



Member of the FM Global Group

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

Class Number 1614

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Foreword

The FM Approvals certification mark is intended to verify that the products and services described will meet FM Approvals' stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of Approval Standards is to present the criteria for FM Approval of various types of products and services, as guidance for FM Approvals personnel, manufacturers, users and authorities having jurisdiction.

Products submitted for certification by FM Approvals shall demonstrate that they meet the intent of the Approval Standard, and that quality control in manufacturing shall ensure a consistently uniform and reliable product. Approval Standards strive to be performance-oriented. They are intended to facilitate technological development.

For examining equipment, materials and services, Approval Standards:

- a) must be useful to the ends of property conservation by preventing, limiting or not causing damage under the conditions stated by the Approval listing; and
- b) must be readily identifiable.

Continuance of Approval and listing depends on compliance with the Approval Agreement, satisfactory performance in the field, on successful re-examinations of equipment, materials, and services as appropriate, and on periodic follow-up audits of the manufacturing facility.

FM Approvals LLC reserves the right in its sole judgment to change or revise its standards, criteria, methods, or procedures.

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1. INTRODUCTION

1.1 Purpose

- 1.1.1 This standard states FM Approvals' criteria for Fiber Reinforced Composite (FRC) pipe and fittings for underground fire service water mains.
- 1.1.2 FM Approvals' criteria may include, but are not limited to, performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a follow-up program.

1.2 Scope

- 1.2.1 This standard encompasses the design and performance requirements for 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. In cases where metric sized FRC pipe and fittings are to be examined for Approval, test criteria comparable to the United States equivalent size shall be used.
- 1.2.2 Approval Standards are intended to verify that the product described will meet the stated conditions of performance, safety and quality useful to the ends of property conservation.
- 1.2.3 FM Approvals 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 Approval testing is to be conducted on production samples.
- 1.2.4 This standard is primarily intended for use in Approving fiberglass pipe and fittings. Other Fiber Reinforced Composite materials can be FM Approved 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 Approval. FRC pipe and fittings having characteristics not anticipated by this standard may be FM Approved if performance equal to, or superior to, that required by this standard is demonstrated, or if the intent of the standard is met. Alternatively, FRC pipe and fittings which meet all of the requirements identified in this standard may not be FM Approved if other conditions which adversely affect performance exist or if the intent of this standard is not met.

1.4 Basis for Approval

Approval 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 by FM Approvals; and as far as practical,
- The durability and reliability of the product.

1.4.2 An initial facilities and procedures audit shall be conducted to evaluate the manufacturer's ability to consistently produce the product that was examined and tested as part of the Approval project. The audit shall review the facility and in-place quality control procedures used in the manufacturing of the product. Typically, areas of review are incoming inspection, work in progress, production testing, final quality control, marking, calibration of equipment, shipping procedures, and document and drawing control. These examinations are repeated periodically as part of the FM Approvals product follow-up program. (Refer to Section 5.2, Facility and Procedures Audit.)

1.5 Basis for Continued Approval

1.5.1 Continued Approval is based upon:

- Production or availability of the product as currently FM Approved;
- The continued use of acceptable quality assurance procedures;
- Satisfactory field experience;
- Compliance with the terms stipulated in the Master Agreement;
- Satisfactory re-examination of production samples for continued conformity to requirements; and
- Satisfactory Facilities and Procedures Audits (F&PAs) conducted as part of FM Approvals' Product Follow-up Program.

1.5.2 Also, as a condition of retaining Approval, manufacturers may not change an FM Approved product or service without prior written authorization by FM Approvals. (Refer to Section 5.1.3 for further details regarding changes.)

1.6 Effective Date

The effective date of an Approval standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products FM Approved under a previous edition shall comply with the new version by the effective date or forfeit Approval.

