Examination Standard for Fiber Reinforced Composite (FRC) Pipe and Fittings for Underground Fire Protection Service

Class Number 1614

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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 fiber reinforced composite (FRC) pipe and fittings for underground fire service water mains.

1.1.2 Testing and certification requirements 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 inch through 36 inch nominal size FRC pipe and fittings for use in underground fire service mains. Other sizes may be evaluated on a case-by-case basis.

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

1.2.3 The certification agency will consider FRC pipe and fittings which are designed in accordance to national or international standards, such as the American Water Works Association (AWWA) C-950 for *Fiberglass Pressure Pipe.* Pipe manufactured in accordance with other nationally or internationally recognized standards will be considered on a case-by-case basis. All certification testing is to be conducted on production samples.

1.2.4 This standard is primarily intended for use in certifying fiberglass pipe and fittings. Other fiber reinforced composite materials can be certified under this standard and will be evaluated on a case-by-case basis.

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 FRC pipe and fittings for the purpose of obtaining certification. FRC pipe and fittings having characteristics not anticipated by this standard may be certified if performance equal to, 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/AWWA C950, *Fiberglass Pressure 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 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 Basis for Thermoplastic Pipe Products*
ASTM D2992, *Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings*
ASTM D3517, *Standard Specification for 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe*
ASTM D3567, *Standard Practice for Determining Dimensions of 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings*

ASTM F412, *Standard Terminology Relating to Plastic Piping Systems*
AWWA, M 45 *Fiberglass Pipe Design*
NSF/ANSI 61, *Standard for Drinking Water Systems Components - Health Effects*

1.9 Terms and Definitions

Generally, terminology relating to FRC pipe and fittings shall be in accordance with ANSI/ASTM D883, *Standard Definitions of Terms 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 FRC 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 Safety Factor.

Hydrostatic Design Basis (HDB)

One of a series of established stress values obtained by categorizing the Long Term Hydrostatic Strength of the material as described in ASTM D2992, *Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe*.

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 safety factor.

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

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 that depends on these 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 material constants.

This stress, *S*, is the hoop stress in the material due to internal pressure at a constant temperature. ASTM D2992, *Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe*, 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.

Pressure Class

The pressure class is the design capacity to resist working pressure at 73.4°F (23°C) with specified maximum allowances for recurring positive pressure surges above the working pressure. Pressure Class is defined in AWWA *Fiberglass Pipe Design (M45),*as:

For stress basis HDB:

$$P_c < \left(\frac{HDB}{FS}\right)\left(\frac{2t}{D}\right)$$

For strain basis HDB:

$$P_c < \left(\frac{HDB}{FS}\right)\left(\frac{2tE_H}{D}\right)$$

Where:

P_C - Pressure Class, in psi_g (kPa_g)
HDB - Hydrostatic Design Basis for water, in psi, (kPa) as determined in ASTM D2992.
FS - Typical Design Factor; Includes Consideration of Degree of Safety and all the variables, including limited surge pressure effects, in the end application
t - Thickness of the pipe wall, in. (mm) as defined in ASTM D3567
D - Mean Pipe Diameter, in. (mm)
E_H - hoop tensile modulus of elasticity, lb/in^2 (kPa)

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, distribution and transmission pipe is limited to nominal sizes 4 inches through 36 inches; other sizes will be evaluated on a case-by-case basis.

Production Run

The length of time a particular piece of extrusion equipment is set up to produce a certain size and class of pipe.

Safety Factor (SF)

A number, typically greater than or equal to 1.8, 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.

Surge Pressure (P_S)

The maximum transient pressure increase in excess of the operating pressure that is anticipated in the system as a result of changes in velocity. For the purposes of FRC piping product selection and system design two types of surge are considered:

Occasional Surge Pressure (P_{OS})

Occasional surge pressure is the result of an infrequent event and is usually the result of a malfunction, such as a power failure or system component failure (such as pump seize-up, valve-stem failure or pressure relief valve failure).

