	**(°C)**	
80	(27)	0.88
90	(32)	0.75
100	(38)	0.62
110	(43)	0.50
120	(49)	0.40
130	(54)	0.30
140	(60)	0.22

Note: The de-rating factors assume sustained elevated pipe and fluid temperatures. When the contents of the PVC pressure pipe under test are only intermittently and temporarily raised above the service temperature shown, a further de-rating may not be needed. Interpolate between the temperatures listed to calculate other factors.

3.3 Materials

3.3.1 All materials used in the fabrication of the PVC pipe and fittings discussed in this examination standard shall be suitable for the intended application. Raw materials shall be evaluated in accordance with the appropriate sections of the manufacturer's Quality Assurance Manual plus any applicable national and/or international standards.

3.3.2 Polyvinyl chloride is manufactured by polymerization of the monomer vinyl chloride, manufactured from ethylene and chlorine. PVC is manufactured in a wide variety of compounds containing such materials as plasticizers and impact modifiers to change the properties of the material. Only unplasticized PVC is used for piping applications due to problems such as embrittlement. The Type I PVC has the highest long-term strength and is usually used for piping applications.

3.3.3 Because of the possibility of connection to potable water systems, PVC piping addressed in this standard shall use only material suitable for potable water service, as listed for this service by the NSF International (NSF) or other nationally recognized and accredited testing laboratory. Tests shall be made in accordance with requirements equivalent to those of NSF Standard Number 61, *Standard for Drinking Water Systems Components - Health Effects*, at minimum.

3.4 Markings

3.4.1 Pipe marking shall include the following and shall be applied at intervals of not more than 5 ft (1.5 m):

- Manufacturer’s name or trademark;
- Nominal size and outside diameter base (e.g., 6 CI, 6 IPS);
- Dimension ratio, (if applicable);
- The letters “PVC” or “PVCO”, as applicable;
- Recognized standard to which the pipe is designed and manufactured;
- Specific production code, including day, month, year, shift, plant and extruder of manufacture, as applicable
- Pressure class; and,
- Certification agency’s mark of conformity.

3.4.2 Fittings shall be clearly marked with the following information:

- Manufacturer’s name or trademark;
- Nominal size and outside diameter base;
- The letters “PVC”;
- Mold cavity identification, (if applicable);
- Recognized standard to which the fitting is designed and manufactured;
- Specific source code, including location of manufacture, as applicable
- Pressure class; and,
- Certification agency’s mark of conformity.

3.4.3 The model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the certification agency’s mark of conformity.

3.4.4 The order of these markings is optional, as long as all are present.

3.4.5 Additional markings are allowed if arranged in such a way as not to interfere with the legibility of the required markings.

3.4.6 The certification agency’s mark of conformity shall be displayed visibly and permanently on the product and/or packaging as appropriate and in accordance with the requirements of the certification agency. The manufacturer shall exercise control of this mark as specified by the certification agency and the certification scheme.

3.4.7 PVC pipe and fittings that are produced at more than one location shall be identified as the product of a particular location.

3.4.8 All markings shall be legible and durable.

3.5 Manufacturer's Installation and Operation Instructions

3.5.1 The installation instructions, including any special dimension requirements shall be furnished by the manufacturer. Instructions shall be provided in each shipping container

3.5.2 The installation instructions identified in Section 3.5.1 shall be made available in multiple languages in support of the regions where the product is intended to be sold.

3.5.3 The manufacturer shall provide installation instructions which clearly address the following:

- Indicate that the PVC pipe and fittings qualified under this standard are restricted to underground service;

- Define requirements of installation including assembly of pipe sections, couplings, and other components.
- Define laying and back filling procedures. Adequate compaction of soil is of particular importance;
- Define thrust blocking and other restraint requirements;
- Define suitable methods for transition connections to other materials.

3.5.4 The certification agency shall determine the minimum acceptable extent of these instructions based upon the specific nature of the PVC pipe and fittings submitted for certification. Any instructions specific to certification constraints shall be labeled as such. Instructions required by the certification agency may be included in a more general instruction publication, provided that it is clearly stated that certification of these products is contingent upon observance of the certification constraints. Instructions shall be furnished by the manufacturer.