The effective date of this standard is **April 30, 2009** 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. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with SI 10-02 Institute of Electrical and Electronics Engineers (IEEE)/American Society for Testing Materials (ASTM) *"Standard for Use of the International System of Units (SI): The Modern Metric System."*

2 FM APPROVALS

1.8 Applicable Documents

The following standards, test methods, and practices are referenced in this standard:

- ANSI A21.1 - 1967, *American National Standard for Thickness Design of Cast Iron Pipe*
ANSI/American Water Works Association, (AWWA) C950 - 2001, *Fiberglass Pressure Pipe*
IEEE/ASTM SI 10-02, *Standard for Use of the International System of Units (SI): The Modern Metric System*
ASTM D618 - 2000, *Standard Practice for Conditioning Plastics for Testing*
ASTM D638 - 2003, *Standard Test Method for Tensile Properties of Plastics*
ASTM D695 - 2002a, *Test Method for Compressive Properties of Rigid Plastics*
ASTM D883 - 2000, *Standard Terminology Relating to Plastics*
ASTM D1238 - 2004c, *Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer*
ASTM D1505 - 2003, *Standard Test Method for Density of Plastics by the Density-Gradient Technique*
ASTM D1598 - 2002, *Standard Test Method for Time-to-Failure of Plastic Pipe under Constant Internal Pressure*
ASTM D1599 - 1999(2005), *Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing and Fittings*
ASTM D1600 - 1999, *Standard Terminology for Abbreviated Terms Relating to Plastics*
ASTM D2290 - 2004, *Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe by Split Disk Method*
ASTM D2412 - 2002, *Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading*
ASTM D2444 - 1999 (2005), *Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)*
ASTM D3517- 2004, *Standard Specification for 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe*
ASTM D2992 - 2001, *Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe*
ASTM D2996 - 2001, *Specification for Filament-Wound 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe*
ASTM D2997 - 2001, *Specification for Centrifugally Cast 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe*
ASTM D3567 - *Standard Practice for Determining Dimensions of 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings*
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 F412 - 2001ae1, *Standard Terminology Relating to Plastic Piping Systems*
ASTM F477 - *Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe*
American Water Works Association (AWWA) *Fiberglass Pipe Design (M45), Second Edition*
FM *Global Property Loss Prevention Data Sheets*
NSF/ANSI 61-2003e: *Standard for Drinking Water Systems Components - Health Effects*
International Standards Organization (ISO) 161-1 - 1996, *Thermoplastic Pipe for the Conveyance of Fluids, Nominal Outside Diameters and Nominal Pressures, Part 1 Metric Series*
ISO 17025 - 1999, *General Requirements for the Competence of Testing and Calibration Laboratories*

1.9 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 Approval 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. When the authority is FM Global, such locations are termed “FM Global Accepted.” Acceptance is based upon an overall evaluation of the installation. Factors other than the use of FM Approved equipment impact upon the decision to accept, or not to accept. Acceptance is not a characteristic of a product. A product accepted for one installation may not be acceptable elsewhere. (Contrast with FM Approved.)

Approval Mark

The Approval Mark is detailed in Appendix B. Its use is mandatory on all units of FM Approved pipe and fittings. These registered marks cannot be used except as authorized by FM Approvals via the granting of Approval to a specific product.

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.

Factor of Safety (F)

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 F is used to account for variations in conditions from those contemplated in the design of an installation, rough handling of piping, and manufacturing variations.

FM Approved

This term refers to products FM Approved by FM Approvals. Such products are listed in the *Approval Guide*, a publication of FM Approvals, issued annually, or its supplements. All products so listed have been successfully examined by FM Approvals, and their manufacturers have signed and returned a Master Agreement to FM Approvals. These forms obligate the manufacturer to allow re-examination of the product and audit of facilities and procedures at FM Approval’s discretion. It further requires the manufacturer not to deviate from the as-FM Approved configuration of the product without review by and agreement of FM Approvals.

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 factor of safety.

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

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°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)*, Second Edition as:

For stress basis HDB

$$PC = \left(\frac{HDB}{FS} \right) \left(\frac{2t}{D} \right)$$

For strain basis HDB

$$PC = \left(\frac{HDB}{FS} \right) \left(\frac{2tE_H}{D} \right)$$

Where:

- PC - 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/in² (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.

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).

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 Joints may be Bell and Spigot (with gaskets or adhesive bonded), Butt Joint, Flanged or via mechanical couplings.
- 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 Approval Application Requirements

- 2.2.1 To apply for an Approval examination the manufacturer, or an authorized representative, shall submit a request to:

Group Manager - Hydraulics
FM Approvals
Hydraulics Laboratory
743A Reynolds Road
West Glocester, RI 02814 U.S.A.

