Approval Standard for Polyethylene (PE) Pipe and Fittings for Underground Fire Protection

Class Number 1613

February 2006

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 Polyethylene (PE) 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 in. through 36 in. nominal size PE 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 PE 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 stated conditions of performance, safety and quality useful to the ends of property conservation.

1.2.3 FM Approvals will consider PE pipe and fittings which are designed in accordance to national or international standards. Only after verification is made that the products to be reviewed are in conformance to American Water Works Association (AWWA) C-906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution*, or other nationally or internationally recognized standards will Approval testing commence. All Approval testing is to be conducted on production samples.

1.3 Basis for Requirements

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

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of PE pipe and fittings for the purpose of obtaining Approval. PE pipe and fittings having characteristics not anticipated by this standard may be FM Approved if performance equal, or superior, to that required by this standard is demonstrated, or if the intent of the standard is met. Alternatively, PE 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 **January 31, 2007** 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 the American National Standards Institute (ANSI)/Institute of Electrical and Electronics Engineers (IEEE)/American Society for Testing Materials (ASTM) SI 10-97, *"Standard for Use of the International System of Units (SI): The Modern Metric System."*

1.8 Applicable Documents

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

ANSI A21.10 - 1967, *American National Standard for Thickness Design of Cast Iron Pipe*
ANSI/American Water Works Association, (AWWA) C901 - 2002, *Polyethylene (PE) Pressure Pipe and Tubing, 1/2 in (13 mm) through 3 in (76 mm), for Water Service*

ANSI/AWWA C906 - 1999, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution*
ANSI/IEEE/ASTM SI 10, 2002, *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 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 D1603 - 2001, *Standard Test Method for Carbon Black in Olefin Plastics*
ASTM D2122 - 2004, *Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings*
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 D2447 - 2003, *Standard Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter*
ASTM D2487 - 2000, *Standard Classification of Soils for Engineering Purposes, (Unified Soil Classification System)*
ASTM D2657 - 2003, *Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings*
ASTM D2683 - 2004, *Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing*
ASTM D2774 - 2004, *Standard Practice for Underground Installation of Thermoplastic Pressure Piping*
ASTM D2837 - 2004, *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products*
ASTM D2839 - 2002, *Standard Practice for Use of a Melt Index Strand for Determining Density of Polyethylene*
ASTM D3035 - 2003a, *Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter*
ASTM D3261 - 2003, *Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing*
ASTM D3350 - 2004, *Standard Specification for Polyethylene Plastic Pipe and Fittings Materials*
ASTM D4218 - 1996 (2001), *Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique*
ASTM 4976 - 2004a, *Standard Specification for Polyethylene Plastics Molding and Extrusion Materials*
ASTM F412 - 2001ae1, *Standard Terminology Relating to Plastic Piping Systems*
ASTM F714 - 2005, *Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter*
ASTM F905 - 2004, *Standard Practice for Qualification of Polyethylene Saddle Fusion Joints*
ASTM F1055 - 1998e1, *Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing*
ASTM F1290 - 1998a (2004), *Standard Practice for Electrofusion Joining Polyolefin Pipe and Fittings*
American Water Works Association (AWWA) M55 - 2005, *PE Pipe - Design and Installation*
FM Global Property Loss Prevention Data Sheets

Plastic Pipe Institute, (PPI) TR-3 - 2004, *Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe*

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 PE 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 PE 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.

Dimension Ratio (DR)

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

Electrofusion Joints

A joint where the mating surfaces, typically a pipe outside diameter and the inside diameter of a coupler, are first mated and then brought to the material melt temperature by means of heating elements embedded in the socket. Once cooled, the result is an electrofused joint.

Factor of Safety (F)

A number, typically greater than or equal to 2.0, 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 specified in ASTM Test Method D2837 for a plastic compound obtained by categorizing the Long Term Hydrostatic Strength of the material as described in ASTM D2837, *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products*.

Hydrostatic Design Stress (HDS)

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

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

For Polyethylene Pressure Pipe for water distribution and transmission the factor of safety is typically 2.

Long Term Hydrostatic Strength (LTHS)

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

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

Where *a* and *b* are constants.