3.6 Calibration

3.6.1 Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage. A copy of the calibration certificate for each piece of test equipment is required. The certificate shall indicate that the calibration was performed against working standards whose calibration is certified and traceable to an acceptable reference standard and certified by an ISO/IEC 17025 accredited calibration laboratory. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date. A copy of the service provider's accreditation certificate as an ISO/IEC 17025 accredited calibration laboratory should be available.

3.6.2 When the inspection equipment and/or environment is not suitable for labels or stickers, other methods such as etching of control numbers on the measuring device are allowed, provided documentation is maintained on the calibration status of thus equipment.

3.7 Tolerances

Tolerances on units of measure shall be as described in Appendix B, unless otherwise specified in this standard.

4. PERFORMANCE REQUIREMENTS

4.1 Examination

4.1.1 Requirements

All PVC pipe and fittings shall conform to the manufacturer's drawings and specifications and to the certification agency's requirements.

4.1.2 Test/Verification

The samples shall be examined and compared to drawings and specifications. It shall be verified that the samples conform to the requirements described in Section 3, General Requirements.

4.2 Quick Burst Strength (Pipe Only)

4.2.1 Requirements

A quick-burst test shall be conducted on all classes and sizes of pipe submitted for certification. The test specimen shall attain a hydrostatic pressure equal to or greater than the values shown in Tables 4.2.1a for water distribution pipe and 4.2.1b for water transmission pipe during a test time of 60 to 70 seconds. The values shown are based on a hoop stress of 6400 psi for extruded AWWA C900 pipe. Specimen failure is not required to demonstrate that minimum quick-burst strength requirements have been met.

Table 4.2.1a Water Distribution Pipe (Nominal Size 4 through 12 in.)

DR	FM Pressure Class, psi (kPa)	Test Pressure, psi (kPa)
18	185 (1275)	755 (5210)
14	250 (1725)	985 (6800)

Table 4.2.1b Water Transmission Pipe (Nominal Size 14 through 36 in.)

DR	FM Pressure Class, psi	Test Pressure, psi (kPa)
26	160 (1100)	500 (3450)
25	165 (1140)	535 (3690)
21	200 (1380)	630 (4350)
18	235 (1620)	755 (5210)
14	305 (2100)	985 (6800)

4.2.2 Tests/Verification

At least one sample of each class and size of pipe, including any integral bell, shall be subjected to a 73.4°F ± 3.6°F (23°C ± 2°C) quick-burst hydrostatic test. Test assemblies shall be made with a standard bell and spigot joint between two end caps. The test assemblies shall contain one section of spigot pipe at least 12” between the bell and the end cap and a total specimen length which meets the requirements of ASTM D1599. For pipe sizes of 6 in. (150 mm) or less, the specimen length between the end closures shall be not less than five times the outside diameter of the pipe, but in no case less than 12 in. (300 mm). For larger sizes, the minimum length shall be not less than three times the outside diameter, but in no case less than 30 in. (760 mm).

A test joint assembly shall be prepared using only the lubricant and procedures recommended by the manufacturer. The joint shall be deflected axially in the socket to the maximum unstressed limit permitted by dimensional clearances between the spigot and the bell and restrained at that deflection for the remainder of the test. In this test the internal pressure shall be raised from 0 to the minimum required pressure in not less than 60 and not more than 70 seconds.

It is the manufacturer’s responsibility to provide a frame strong enough to restrain each joint test assembly and to permit deflection of the joint as described above.

4.3 Hydrostatic Strength (Pipe and Fittings)

4.3.1 Requirements

Hydrostatic strength test shall be conducted on all classes and sizes of pipe, including joints and fittings. The test specimen shall attain a hydrostatic pressure equal to or greater than the values shown in Table 4.3.1 for a period of 5 minutes without leakage, rupture, ballooning or weeping.