- 2.2.2 The manufacturer shall provide the following preliminary information with any request for Approval consideration:
- A complete list of all models, types, sizes, and options for the products or services being submitted for Approval 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
 - Number and location of manufacturing facilities making the products submitted for Approval.
- 2.2.3 All the submitted documents shall be controlled by the manufacturer's Quality Assurance procedures, and shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All foreign language documents shall be provided with English translation, at the time of submittal.

2.3 Requirements for Samples for Examination

Following set-up and authorization of an Approval examination, the manufacturer shall submit samples for examination and testing. Sample requirements are to be determined by FM Approvals following review of the preliminary information. Sample requirements may vary depending on design features, results of prior testing, and results of the foregoing tests. It is the manufacturer's responsibility to submit samples representative of production. Any decision to use data generated utilizing prototypes is at the discretion of FM Approvals. The manufacturer shall provide any special test fixtures, which may be required to evaluate the pipe.

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 Approval 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.
- 3.1.3 All documents pertaining to the product materials, dimensions, processing, and marking shall be controlled by the manufacturer's Quality Assurance procedures, and shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All foreign language documents shall be provided with English translation.

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 FM Approvals will determine if the products may be considered for Approval.
- 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°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*. FM Approvals 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 factor of safety 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 4.3 (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 Approval. However, all fitting configurations need not be tested for qualification of a given line. FM Approvals will designate those items to be tested which, in its judgment, adequately sample the products submitted for Approval.

3.3 Materials

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- 2003, *Standard for Drinking Water Systems Components - Health Effects*, at minimum.

3.4 Markings

- 3.4.1 All FM Approved pipe and fittings shall bear the Approval Mark (see Appendix B). The Approval Mark shall be displayed visibly and permanently on the product. The manufacturer shall not use this Mark on any other product unless such product is covered by separate agreement with FM Approvals.
- 3.4.2 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;
 - Specific production code, including day, month, year, shift, plant and extruder of manufacture, as applicable; and
 - The Approval Mark.
- 3.4.3 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;
 - 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
 - The Approval Mark.
- 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 All markings shall be legible and durable throughout the useful life of the product.

3.5 Manufacturer's Installation and Operation Instructions

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

- Indicate that the FRC pipe and fittings qualified under this standard and FM Approved by FM Approvals 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.

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

3.6 Calibration

All equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage of the equipment. For testing conducted at locations other than FM Approvals, a copy of the calibration certificate for each piece of test equipment is required for FM Approvals records that indicates that the calibration was performed to standards traceable to the National Institute of Standards and Technology (NIST) or to other acceptable reference standards by an accredited ISO 17025, *General Requirements for the Competence of Testing and Calibration Laboratories* calibration laboratory. The test equipment must be clearly identified by label or sticker showing the last date of the calibration and the next due date. In addition, a copy of the ISO 17025 accreditation certificate for the calibration laboratory is required for FM Approvals records.

The calibration of recently purchased new equipment is also required. Documentation indicating either the date of purchase or date of shipment, equipment description, model and serial number is required for identification. The period from the time the equipment was put into service to the date of testing must be within an interval that does not require the equipment to be calibrated as determined on the basis of the parameters mentioned above.

3.7 Tolerances

Tolerances on units of measure shall be as described in Appendix F, 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 FM Approvals' 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 Standard Design

4.2.1 Requirements

If the manufacturer's literature or pipe markings reference any recognized standard specifying design, manufacture, or performance, FM Approvals shall verify, as a part of its examination, that all criteria of such a referenced standard are met. The intent of the requirement is that FRC pipe and fittings conform to any recognized standard to which they are manufactured.

4.2.2 Test/Verification

The manufacturer shall submit to FM Approvals a copy of the relevant standard(s), along with drawings, specifications, and other documents necessary to confirm compliance. FM Approvals shall verify that all requirements of that standard are met.

4.3 Hydrostatic Strength (Pipe and Fittings)

4.3.1 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.