Recurring Surge Pressure (P_{rs})

Recurring surge pressures occur frequently and are inherent in the design and operation of the piping system (such as normal pump startup or shutdown and normal valve opening and closing).

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 Nominal sizes of FRC pipe and fittings for fire protection service addressed in this standard are 4 inches through 36 inches. Other sizes shall be evaluated on a case-by-case basis.

2.1.2 FRC pipe and fittings are manufactured as a composite structure of thermosetting resin, fiber reinforcement, stabilizers, colorants, anti-oxidants and ultra-violet (UV) screens. Thermoplastic or thermosetting liners or coatings may be included.

2.1.3 FRC pipe and fittings shall be fabricated in conformance to nationally or internationally recognized standards.

2.1.4 Connections between lengths of FRC pipes, or between pipes and devices such as fittings, valves, hydrants, etc. are generally self restraining. Examples would be flanged, threaded, adhesive joint bell and spigot, or key-lock. Sealing is either achieved with the joint itself, or with the use of a gasket incorporated in the joint.

2.1.5 In order to meet the intent of this standard, FRC pipe and fittings 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 in identical materials by different manufacturers or, even by different plants of the same manufacturer, have been seen to perform differently in testing. Sample FRC 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, and options for the products or services being submitted for certification consideration;
- general assembly drawings, one complete set of manufacturing drawings, materials list(s), anticipated marking format, brochures, sales literature, specification sheets, installation, operation and maintenance procedures, and
- the number and location 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 FRC pipe and fittings.

2.3.3 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 product shall be capable of being used within the limits of the certification investigation.

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

3.2 Physical or Structural Features

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

3.2.2 Nominal sizes of FRC pipe and fittings shall be 4 inches through 36 inches; other sizes may be evaluated on a case-by-case basis.

3.2.3 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.

3.2.4 The maximum pressure rating for FRC pipe shall be determined using procedures outlined in AWWA C950, *Fiberglass Pressure Pipe*, and ASTM D3517, *Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe*, 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.

Material shall be assigned a hydrostatic design basis (*HDB*) for water at 73.4°F (23°C). This value shall be derived from sustained pressure tests conducted per ASTM D1598, *Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure*, and evaluated per ASTM D2837, *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products*.

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 ANSI/ASTM Standard.

The hydrostatic design stress (*HDS*) shall then be determined in accordance with ASTM D1598, *Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure*, and ASTM D2837, *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products*. The actual safety factor used shall be adjusted, if necessary, to provide at least a projected 50 year life at the rated pressures and temperature.

3.2.5 Pressure ratings for FRC fittings cannot be easily determined. Fittings submitted for use with a given pipe must be of compatible material characteristics and must meet the requirements described in Section 4.2 (Hydrostatic Strength).

3.2.6 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 and pressure classes submitted for certification. For joint styles that incorporate adhesives, there shall be a listing of the adhesives to be included in the examination as well. The certification agency will use the submittal information to designate those items to be tested in order to represent the full scope of products considered in the certification.

3.2.7 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 3.2.7.

Table 3.2.7 Thermal De-Rating Factors for PE Pipes and Fittings

Pipe Surface Temperature		***Multiply the Pressure Rating or Pressure Class at 80°F (27°C) by These Factors***
°F	***°C***	
81-90	(28-32)	0.9
91-100	(32-38)	0.8

3.3 Materials

3.3.1 All materials used in the fabrication of the FRC 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 Because of the possibility of connection to potable water systems, FRC 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/ANSI 61, *Standard for Drinking Water Systems Components - Health Effects*, at minimum.

3.4 Markings

3.4.1 Pipe markings shall be repeated at a minimum interval of 5 ft (1.5 m) along the pipe, and shall include, as a minimum, the following information:

- Manufacturer's name or trademark;
- Nominal size and outside diameter base (e.g., 6 CI, 6 IPS);
- Pressure class;
- 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; and
- Certification agency's mark of conformity.