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

Polyethylene (PE)

A polymer prepared by the polymerization of no less than 85 percent ethylene and no less than 95 percent of total olefins by weight, plus compounding ingredients.

Pressure Class

The pressure class is the design capacity to resist working pressure up to 80°F (27°C) maximum service temperature with specified maximum allowances for recurring positive pressure surges above the working pressure. Pressure Class is defined as:

$$PC = \frac{2}{DR - 1} \times HDB \times DF$$

Where:

PC - Pressure Class, in pounds per square inch gauge (kPa gauge)

DR - Dimension Ratio = D_o/t

HDB - Hydrostatic Design Basis for water, in pounds per square inch, psi, (kPa) as determined in AWWA C906.

DF - 0.5; Typical Design Factor; Includes Consideration of Degree of Safety and all the variables, including limited surge pressure effects, in the end application

t - Minimum Pipe Wall Thickness, inches

D_o - Average Outside Diameter for IPS and DI sizes; minimum outside diameter for ISO sizes, inches

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. Water distribution and transmission pipe pressure classes are typically based on a factor of safety of 2.

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 PE 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 and 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 constant internal pressure that can be exerted continuously with a high degree of certainty that failure of the pipe will not occur, at a given temperature, exclusive of pressure surges.

Working Pressure Rating (WPR)

The working pressure rating is the design capacity to resist working pressure at the anticipated operating temperature with sufficient capacity against the actual anticipated positive pressure surges above the working pressure. A pipe's *WPR* may be equal to, or less than, its nominal *PC* depending on the positive transient pressure characteristics of the system and pipe operating temperature if above 80°F (27°C). *WPR* should be determined in accordance with AWWA C906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution*.

2. GENERAL INFORMATION

2.1 Product Information

2.1.1 Nominal sizes of PE 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 PE pipe and fittings are manufactured from materials with specific properties. They are thermoplastic compounds prepared by combining the base polymer, polyethylene or a copolymer of ethylene and higher olefins, with stabilizers, colorants, anti-oxidants and ultra-violet (UV) screens for processing, property control, and coloring.

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

2.1.4 In order to meet the intent of this standard, PE 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 PE 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, A Member of the FM Global Group
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

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

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

3.2.3 PE pipe and fitting materials shall be formed using High Density Polyethylene with a density cell classification of Type III or Type IV as defined in ASTM D3350, *Standard Specification for Polyethylene Plastic Pipe and Fittings Materials*. When other materials are submitted, special tests may be necessary to verify their suitability. 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 testing shall have been performed on pipe made of the same raw material as that of the pipe submitted for Approval and produced on equipment and under conditions equivalent to those to be used in its commercial production. The hydrostatic design stress (*HDS*) shall then be determined in accordance with ASTM D1598, *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.

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.

If the PPI has listed the material in question to have an *HDS* meeting these requirements, even if that listing is based upon a documented equivalency to other pipe rather than on direct testing to the pipe submitted for Approval, that *HDS* shall be acceptable, and submission of calculations and test data may not be required.

3.2.4 Clean rework materials derived from a manufacturer's own pipe or fitting product may be used by the same manufacturer for similar purposes provided that:

- The cell classification of the rework material is identical with the material to which it will be added;
- The finished products meet the requirements specified by the purchaser and comply with all requirements of this standard.

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

3.2.6 The maximum pressure rating for PE pipe shall be determined using procedures outlined in AWWA C906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution*, as applicable. A manufacturer need not take full advantage of the properties of his material in establishing pressure ratings. That is, more conservative ratings than those derived from this calculation may be assigned.

3.2.7 Pressure ratings for PE 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 4.4 (Hydrostatic Strength).

3.2.8 Testing shall use production pipe and fittings assembled according to the manufacturer's published instructions. All joining techniques submitted shall be tested in all sizes 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.

3.2.9 All performance tests described in Section 4, unless otherwise noted, shall be run at an ambient temperature of 73°F (23°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 3.2.9.

Table 3.2.9 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

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

3.2.10 Polyethylene pipe and fittings are generally joined by fusion, either butt fusion or electrofusion, or through the use of flanges. Other joining methods will be examined on a case-by-case basis.