4.3.2 Test/Verification

One sample of each size and pressure class of pipe, joining method and fitting submitted for Approval, shall be subjected to a hydrostatic strength test. Pipe test samples shall include a joint made according to the manufacturer's recommended joining methods. Pipe segments between joints shall be, at minimum, 1 ft (305 mm) long. 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.

4.4 Leakage (Pipe, Joints and Fittings)

4.4.1 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.

4.4.2 Test/Verification

One sample of each size and pressure class of pipe, joining method and fitting submitted for Approval, shall be subjected to a hydrostatic strength test. Pipe segments between joints shall be, at minimum, 1 ft (305 mm) long. 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.

4.5 Stiffness Factor (Pipe Only)

4.5.1 Requirements

Pipe submitted for Approval 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:

- Δy - Change in vertical diameter of pipe, inches (mm)
- D_l - Deflection Lag Factor = 1.25
- W_e - Earth loads on pipe per unit length, lb/lin·ft (N/m) (As specified in Table 1-8 of ANSI A21.1)
- W_l - Live load on pipe per unit length, lb/lin·ft (N/m) (As specified in Table 1-8 of ANSI A21.1)
- K - Bedding Constant = 0.1
- r - Mean pipe radius, inches (mm)
- E - Modulus of elasticity of pipe material in the hoop direction, psi (kPa)
- I - Moment of Inertia of Pipe Wall per unit length, in³ (mm³)
- E' - Modulus of Soil Reaction = 400 psi (2760 kPa) (Minimum)
- PS - Pipe Stiffness
- F - Force applied to produce a given deflection, lb_f/inch of length (N/m of length)
- SF - Stiffness Factor

4.5.2 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 Approval. 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.

4.5.3 Additional Requirements

Each sample tested in 4.5.2 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.

4.6 Abuse Test (Pipe and Fittings)

4.6.1 Requirements

A 10 lb-ft (13.5 Nm) impact shall not impair the hydrostatic integrity of the pipe and fittings. The intent of the requirement is that piping be resistant to minor impacts encountered in handling, installation and service. There should be no visible signs of shattering, cracking, splitting, interlaminar separation, tensile failure of the glass-fiber reinforcement, fracture, or buckling of the pipe wall as a result of this test.

4.6.2 Tests/Verification

Samples of pipe and fittings submitted for Approval 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 10 lb-ft (13.5 Nm) impact, once on the pipe wall and once on the "critical area" of each fitting. The "critical area" of a fitting selected for impact is that area, which would be the most vulnerable when the fitting is assembled to the 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.

4.7 Vacuum

4.7.1 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 repeated after the vacuum test of each sample assembly. There should be no leakage or permanent deformation as a result of this test.

4.7.2 Tests/Verification

Samples of pipe and fittings submitted for Approval 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.

4.8 Additional Tests

Additional tests may be required, depending on design features, results of any tests, material application, or to verify the integrity and reliability of the FRC pipe and fittings, at the discretion of FM Approvals.

Unexplainable failures shall not be permitted. A re-test shall only be acceptable at the discretion of FM Approvals and with adequate technical justification of the conditions and reasons for failure.

5. OPERATIONS REQUIREMENTS

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 Approval examination and tests, and is documented in the Approval Report. Conformance to design is verified by control of quality and is covered in the Facilities and Procedures Audit (F&PA). Quality of performance is determined by field performances and by periodic re-examination and testing.

5.1 Demonstrated Quality Control Program

5.1.1 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, Operating Manual, and specific Test Procedure change control
- Packaging and shipping
- Handling and disposition of non-conformance materials.
- In order to assure adequate traceability of materials and products, the manufacturer shall maintain records of all quality control tests performed, for a minimum period of two years from the date of manufacture.

5.1.2 Documentation/Manual

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

5.1.3 Drawing, Specification and Document 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 Approval Report, must be reported to, and authorized by, FM Approvals prior to implementation for production. The manufacturer shall assign an appropriate person or group to be responsible for reporting proposed revisions to FM Approved products to FM Approvals. In situations involving significant modifications to an FM Approved product, the notification shall be in the form of a formal request for

an Approval examination. For modifications of a more common nature, the manufacturer shall provide notification to FM Approvals by means of FM Approvals Form 797, Approved Product/Specification-Tested Revision Report or Address/Main Contact Change Report. Records of all revisions to all FM Approved products shall be maintained. Forms 797 are provided to the manufacturer by FM Approvals.