Table 4.3.1 Hydrostatic Strength Pressures

Type	**Size**	**Required Test Pressure**
Water Distribution	4 through 12 in.	3.2 x Pressure Rating
Water Transmission	14 through 36 in.	2.5 x Pressure Rating

4.3.2 Test/Verification

One sample of each size and class of pipe, joining method and fitting submitted for certification, shall be subjected to a 73.4°F ± 3.6°F (23°C ± 2°C) hydrostatic strength test. Test specimens shall meet the length requirements of Section 4.2.2. Test pressure shall be as shown in Table 4.3.1. Pressure shall be maintained for 5 minutes.

4.4 Stiffness Factor (Pipe Only)

4.4.1 Requirements

Pipe submitted for certification shall have sufficient stiffness to remain intact and not leak when exposed to external forces caused by earth and heavy vehicle loads. Stiffness factors shall be determined on representative samples in accordance with references in Section 1.8. Pipe deflection shall be determined using the Spangler Equation and the measured stiffness factors. Deflection of the pipe shall not exceed 5 percent of the inside diameter of the pipe for all depths of bury from 2.5 ft (0.75 m) to 8 ft (2.44 m).

The Spangler Equation used to determine pipe deflections is:

$$\Delta y = \frac{(D_l W_e + W_l) K r^3}{EI + 0.061 E' r^3}$$

Also:

$$PS = \frac{F}{\Delta y} \qquad SF = EI = \frac{0.149 F r^3}{\Delta y}$$

Where:

- y - Vertical deflection of pipe, inches
- D_l - Deflection Lag Factor = 1.25
- We - Earth loads on pipe per unit length, (As specified in Table 1-8 of ANSI A21.1-1967)
- W_l - Live load on pipe per unit length, (As specified in Table 1-8 of ANSI A21.1-1967)
- K - Bedding Constant = 0.1
- r - Mean pipe radius, inches
- E - Modulus of elasticity of pipe material, psi
- I - Moment of Inertia of Pipe Wall per unit length, in^3
- E´ - Modulus of Soil Reaction = 400 psi (Minimum)
- PS - Pipe Stiffness
- F - Force applied to produce a given deflection, lb_f/inch of length
- SF - Stiffness Factor

4.4.2 Tests/Verification

Compliance shall be verified by test of a minimum of three 6 in. to 9 in. (150 to 230 mm) long samples of each size and class of pipe submitted for certification. Each specimen shall be subjected to the force necessary to produce a 5 percent deflection of pipe measured by multiplying the average inside diameter from a minimum of three measurements by 0.05. The force necessary to produce this deflection shall be used in the above equations to determine the Pipe Stiffness. Using this value for the Pipe Stiffness, pipe deflection shall be determined for all depths of bury from 2.5 ft (0.75 m) to 8 ft (2.44 m). Pipe deflections shall not exceed 5 percent of the inside diameter for all depths of bury. W_e, (earth loads on pipe per unit length) and W_l, (live load on pipe per unit length), as specified in Table 1-8 of ANSI A21.1 have been reproduced in Appendix C, Table C-1 of this standard.

A sample calculation is shown in Appendix C.

4.5 Abuse Test (Pipe and Fittings)

4.5.1 Requirements

A 100 lb-ft (135 N·m) impact shall not impair hydrostatic integrity of the pipe and fittings. The intent of the requirement is that pipe and fittings be resistant to minor impacts encountered in handling, installation and service. There should be no visible signs of shattering, cracking or splitting as a result of this test. If necessary, following the impact test, the sample shall be hydrostatically pressurized to two times its pressure class or pressure rating. There shall be no leakage as a result of this test.

4.5.2 Tests/Verification

At least one sample assembly of each class and size of pipe and “fitting type” submitted for certification shall be impacted with a weight having a spherical impact nose as specified for a “B tup” in ASTM D2444. The tup shall be dropped from a height necessary to produce a 100 lb-ft (135 N·m) impact, once on the pipe wall and once on the “critical area” of each fitting. A “fitting type” is determined by inspection for the design of the various fittings submitted. For example, if wall thicknesses are identical, a 90° and 45° elbow should be of the same “fitting type” and a test of a given size 90° elbow would suffice for the same size 45° elbow. Similarly, tees, reducing tees, and crosses are of the same “fitting type”, as are couplings and reducers. The “critical area” of a fitting selected for impact is that area, which would be the most vulnerable when the fitting is assembled to pipe. For most fittings this is the upper horizontal surface when the fitting joins horizontal pipes. Because of the difficulty in design of transition fittings, which connect the plastic piping to non-plastic piping or devices, all such fittings shall be subjected to the impact test.