3.3 Materials

3.3.1 Polyethylene is a thermoplastic that is manufactured by polymerization of the monomer ethylene. PE Pipe shall be manufactured by polymerization of no less than 85 percent ethylene and no less than 95 percent of total weight of total olefins and additional compounding ingredients.

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

3.4 Markings

3.4.1 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;
- Dimension ratio, (if applicable);
- Standard material code designation (e.g. PE3048);
- 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
- 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;
- The letters "PE";
- Mold cavity identification, (if applicable);
- Recognized standard to which the fitting is designed and manufactured;
- 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 PE 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 indicate 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 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.

4. PERFORMANCE REQUIREMENTS

4.1 Examination

4.1.1 Requirement

The PE pipe and fittings shall conform to the manufacturer's drawings and specifications and to Approval 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 PE 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 Bend Back (Pipe Only)

4.3.1 Requirement

A bend-back test shall be conducted on all PE material formulations used in production of products submitted for Approval. The test specimen shall give no indications of brittle-like cracking or crazing when examined by the naked eye.

4.3.2 Test/Verification

A total of five specimens shall be prepared from finished pipe. Specimens shall be 1-1/4 in. (31.75 mm) wide, 6 in. (150 mm) long and 3/8 in. (9.5 mm) thick (or pipe wall thickness if wall is less than 3/8 in.). If thickness is machined to produce the required specimen, the pipe inside surface shall not be disturbed. 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 specimen shall be bent over itself so that the outside surfaces of the specimen are in full contact with each other, beginning at a distance no greater than 3/8 in. (9.5 mm) from the crotch of the bend (see Figure F-1). The time from beginning to end of the bending operation shall be five minutes or less. The bent inside surface shall be examined in a well-lit area for signs of cracking or crazing. No cracking or crazing visible to the naked eye is allowed.

4.4 Elongation at Break (Pipe Only)

4.4.1 Requirement

An elongation at break test shall be conducted on all PE material formulations used in production of products submitted for Approval. The elongation at break for each test sample shall exceed 400 percent.

4.4.2 Test/Verification

A total of five specimens shall be prepared from the pipe material in accordance with ASTM D638, *Standard Test Method for Tensile Properties of Plastics*, Type III or Type IV. Specimen thickness shall be pipe thickness, or 0.55 in. (14 mm), whichever is less, for Type III specimens; and pipe thickness, or 0.13 in. (3.2 mm), whichever is less, for Type IV specimens. If thickness is machined to produce the required specimen, the pipe inside surface shall not be disturbed. 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 specimen shall be tested using a cross-head separation of 2 in. (50.8 mm) per minute. The elongation at break shall be greater than 400 percent.

4.5 Hydrostatic Strength (Pipe and Fittings)

4.5.1 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 leakage, rupture, ballooning or weeping.

4.5.2 Test/Verification

One sample of each size and cell classification 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. Test pressure shall be four times the rated working pressure. Pressure shall be maintained for 5 minutes.

4.6 Stiffness Factor (Pipe Only)

4.6.1 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 (2.44 m).

The Spangler Equation used to determine pipe deflections is:

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

Also:

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

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

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

A sample calculation is shown in Appendix C.

4.7 Ring-Tensile Strength (Pipe Only)

4.7.1 Requirements

Ring-tensile Strength tests shall be conducted on all PE material formulations used in production of products submitted for Approval in accordance with ASTM D2290, *Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe by Split Disk Method*. The tensile strength shall not be less than 2,500 psi (17.2 MPa) for PE 2406 material and not less than 2,900 psi (20.2 MPa) for PE 3406 and PE 3408 materials. Minimum tensile strength for other materials shall be established as part of the Approval process.

4.7.2 Tests/Verification

Samples shall be prepared from sections of pipe in accordance with ASTM D2290, *Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe by Split Disk Method*; Procedure B. Samples shall be cut from full diameter, full thickness pipe, 0.50 in. (12.7 mm) long. Two areas of reduced section shall be machined, 0.125 in. (3.2 mm) in diameter.