In summary, when a manufacturer revises a drawing, specification, or document which is listed in the controlled document list of the Approval Report, the manufacturers' representative must submit a Form 797 to FM Approvals by mail or electronically. The following information must be included: the revised drawing which clearly specifies the change and reason for the change; the product model and size affected; the original FM Approvals Project ID(s); and the FM Approvals representative who should be on of the two signatories of the original Approval Report.

5.1.3.1 The table below has been included as a guide to manufacturers of what is considered to be a significant change to FM Approvals. As mentioned above, modifications that fit this category shall be documented by means of a letter stating the change, and requesting a quotation for an Approval examination.

<i>Modification</i>	<i>Description/Example</i>
Increase of Pressure Rating:	<ul style="list-style-type: none"> The product was originally FM Approved for 150 psi (1035 kPa), and now is to be evaluated to 160 psi (1105 kPa).
Addition of Product Sizes	<ul style="list-style-type: none"> The product was originally FM Approved for 4 - 8 inch NPS, and now Approval of 10 and 12 inch NPS is desired.
Addition or Relocation of the Manufacturing Location:	<ul style="list-style-type: none"> The product was originally FM Approved in location A, and now is desired to be made in locations A and B, or only in location B.
Change of Resin:	<ul style="list-style-type: none"> Pipe/fittings were originally FM Approved using Resin A. Manufacturer now wishes to make pipe/fitting from Resin B.
Changes to Critical Dimensions:	<ul style="list-style-type: none"> Modifications that would depart from the national or international standards that are used in the manufacturing of the product as originally FM Approved.
	<ul style="list-style-type: none"> Modifications that would have an effect on the use of the pipe with standardized fittings/couplings.
	<ul style="list-style-type: none"> Modifications that would have an effect on the ability of the product to maintain the same performance as the originally FM Approved product. An example of this would be a significant reduction of pipe wall thickness.

5.1.3.2 The table below has been included as a guide to manufacturers of modifications that are commonly submitted on FM Approvals Form 797.

<i>Modification</i>	<i>Description/Example</i>
Change in Company Contact Information:	<ul style="list-style-type: none"> Name, Title, Phone Number, Fax Number, Email Address, Company Office Address, Company Name
Updating of Drawings:	<ul style="list-style-type: none"> The Form 797 is used to notify FM Approvals in the event of: minor dimensional changes to non-critical features, minor changes in notes, location of title block, re-creation of the same drawing on CAD, etc.
Changes in Markings:	<ul style="list-style-type: none"> Please describe what changes are to be made and include a drawing of the proposed marking.
Updating of Documentation:	<ul style="list-style-type: none"> Creation of New or Revisions to Sales literature, Installation Instructions, Grooving Dimensions, Quality Manual, etc.

5.1.3.3 For the instances where the modification is difficult to categorize, manufacturers are encouraged to contact FM Approvals to discuss the nature of the change, and inquire about how to send the information to FM Approvals.

5.2 Facilities and Procedures Audit (F&PA)

5.2.1 An audit of the manufacturing facility is part of the Approval investigation to verify implementation of the quality control program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to insure a consistently uniform and reliable product. Initial inspections of facilities already producing similar FM Approved products may be waived at the discretion of FM Approvals.

5.2.2 Unannounced follow-up inspections shall be conducted at least annually by FM Approvals, or its designate, to determine continued compliance. More frequent audits may be required by FM Approvals.

5.2.3 The manufacturer shall manufacture the product or service only at the location(s) audited by FM Approvals and as specified in the Approval Report. Manufacture of products bearing the Approval Mark is not permitted at any other locations without prior written authorization by FM Approvals.

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 FM Approvals.

5.4 Manufacturer's Responsibilities

- 5.4.1 The manufacturer shall notify FM Approvals of changes in product construction, design, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation of such changes.
- 5.4.2 Where all or part of the quality control has been subcontracted, the manufacturer shall, at a minimum, conduct sufficient oversight audits to verify the continued application of the required controls.

5.5 Manufacturing and Production Tests

5.5.1 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 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 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 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 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.