4.6 Vacuum Test

4.6.1 Requirements

To verify the integrity of flexible elastomeric seals which are a component of the pipe joints, a one-hour vacuum test shall be conducted. There shall be no leakage as a result of this test.

4.6.2 Tests/Verification

At least one sample of each flexible elastomeric seal shall be subjected to a 73.4°F ± 3.6°F (23°C ± 2°C) vacuum test. Test specimens shall meet the length requirements of Section 4.2.2. A test joint assembly shall be prepared using only the lubricant and procedure recommended by the manufacturer. The joint shall be deflected axially in the socket to the maximum unstressed limit permitted by dimensional clearance between spigot and bell, and restrained at that deflection for the remainder of the test. The assembly shall then be subjected to a 22 inHg (75 kPa) vacuum for 60 minutes without leakage.

It is the manufacturer's responsibility to provide a frame strong enough to restrain each joint test assembly and to permit deflection of the joint as described above.

4.7 One-Hour Pressure Test

4.7.1 Requirements

To verify the integrity of flexible elastomeric seals which are a component of the pipe joints, a one-hour pressure test shall be conducted. The test specimen shall attain a hydrostatic pressure equal to or greater than the values shown in Tables 4.7.1. There shall be no leakage as a result of this test.

Table 4.7.1a One-Hour Pressures - Water Distribution Pipe (Nominal Size 4 through 12 in.)

DR	**FM Pressure Class, psi (kPa)**	**Test Pressure, psi (kPa)**
18	185 (1275)	375 (2585)
14	250 (1725)	500 (3450)

Table 4.7.1b One-Hour Pressures - Water Transmission Pipe (Nominal Size 14 through 36 in.)

DR	**FM Pressure Class, psi**	**Test Pressure, psi (kPa)**
26	160 (1100)	400 (2760)
25	165 (1140)	415 (2860)
21	200 (1380)	500 (3450)
18	235 (1620)	590 (4070)
14	305 (2100)	765 (5275)

4.7.2 Test/Verification

At least one sample of each flexible elastomeric seal shall be subjected to a 73.4°F ± 3.6°F (23°C ± 2°C) one-hour pressure test. Test specimens shall meet the length requirements of Section 4.2.2. A test joint assembly shall be prepared using only the lubricant and procedures recommended by the manufacturer. The joint shall be deflected axially in the socket to the maximum unstressed limit permitted by dimensional clearances between the spigot and the bell and restrained at that deflection for the remainder of the test. The assembly shall then be hydrostatically pressurized to the test pressure shown in Table 4.7.1 for 60 minutes without leakage.

It is the manufacturer's responsibility to provide a frame strong enough to restrain each joint test assembly and to permit deflection of the joint as described above.

Following this test the sample shall be tested to the minimum short-term rupture requirement in not less than 60 seconds or more than 70 seconds, as described in Section 4.2, without failure.

5. OPERATIONS REQUIREMENTS

5.1 Demonstrated Quality Control Program

5.1.1 A quality assurance program is required to assure that subsequent PVC pipe and fittings produced by the manufacture shall present the same quality and reliability as the PVC pipe and fittings examined. Design quality, conformance to design, and performance are the areas of primary concern.

- Design quality is determined during the examination and tests and may be documented in the certification report.

- Continued conformance to this standard is verified by the certifier's surveillance program.

- Quality of performance is determined by field performances and by periodic re-examination and testing.

5.1.2 The manufacturer shall demonstrate a quality assurance program which specifies controls for at least the following areas:

- existence of corporate quality assurance guidelines;
- incoming quality assurance, including testing;
- in-process quality assurance, including testing;
- final inspection and tests;
- equipment calibration;
- drawing and change control;
- packaging and shipping;
- handling and disposition of non-conforming materials;

5.1.3 Documentation/Manual

There should be an authoritative collection of procedures/policies. It should provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system should require that sufficient records are maintained to demonstrate achievement of the required quality and verify operation of the quality system.