3.4.2 Each fitting's markings shall include, as a minimum, the following information:

- Manufacturer's name, or trademark;
- Nominal size and outside diameter base;
- Pressure rating;
- Recognized standard to which the pipe is designed and manufactured
- A Material Designation (i.e. FRP or a classification in accordance with the recognized standard)
- Mold cavity identification, (if applicable);
- Specific source code, indicating location of manufacture, as applicable; 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.

3.3.6 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.

3.3.7 FRC 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 throughout the useful life of the product.

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 FRC pipe and fittings qualified under this standard and certified by the certification agency 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 FRC 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.

4. PERFORMANCE REQUIREMENTS

4.1 Examination

4.1.1 Requirement

The FRC pipe and fittings shall conform to the manufacturer's drawings and specifications and to certification requirements.

4.1.2 Test/Verification

A sample shall be examined and compared to drawings and specifications. It shall be verified that the sample conforms to the physical and structural requirements described in Section 3, General Requirements.

4.2 Hydrostatic Strength (Pipe, Joints and Fittings)

4.2.1 Requirement

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 four times the rated working pressure for a period of 5 minutes without structural failure. Microcracking, weeping, and/or minor glass-fiber breakage are allowed.

Joints designed to axially restrain the pipe shall be tested without external restraints, and shall not separate, or slip on the pipe, or permit movement within the joint to the point of allowing joint leakage.

4.2.2 Test/Verification

One sample of each size and pressure class of pipe, joining method and fitting submitted for certification, shall be subjected to a hydrostatic strength test. Pipe test samples shall include a joint made according to the manufacturer's recommended joining methods. At a minimum, pipe segments shall be at least 2 diameters long and in no case less than 1 ft (305 mm) long. Specimens shall be conditioned to 73.4°F ± 3.6°F (23°C ± 2°C) prior to testing and the test shall be conducted at this temperature. Joints capable of being deflected shall be tested in the maximum deflected angle allowed by the manufacturer's installation instructions. Test pressure shall be four times the rated working pressure. Pressure shall be maintained for 5 minutes.

4.3 Leakage (Pipe, Joints and Fittings)

4.3.1 Requirement

Tests 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 two times the rated working pressure for a period of 5 minutes without signs (visible without magnification) of tensile failure of the glass-fiber reinforcement, leakage, weeping, cracking, crazing or interlaminar separation.

4.3.2 Test/Verification

One sample of each size and pressure class of pipe, joining method and fitting submitted for certification, shall be subjected to a hydrostatic strength test. At a minimum, pipe segments shall be at least 2 diameters long and in no case less than 1 ft (305 mm) long. Specimens shall be conditioned to 73.4°F ± 3.6°F (23°C ± 2°C) prior to testing and the test shall be conducted at this temperature. Joints capable of being deflected shall be tested in the maximum deflected angle allowed by the

manufacturer's installation instructions. Test pressure shall be two times the rated working pressure. 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 (2.5 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-)
- W_l - Live load on pipe per unit length, (As specified in Table 1-8 of ANSI A21.1-)
- 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. Specimens shall be conditioned to 73.4°F ± 3.6°F (23°C ± 2°C) prior to testing and the test shall be conducted at this temperature. Each specimen shall be subjected to the force necessary to produce a 5 percent change in diameter of the 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, the change in diameter of the pipe shall be determined for all depths of bury from 2.5 ft (0.75 m) to 8 ft (2.5 m). The change in diameter of the pipe 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.

4.4.3 Additional Requirements

Each sample tested in 4.4.2 above shall then be further deflected to 9 percent and 15 percent of inside diameter.

At a deflection equal to 9 percent of the inside diameter, the pipe shall not exhibit cracking or crazing. The inspection shall be made without magnification.

At a deflection equal to 15 percent of the inside diameter, the pipe shall not exhibit evidence of structural damage. The pipe shall be inspected while deflected for evidence of interlaminar separation, tensile failure of the glass-fiber reinforcement, fracture, or buckling of the pipe wall. The inspection shall be made without magnification.