APPENDIX A: Units of Measurement

FLOW:	gal/min - "gallons per minute"; (L/min - "liter per minute") $L/min = gal/min \times 3.7854$
FORCE:	lb - "pounds"; (N- "Newtons") $N = lb \times 4.4482$
LENGTH:	in. - "inches"; (mm - "millimeters") $mm = in. \times 25.4$ ft - "feet"; (m - "meters") $m = ft \times 0.3048$
MASS:	lb - "pounds"; (kg - "kilograms") $kg = lb \times 0.454$
PRESSURE:	psi - "pounds per square inch"; (kPa - "kilopascals") $kPa = psi \times 6.895$
TEMPERATURE:	$^{\circ}F$ - "degrees Fahrenheit"; ($^{\circ}C$ - "degrees Celsius") $^{\circ}C = (^{\circ}F - 32) \times 0.556$
TORQUE or MOMENT:	lb·ft - "pound-feet"; (N·m - "newton-meter") $N \cdot m = lb \cdot ft \times 1.356$
VACUUM:	inHg - "inches of mercury" psi - "pounds per square inch" (kPa - "kilopascals") $psi = inHg \times 0.4912$; $kPa = inHg \times 3.3864$
WORK:	ft·lb - "foot-pounds"; (J - "joule") $J = ft \cdot lb \times 1.356$

APPENDIX B: FM Approvals Certification Marks

FM Approvals certifications marks are to be used only in conjunction with products or services that have been FM Approved by FM Approvals and in adherence with usage guidelines.



FM APPROVED mark:

Authorized by FM Approvals as a certification mark for any product that has been FM Approved. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.



Cast-On FM Approvals marks:

Where reproduction of the FM Approved mark described above is impossible because of production restrictions, use these modified versions of the FM Approved mark. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable.



FM Approved mark With "C" only:

Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with Canadian codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background



FM Approved mark with "C" and "US":

Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with US and Canadian codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.

FM APPROVALS CERTIFICATION MARKS (Con't)

USAGE GUIDELINES

All FM Approvals certification marks are the sole property of FM Approvals LLC ("FM Approvals") and are registered or the subject of applications for registration in the United States and many other countries. They are for use only according to these guidelines.

FM Approvals certification marks may be used only on FM Approved products and related product packaging, in advertising material, catalogs and news releases. Use of FM Approvals certification marks on such material is not a substitute for use of the complete FM Approvals certification mark on FM Approved products and/or product packaging.

No FM Approvals certification mark or aspect thereof may be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. This includes both design aspects (the FM Approvals "diamond," etc.) and word aspects ("FM," "Approved," etc.). The use of any FM Approvals certification mark as a trademark is strictly prohibited.

The Approval Standard number or class number may not be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. For example, a company may not say "ABC Company's 4100 Fire Door is FM Approved"; the proper terminology is, "ABC Company's Fire Door is FM Approved per Approval Standard 4100."

FM Approvals certification marks, except for the FM Approvals Quality System Registration mark, may not be used on business stationery/cards/signage because this could mischaracterize the relationship with FM Approvals. Additionally, these items should not reference any FM Approvals certification mark.

Products or services may not be marketed under any mark or name similar to "FM Global," "FM Approvals" or any of the FM Approvals certification marks. Further, products or services may not be marketed to imply a relationship beyond the scope of any Approval made by FM Approvals.

When an FM Approvals certification mark is used in advertising material or on product packaging, all material must reflect the specific circumstances under which the product was FM Approved. The material must clearly differentiate between products that are FM Approved and those that are not, and may not, in any way, imply a more substantial relationship with FM Approvals.

A company may not reference the intent to submit a product for Approval or the expectation that a company will have a certain product FM Approved in the future. For example, a company may not state, "Approval by FM Approvals pending" or "Approval by FM Approvals applied for."

FM Approvals certification marks should not be preceded or followed by a qualifier that indicates a degree of certification or acceptability. For example, "exceeds," "first" or "only" may not be used to qualify any FM Approvals certification mark.

Only original artwork issued by FM Approvals should be used. The FM Approvals certification marks should not be altered in any way other than to resize the artwork proportionately. Unacceptable uses of the marks include, but are not limited to, adding/deleting wording or artwork, reducing the artwork to an illegible size, animation or distortion.