5.1.4 Drawing and Change Control

The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes to critical documents, identified in the certification report, may be required to be reported to, and authorized by the certification agency prior to implementation for production.

Records of all revisions to all certified products shall be maintained.

5.2 Surveillance Audit Program

5.2.1 An audit of the manufacturing facility may be part of the certification agency's surveillance requirements to verify implementation of the quality assurance program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to ensure a uniform product consistent with that which was tested and certified.

5.2.2 Certified products or services shall be produced or provided at, or provided from, location(s) disclosed as part of the certification examination. Manufacture of products bearing a certification mark is not permitted at any other location prior to disclosure to the certification agency.

5.3 Installation Inspections

Field inspections may be conducted to review an installation. The inspections are conducted to assess ease of application, and conformance to written specifications. When more than one application technique is used, one or all may be inspected at the discretion of the certification agency.

5.4 Manufacturer's Responsibilities

The manufacturer shall notify the certification agency of proposed changes in product construction, design, component, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation of such changes.

5.5 Manufacturing and Production Tests

All tests shall be run at an ambient temperature of 73.4°F ± 3.6°F (23°C ± 2°C) unless otherwise noted. For tests conducted at higher temperatures, the de-rating factors shown in Table 3.2.11 may be applied.

5.5.1 Test Requirement No. 1 - Dimension and Tolerances (Pipe and Fittings)

Pipe - The manufacturer shall measure critical pipe dimensions, including bells, at the beginning of production of each size and class of pipe. Thereafter, critical pipe dimensions shall be measured every 2 hours.

Fittings - The manufacturer shall measure critical fitting dimensions, including bells, at the beginning of production of each size and class of fitting. Thereafter, critical fitting dimensions shall be measured every 8 hours.

5.5.2 Test Requirement No. 2 - Heat Reversion Test (Molded Fittings Only)

The manufacturer shall conduct a heat reversion test at the beginning of production of each size and class of fitting. This test shall be conducted per the requirements of ASTM F610-610M.

5.5.3 Test Requirement No. 3 - Accelerated Regression Test (Molded Fittings Only)

The manufacturer shall conduct an accelerated regression test at the beginning of production, and semiannually thereafter, of each size and class of fitting. This test shall be conducted per the requirements of ASTM C907-.

5.5.4 Test Requirement No. 4 - Hydrostatic Proof Test (Pipe Only)

The manufacturer shall conduct a hydrostatic proof test on each standard and random length of pipe at 3.2 times the Pressure Class for distribution pipe or two times the pressure rating for transmission pipe. The test shall be run for a minimum dwell of 5 seconds.

5.5.5 Test Requirement No. 5 - Flattening Test (Pipe Only)

The manufacturer shall conduct a flattening capability test as specified in ASTM D2412- at the beginning of production of each size and class of pipe by flattening a sample to 40 percent of the outside diameter of the pipe. Thereafter, the test shall be conducted every 8 hours for nominal pipe sizes less than 14 inch. No evidence of splitting, cracking, flaking or breaking is permitted.

5.5.6 Test Requirement No. 6 - Extrusion Quality (Pipe Only)

The manufacturer shall conduct a test for extrusion quality by the acetone-immersion method as specified in ASTM D2152 at the beginning of production of each size and class of pipe. Thereafter, the test shall be conducted every 8 hours.

5.5.7 Test Requirement No. 7 - Quick Burst (Distribution Pipe Only)

The manufacturer shall conduct a quick burst test at the beginning of production of each size and class of distribution pipe. This test shall be conducted per the requirements of ASTM D1599-. The bell shall be included in this sample. Thereafter, one sample shall be tested every 24 hours. The sample must meet the minimum requirements shown in Table 4.2.1a or Table 4.2.1b.