4.5 Abuse Test (Pipe and Fittings)

4.5.1 Requirements

A 10 lb-ft (13.5 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-. Specimens shall be conditioned to 73.4°F ± 3.6°F (23°C ± 2°C) prior to testing and the test shall be conducted at this temperature. The tup shall be dropped from a height necessary to produce a 10 lb-ft (13.5 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 (Pipe, Joints and Fittings)

4.6.1 Requirements

Pipe or fittings that employ a gasketed pipe joint shall withstand without leakage a vacuum of greater than 22 inHg for a duration of 30 minutes. A 20 psi (138 kPa) leakage test shall be conducted after the vacuum test of each sample assembly. There should be no leakage or permanent deformation 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 vacuum test. Pipe test samples shall include a joint made according to the manufacturer's recommended joining methods. At a minimum, pipe segments shall be at least 2 diameters long and in no case less than 1 ft (305

mm) long. Specimens shall be conditioned to 73.4°F ± 3.6°F (23°C ± 2°C) prior to testing and the test shall be conducted at this temperature. Joints capable of being deflected shall be tested in the maximum deflected angle allowed by the manufacturer's installation instructions. Samples shall be subjected to an internal vacuum condition of greater than 22 inHg (75 kPa) for thirty minutes. The vacuum pressure shall be applied to the sample and then the vacuum pump shall be disconnected. A vacuum of greater than 22 inHg (75 kPa) may be applied, followed by subsequent slow leakage, as long as the final vacuum is greater than 22 inHg (75 kPa). After the vacuum test, the samples shall be filled with water and subjected to a 20 psi (138 kPa) hydrostatic pressure for a duration of five minutes. No leakage or other failure shall be observed as a result of the hydrostatic test.

5. OPERATIONS REQUIREMENTS

5.1 Demonstrated Quality Control Program

5.1.1 A quality control program is required to assure that subsequent FRC pipe and fittings produced by the manufacturer at an authorized location, shall present the same quality and reliability as the specific FRC 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

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

Pipe - The manufacturer shall measure critical pipe dimensions, at least once per hour or once per 100 lengths of pipe, whichever is more frequent.

Fittings - The manufacturer shall measure critical fitting dimensions, at least once per hour, and at the beginning of each production run.

5.5.2 Test Requirement No. 2 - Hydrostatic Pressure Test (Pipe and Fittings)

Pipe - The manufacturer shall conduct a thirty-second pressure test at least once per production run at a pressure equal to two times the pressure class of the pipe. The pipe shall show no visible signs of weeping or leakage. Integral bells, including reinforcing sleeves, if any, or any affixed couplings, shall be tested with the pipe.

Fittings - The manufacturer shall conduct a thirty second pressure test, at a pressure equal to two times the pressure class of the fitting, on the first fitting of a particular outside diameter and style and every fiftieth fitting thereafter for fabricated fittings.

5.5.3 Test Requirement No. 3 - Stiffness Testing (Pipe Only)

The manufacturer shall perform stiffness tests, once per 100 lengths of pipe or from each manufacturing run, whichever is more frequent. Stiffness tests shall be performed in accordance with AWWA C950.

5.5.4 Test Requirement No. 4 - Hoop Tensile Strength Test (Pipe Only)

The manufacturer shall perform hoop tensile strength tests, once per 100 lengths of pipe or from each manufacturing run, whichever is more frequent. Hoop tensile strength tests shall be performed in accordance with AWWA C950.

5.5.5 Test Requirement No. 5 - Axial Tensile Strength Test (Pipe Only)

The manufacturer shall perform axial tensile strength tests, once per 100 lengths of pipe or from each manufacturing run, whichever is more frequent. Axial tensile strength tests shall be performed in accordance with AWWA C950.