The text of the FM Approvals certification marks may not be translated into any language other than English.

FM Approvals certification marks must appear in a size and location that is readily identifiable, but less prominent than the name of the owner of the certification or the manufacturer/seller/distributor of the certified products.

APPENDIX C: Sample Calculation

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 be 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:

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

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:

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

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

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:

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

Simplifying yields:

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

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:

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

Substituting into Eq. 5 yields:

$$\Delta y = 0.000233(1.25W_e + W_i) \quad \text{Eq. 7}$$

Using the *We* (568) and *Wi* (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)

$$y = 0.000233[1.25(568) + 1217]$$

$$y = 0.448 \text{ inches}$$

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)

$$y = 0.000233[1.25(2218) + 270]$$

$$y = 0.708 \text{ inches}$$

Percent Deflection = 0.708/13.55 x 100 = 5.23 percent

UNACCEPTABLE

This is an example of a pipe that would not be FM Approved. 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 FM APPROVED.

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

Pipe Size in. (mm)	Depth of Cover							
	2-1/2 ft (0.75 m)		3-1/2 ft (1.0 m)		5 ft (1.5 m)		8 ft (2.5 m)	
	<i>We</i>	<i>Wi</i>	<i>We</i>	<i>Wi</i>	<i>We</i>	<i>Wi</i>	<i>We</i>	<i>Wi</i>
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)	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)	765 (1140)	54 (80)
6 (150)	309 (460)	567 (845)	448 (665)	324 (480)	657 (980)	189 (280)	1,075 (1600)	94 (140)
8 (205)	380 (565)	783 (1165)	557 (830)	486 (725)	824 (1225)	297 (440)	1,356 (2020)	148 (220)
10 (255)	448 (665)	972 (1445)	666 (990)	621 (925)	992 (1475)	378 (565)	1,645 (2450)	189 (280)
12 (305)	511 (760)	1,161 (1725)	770 (1145)	756 (1125)	1,159 (1725)	459 (685)	1,950 (2900)	243 (360)
14 (355)	568 (845)	1,217 (1810)	868 (1290)	807 (1200)	1,318 (1960)	540 (805)	2,218 (3300)	270 (400)
16 (405)	617 (920)	1,307 (1945)	959 (1425)	879 (1310)	1,470 (2185)	590 (880)	2,381 (3545)	324 (480)
18 (455)	665 (990)	1,400 (2085)	1,042 (1550)	964 (1435)	1,616 (2405)	632 (925)	2,533 (3770)	364 (540)
20 (510)	714 (1060)	1,524 (2270)	1,119 (1665)	1,076 (1600)	1,755 (2610)	729 (1085)	2,686 (3995)	410 (610)
24 (610)	814 (1210)	1,662 (2475)	1,256 (1870)	1,159 (1725)	2,011 (2990)	769 (1145)	2,994 (4455)	462 (685)
30 (760)	963 (1435)	1,925 (2865)	1,457 (2170)	1,356 (2020)	2,340 (3480)	918 (1365)	3,459 (5145)	564 (840)
36 (915)	1,121 (1670)	2,182 (3245)	1,668 (2480)	1,577 (2345)	2,628 (3910)	1,090 (1620)	3,927 (5845)	632 (940)

*Extracted from Table 1-8, ANSI A21.10, American National Standard for Thickness Design of Cast-Iron Pipe.

APPENDIX D: Tolerance

Unless otherwise stated, the following tolerances shall apply:

Angle:	$\pm 2^\circ$
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:	$\pm 4^\circ\text{F}$ (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 $68^\circ\text{F} \pm 9^\circ\text{F}$ ($20^\circ\text{C} \pm 5^\circ\text{C}$).

APPENDIX E: Sample Listing

Fiber Reinforced Composite Pipe and Fittings

Pipe and fittings made in various configurations of fiber reinforced composites are acceptable when FM Approved.

<i>Product Designation</i>	<i>Nominal Pipe Size, in.</i>	<i>Pressure Rating bar (psi)</i>	<i>Remarks</i>
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

Installation of pipe and fittings should be according to pipe manufacturer's instructions and FM Approvals standards. For underground use only.

- 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.



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