5.5.8 Test Requirement No. 8 - Sustained Pressure Test (Distribution Pipe Test Only)

The manufacturer shall conduct a sustained pressure test as defined in ASTM D1598-15a, at the sustained pressures listed in Table 5.5.8 for 1,000 hours:

Table 5.5.8 Sustained Pressure Requirements

DR	**FM Pressure Class**	**Sustained Pressure Requirements**
26	160 psi (1100 kPa)	340 psi (2350 kPa)
25	165 psi (1140 kPa)	350 psi (2420 kPa)
21	200 psi (1380 kPa)	420 psi (2900 kPa)
18	185 psi (1275 kPa)	500 psi (3450 kPa)
14	250 psi (1725 kPa)	650 psi (4490 kPa)

This test shall be conducted at the beginning of production after obtaining certification and semi-annually thereafter. The pipe shall not rupture, balloon, or weep.

6. BIBLIOGRAPHY

ASTM D2122, *Standard Test Method of Determining Dimensions of Thermoplastic Pipe and Fittings*
ASTM D2241, *Standard Specification for Poly (Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)*
ASTM D2487, *Standard Practice for Classification of Soils for Engineering Purposes, (Unified Soil Classification System)*
ASTM D2774, *Standard Practice for Underground Installation of Thermoplastic Pressure Piping*
ASTM D3139, *Standard Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals*
ASTM F1483, *Standard Specification for Oriented Poly (Vinyl Chloride) (PVCO) Pressure Pipe*
AWWA Manual M23, *PVC Pipe - Design and Installation, Second Edition*
ISO 161-1, *Thermoplastic Pipe for the Conveyance of Fluids, Nominal Outside Diameters and Nominal Pressures, Part 1 Metric Series*
ISO/IEC 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*
PPI TR-3, *Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe*

APPENDIX A:

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APPENDIX B: TOLERANCES

Unless otherwise stated, the following tolerances shall apply:

Angle	± 2°
Length	± 2 percent of value
Volume	± 5 percent of value
Volume Per Unit Area	± 5 percent of value
Pressure	± 5 psi (± 35 kPa)
Temperature	± 3.6°F (± 2°C)
Time	+ 5/-0 seconds +0.1/-0 minutes

Unless stated otherwise, all tests shall be carried out at a room (ambient) temperature of 73.4°F ± 3.6°F (23°C ± 2°C).

APPENDIX C: SAMPLE CALCULATION

Shown below is a sample stiffness factor calculation for 10 inch CIOD, DR18, AWWA C909 PVCO pressure pipe:

The average of three outside diameter (*OD*) measurements was found to be 11.105 inches.
The average of three wall thickness (*t*) measurements was found to 0.343 inches.
The average of three sample length (*l*) measurements was found to be 8.052 inches.
The sample inside diameter (*ID*) was calculated as follows:

$$ID = OD - 2(t) = 10.419 \text{ inches.}$$

The maximum allowable pipe deflection (y_{max}) was calculated as follows:

$$Y_{max} = (0.05) \times ID = 0.521 \text{ inches.}$$

The sample was placed in a compression test apparatus and the force required to deflect the pipe 0.521 inches was found to be 279 lbs.

Re-writing the Spangler Equation from Section 4.4.1, we know that:

$$\Delta y = \frac{(D_l W_e + W_l) K r^3}{EI + 0.061 E' r^3} \qquad \text{Eq. 1}$$

Also, from ASTM D2412-11, *Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading*, we know that pipe stiffness (*PS*) and stiffness factor (*SF*) are related as follows:

$$PS = \frac{F}{\Delta y} \qquad \text{Eq. 2}$$

$$SF = EI = \frac{0.149 F r^3}{\Delta y} \qquad \text{Eq. 3}$$

Substituting the pipe stiffness and other constants and knowing that the values of the earth loads (W_e) and live loads (W_l) from Table 1-8 of ANSI A21.1-, (reproduced in Table C-1 of this standard), are given in lb/lin ft the Spangler Equation can be re-written as:

$$\Delta y = \frac{(1.25 W_e + W_l)\left(K/12\right) r^3}{0.149 r^3 (PS) + 24.4 r^3} \qquad \text{Eq. 4}$$