6. BIBLIOGRAPHY

ASTM D618, *Standard Practice for Conditioning Plastics for Testing*
ASTM D638, *Standard Test Method for Tensile Properties of Plastics*
ASTM D695, *Test Method for Compressive Properties of Rigid Plastics*
ASTM D883, *Standard Terminology Relating to Plastics*
ASTM D1238, *Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer*
ASTM D1505, *Standard Test Method for Density of Plastics by the Density-Gradient Technique*
ASTM D1599, *Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing and Fittings*
ASTM D1600, *Standard Terminology for Abbreviated Terms Relating to Plastics*
ASTM D2290, *Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe by Split Disk Method*
ASTM D2996, *Specification for Filament-Wound 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe*
ASTM D2997, *Specification for Centrifugally Cast 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe*
ASTM D3681, *Standard Test Method for Chemical Resistance of 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe in a Deflected Condition*
ASTM D4161, *Standard Specification for 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals*
ASTM D5365, *Standard Test Method for Long-Term Ring-Bending Stain of 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe*
ASTM F477, *Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe*
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*

APPENDIX A:

Appendix A is intentionally blank

APPENDIX B: TOLERANCES

Unless otherwise stated, the following tolerances shall apply:

Angle:	± 2°
Frequency (Hz):	± 5 percent of value
Length:	± 2 percent of value
Volume:	± 5 percent of value
Volume Per Unit Area:	± 5 percent of value
Pressure:	± 5 psi (35 kPa)
Temperature:	± 4°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 CALCULATIONS

Shown below is a sample stiffness factor calculation for 14 inch nominal pipe with a pressure rating of 175 psi

The average of three outside diameter (*OD*) measurements was found to be 14.050 inches
The average of three wall thickness (*t*) measurements was found to 0.249 inches
The average of three sample length (*l*) measurements was found to be 11.75 inches
The sample average inside diameter (*ID*) was calculated as follows:

$$ID = OD - 2(t) = 13.553.$$

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

$$Y_{max} = (0.05) \times ID = 0.678 \text{ inches.}$$

The sample was placed in a compression test apparatus and the force required to deflect the pipe by 0.678 inches was found to be 609 pounds.

Re-writing the Spangler Equation from Section 4.5.1, 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, *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 (We) 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:

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

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:

$$PS = \frac{F}{\Delta y} = \frac{\frac{609}{11.75}}{0.678} = 76.46 \qquad \text{Eq. 6}$$

Substituting into Eq. 5 yields:

$$\Delta y = 0.000233\left(1.25W_e + W_l\right) \text{Eq. 7}$$

Using the *We* (568) and W_l (1217) values from Table 1-8 of ANSI A21.1 we can now check the percent deflection for a depth of bury of 2.5 ft (0.75 m)

y = 0.000233[1.25(568) + 1217]

y = 0.448 inches

Percent Deflection = 0.448/13.55 x 100 = 3.31 percent

ACCEPTABLE

Using the *We* (2,218) and *W* (270) values from Table 1-8 of ANSI A21.1 we can now check the percent deflection for a depth of bury of 8 ft (2.5 m)

y = 0.000233[1.25(2218) + 270]

y = 0.708 inches

Percent Deflection = 0.708/13.55 x 100 = 5.23 percent

UNACCEPTABLE

This is an example of a pipe that would not be certified. Both 2-1/2 ft (0.75 m) bury and 8 ft (2.5 m) bury depths would have to yield ACCEPTABLE results for the pipe to be certified.