Test specimens shall be measured and mounted in a suitable test fixture. They shall be loaded at 0.50 in./min. (12.7 mm/min.) and the yield and ultimate loads recorded.

Apparent tensile strength at yield shall be calculated and compared to the criterion.

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 PE 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 PE pipe and fittings produced by the manufacturer at an authorized location, shall present the same quality and reliability as the specific PE 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 and 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 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 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, and require that, proposed changes to FM Approved or Listed products be reported to FM Approvals before implementation. The manufacturer shall notify FM Approvals of changes in the product or of persons responsible for keeping FM Approvals advised by means of FM Approvals Form 797, FM Approved Product/Specification-Tested Revision Report or Address/Main Contact Change Report. Records of all revisions to all FM Approved products shall be maintained.

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.

Modification	***Description/Example***
Increase of Pressure Rating:	• The product was originally FM Approved for 150psi (1035 kPa), and now is to be evaluated to 160psi (1105 kPa).
Addition of Product Sizes:	• The product was originally FM Approved for 4 - 8inch NPS, and now Approval of 10 and 12 inch NPS is desired.
Addition or Relocation of the Manufacturing Location:	• 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:	• Pipe/fittings were originally FM Approved using Resin A. Manufacturer now wishes to make pipe/fitting from Resin B.
Changes to Critical Dimensions:	• Modifications that would depart from the national or international standards that are used in the manufacturing of the product as originally FM Approved. • Modifications that would have an effect on the use of the pipe with standardized fittings/couplings. • 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.

Modification	*Description/Example*
Change in Company Contact Information:	• Name, Title, Phone Number, Fax Number, Email Address, Company Office Address, Company Name
Updating of Drawings:	• 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:	• Please describe what changes are to be made and include a drawing of the proposed marking.
Updating of Documentation:	• 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

All tests shall be run at an ambient temperature of 73°F (23°C) unless otherwise noted. For tests conducted at higher temperatures, the de-rating factors shown in Table 3.2.9 may be applied.

5.5.1 Elevated Temperature Sustained Pressure Test (Pipe Test Only)

The manufacturer shall conduct an elevated temperature sustained pressure test as defined in ASTM D1598, *Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure*, and AWWA C906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution*. This test shall be conducted at the beginning of production and semi-annually thereafter. The pipe shall not rupture, balloon, or weep.

5.5.2 Dimension and Tolerances (Pipe and Fittings)

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

Fittings - The manufacturer shall measure critical fitting dimensions, at least once per hour.

5.5.3 Bend Back Test (Pipe Only)

The manufacturer shall conduct a bend-back test daily, or at least once per production run, whichever is more frequent. The test shall be conducted per the requirements of AWWA C906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution*. The Elongation at Break Test may be substituted for this test.

5.5.4 Elongation at Break Test (Pipe Only)

The manufacturer shall conduct an Elongation at Break Test daily, or at least once per production run, whichever is more frequent. The test shall be conducted per the requirements of AWWA C906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution*. The Bend Back Test may be substituted for this test.

5.5.5 Ring–Tensile Strength Test (Pipe Only)

The manufacturer shall conduct a Ring-Tensile Test at least once per production run. This test shall be conducted per the requirements of AWWA C906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution*. The sample must meet the minimum requirements shown in Table 4.7.1. The Quick Burst Test or the Five-Second Pressure Test as defined in AWWA C906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution* may be substituted for this test.

5.5.6 Quick Burst Test (Pipe Only)

The manufacturer shall conduct a quick burst test at least once per production run. This test shall be conducted per the requirements of ASTM D1599, *Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing and Fittings*. The sample shall meet the minimum requirements of AWWA C906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution* for Quick Burst Testing. The test pressure at failure, shall not be less than that which results from a minimum hoop stress value of 2,500 psi (17.2 MPa) for PE2406 materials. For PE3408 materials, the minimum hoop stress value shall be 2,900 psi (20.2 MPa). The Ring-tensile Strength Test or the Five-Second Pressure Test may be substituted for this test.