Simplifying yields:

$$\Delta y = 0.00833 \frac{(1.25 W_e + W_l)}{0.149(PS) + 24.4} \qquad \text{Eq. 5}$$

Knowing the force required to deflect the pipe 5 percent of its *ID*, and realizing that F is the force required to produce a given deflection per linear inch, we can determine the pipe stiffness as follows:

$$PS = \frac{F}{\Delta y} = \frac{\frac{279}{8.052}}{0.521} = 66.51 \qquad \text{Eq. 6}$$

Substituting into Eq. 5 yields:

$$\Delta y = 0.0002428(1.25W_e + W_l) \qquad \text{Eq. 7}$$

Using the W_e (448) and W_l (972) values from Table 1-8 of ANSI A21.1-1967 we can now check the percent deflection for a depth of bury of 2.5 ft.

$$\Delta y = 0.0002428(1.25W_e + W_l)$$

$$\Delta y = 0.0002428(1.25(448) + 972)$$

$$\Delta y = 0.372\ inches$$

Percent Deflection = 0.372/10.419 *x* 100 = 3.6 percent

ACCEPTABLE

Using the W_e (1,645) and W_l (189) values from Table 1-8 of ANSI A21.1-1967 we can now check the percent deflection for a depth of bury of 8 ft.

$$\Delta y = 0.0002428(1.25W_e + W_l)$$

$$\Delta y = 0.0002428(1.25(1645) + 189)$$

$$\Delta y = 0.545\ inches$$

Percent Deflection = 0.545/10.419 *x* 100 = 5.23 percent

UNACCEPTABLE

Table C-1 Earth Loads (*We*) and Live Loads (*W*)*

Pipe Size in.	Depth of Cover							
	2-1/2 ft.		3-1/2 ft.		5 ft.		8 ft.	
	W_e lb/lin ft	W_l lb/lin ft	W_e lb/lin ft	W_l lb/lin ft	W_e lb/lin ft	W_l lb/lin ft	W_e lb/lin ft	W_l lb/lin ft
4	226	297	324	162	471	81	765	54
6	309	567	448	324	657	189	1,075	94
8	380	783	557	486	824	297	1,356	148
10	448	972	666	621	992	378	1,645	189
12	511	1,161	770	756	1,159	459	1,950	243
14	568	1,217	868	807	1,318	540	2,218	270
16	617	1,307	959	879	1,470	590	2,381	324
18	665	1,400	1,042	964	1,616	632	2,533	364
20	714	1,524	1,119	1,076	1,755	729	2,686	410
24	814	1,662	1,256	1,159	2,011	769	2,994	462
30	963	1,925	1,457	1,356	2,340	918	3,459	564
36	1,121	2,182	1,668	1,577	2,628	1,090	3,927	632

*Extracted from Table 1-8, ANSI A21.1, American National Standard for Thickness Design of Cast-Iron Pipe.

APPENDIX D: SAMPLE LISTING

Product Designation	***Nominal Pipe Size, in.***	***Pressure Rating, psi (kPa)***	***Remarks***
AWWA C900 Pipe DR18 PC 150	4, 6, 8, 10, 12	185 (1275)	a
AWWA C900 Pipe DR14 PC 200	4, 6, 8, 10, 12	250 (1725)	a
90° Elbows	4, 6, 8, 10, 12	185 (1275)	
45° Elbows	4, 6, 8, 10, 12	185 (1275)	
22.5° Elbows	4, 6, 8, 10, 12	185 (1275)	
Tees	4, 6, 8, 10, 12	185 (1275)	
Reducing Tees	6 x 6 x 4	185 (1275)	
	8 x 8 x 4	185 (1275)	
	8 x 8 x 6	185 (1275)	
	10 x 10 x 4	185 (1275)	
	10 x 10 x 6	185 (1275)	
	10 x 10 x 8	185 (1275)	
	12 x 12 x 4	185 (1275)	
	12 x 12 x 6	185 (1275)	
	12 x 12 x 8	185 (1275)	
	12 x 12 x 10	185 (1275)	

Remarks:
a. Pipe lengths are joined by single gasketed bell and spigot ends and can be joined to ductile iron fittings having standardized mechanical joint connection.