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

		Depth of Cover											
		2-1/2 ft (0.75 m)				***3-1/2 ft (1.0 m)***				***5 ft (1.5 m)***			
Pipe Size		***We***		***W_l***		***We***		***W_l***		***We***		***W_l***	
in.	***(mm)***	***lb/lin ft***	***(kg/m)***	***lb/lin ft***	***(kg/m)***	***lb/lin ft***	***(kg/m)***	***lb/lin ft***	***(kg/m)***	***lb/lin ft***	***(kg/m)***	***lb/lin ft***	***(kg/m)***
4	(100)	226	(335)	297	(440)	324	(480)	162	(240)	471	(700)	81	(120)
6	(150)	309	(460)	567	(845)	448	(665)	324	(480)	657	(980)	189	(280)
8	(205)	380	(565)	783	(1165)	557	(830)	486	(725)	824	(1225)	297	(440)
10	(255)	448	(665)	972	(1445)	666	(990)	621	(925)	992	(1475)	378	(565)
12	(305)	511	(760)	1,161	(1725)	770	(1145)	756	(1125)	1,159	(1725)	459	(685)
14	(355)	568	(845)	1,217	(1810)	868	(1290)	807	(1200)	1,318	(1960)	540	(805)
16	(405)	617	(920)	1,307	(1945)	959	(1425)	879	(1310)	1,470	(2185)	590	(880)
18	(455)	665	(990)	1,400	(2085)	1,042	(1550)	964	(1435)	1,616	(2405)	632	(925)
20	(510)	714	(1060)	1,524	(2270)	1,119	(1665)	1,076	(1600)	1,755	(2610)	729	(1085)
24	(610)	814	(1210)	1,662	(2475)	1,256	(1870)	1,159	(1725)	2,011	(2990)	769	(1145)
30	(760)	963	(1435)	1,925	(2865)	1,457	(2170)	1,356	(2020)	2,340	(3480)	918	(1365)
36	(915)	1,121	(1670)	2,182	(3245)	1,668	(2480)	1,577	(2345)	2,628	(3910)	1,090	(1620)

5 ft (1.5 m)				***8 ft (2.5 m)***					
We		***W_l***		***We***		***W_l***			
lb/lin ft	***(kg/m)***	***lb/lin ft***	***(kg/m)***	***lb/lin ft***	***(kg/m)***	***lb/lin ft***	***(kg/m)***		
471	(700)	81	(120)	765	(1140)	54	(80)		
657	(980)	189	(280)	1,075	(1600)	94	(140)		
824	(1225)	297	(440)	1,356	(2020)	148	(220)		
992	(1475)	378	(565)	1,645	(2450)	189	(280)		
1,159	(1725)	459	(685)	1,950	(2900)	243	(360)		
1,318	(1960)	540	(805)	2,218	(3300)	270	(400)		
1,470	(2185)	590	(880)	2,381	(3545)	324	(480)		
1,616	(2405)	632	(925)	2,533	(3770)	364	(540)		
1,755	(2610)	729	(1085)	2,686	(3995)	410	(610)		
2,011	(2990)	769	(1145)	2,994	(4455)	462	(685)		
2,340	(3480)	918	(1365)	3,459	(5145)	564	(840)		
2,628	(3910)	1,090	(1620)	3,927	(5845)	632	(940)		

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

APPENDIX D: SAMPLE LISTING

Fiber Reinforced Composite Pipe and Fittings

Pipe and fittings made in various configurations of fiber reinforced composites are acceptable when certified. Installation of pipe and fittings should be according to pipe manufacturer's instructions and certification standards. For underground use only.

Product Designation	***Nominal Pipe Size, in.***	***Pressure Rating bar (psi)***	***Remarks***
Series 89 Key Lock Pipe			
N89KL	2, 3, 4, 6, 8, 10	20 (290)	a
Series 89 Taper × Taper Pipe			
N89TT	2, 3, 4, 6, 8, 10	20 (290)	d
Series 99 Taper × Taper Coupling			
S99691	6	14 (205)	e, f
S99692	8	14 (205)	e, f
S92693	10	14 (205)	e, f
S59794	12	14 (205)	e, f
Series 99 Key Lock Adapter Reducer			
S55055	8×4	14 (205)	c, e
S55056	8×6	14 (205)	c, e
Series 99 Key Lock Reducing Tee			
S5264030	6×6×4	16 (230)	b, d, e
S5264130	8×8×4	16 (230)	b, d, e
S5264140	8×8×6	16 (230)	b, d, e

Remarks:
a. Pipe with one integral key-lock female end and one integral key-lock male end.
b. Fittings with key-lock female ends.
c. Fittings with one key-lock female end and one key-lock male end.
d. Bonded joints made with ABC adhesive.
e. Bonded joints made with XYZ adhesive.
f. Fittings with Quick-lock bell ends.