5.5.7 Carbon Black Content Test (Pipe and Fittings)

Carbon black levels shall be determined daily or for each production run of pipe, whichever is more frequent. The test shall be performed in accordance with AWWA C906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution* and ASTM D1603, *Standard Test Method for Carbon Black in Olefin Plastics* or ASTM D4218, *Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique,* or equivalent methods. For colored pipe, the quantity of UV stabilizer shall be verified either by direct analytical measurement or by verification of the blend percentages at the same frequency as carbon black levels.

5.5.8 Five Second Pressure Test (Pipe and Fittings)

Pipe - The manufacturer shall conduct a five-second pressure test at least once per production run at a pressure equal to four times the pressure class of the pipe. The Ring-Tensile Strength Test or the Quick Burst Test may be substituted for this test.

Fittings - The manufacturer shall conduct a five-second pressure test, at a pressure equal to four 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. Injection molded fittings shall be tested once per production run.

5.5.9 Melt-flow index Test (Pipe and Fittings)

Specimens taken from the pipe shall be tested in accordance with ASTM D1238, *Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer*, and AWWA C906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution*. This test shall be run at least once per day.

5.5.10 Density Test (Pipe and Fittings)

Specimens taken from the pipe shall be tested in accordance with ASTM D2839, *Standard Practice for Use of a Melt Index Strand for Determining Density of Polyethylene*, and AWWA C906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution.* This test shall be run at least once per day, or once per lot of pre-compounded PE material, whichever is more frequent.

APPENDIX A: UNITS OF MEASUREMENT

FLOW: gal/min - “gallons per minute”; (L/min - “liter per minute”)
L/min = gal/min x 3.7854

FORCE: lb - “pounds”; (N- “Newtons”)
N = lb x 4.4482

LENGTH: in. - “inches”; (mm - “millimeters”)
mm = in. x 25.4
ft - “feet”; (m - “meters”)
m = ft x 0.3048

MASS: lb - “pounds”; (kg - “kilograms”)
kg = lb x 0.454

PRESSURE: psi - “pounds per square inch”; (kPa - “kilopascals”)
kPa = psi x 6.895

TEMPERATURE: °F - “degrees Fahrenheit”; (°C - “degrees Celsius”)
°C = (°F - 32) x 0.556

TORQUE or MOMENT: lb·ft - “pound-feet”; (N·m - “newton-meter”)
N·m = lb·ft x 1.356

VACUUM: inHg - “inches of mercury”
psi - “pounds per square inch” (kPa - “kilopascals”)
psi = inHg × 0.4912; kPa = inHg × 3.3864

WORK: ft·lb - “foot-pounds”; (J - “joule”)
J = ft·lb x 1.356

APPENDIX B: APPROVAL MARKS

For use on nameplates, in literature, advertisements, packaging and other graphics.

1) The FM Approvals diamond mark is acceptable to FM Approvals as an Approval mark when used with the word "Approved."

2) The Approval mark has no minimum size requirement, but should always be large enough to be readily identifiable.

3) Color should be black on a light background or a reverse may be used on a dark background.

For Cast-On Marks

4) Where reproduction of the mark described above is impossible because of production restrictions, a modified version of the diamond is suggested. Minimum size specifications are the same as for printed marks. Use of the word "Approved" with this mark is optional.

NOTE: These Approval marks are to be used only in conjunction with products or services that have been FM Approved. The Approval marks should never be used in any manner (including advertising, sales or promotional purposes) that could suggest or imply Approval or endorsement of a specific manufacturer or distributor. Nor should It be implied that Approval extends to a product or service not covered by written agreement with FM Approvals. The Approval marks signify that products or services have met certain requirements as reported by FM Approvals.

Additional reproduction art is available through

FM Approvals
P.O. Box 9102,
Norwood, Massachusetts 02062
USA

APPENDIX C: SAMPLE CALCULATION

Shown below is a sample stiffness factor calculation for 10 inch IPS, Class 150, DR 11, AWWA C906, *Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution*, PE pressure pipe:

The average of three outside diameter (*OD*) measurements was found to be 10.755 inches.
The average of three wall thickness (*t*) measurements was found to 0.981 inches.
The average of three sample length (*l*) measurements was found to be 8.052 inches.
The sample inside diameter (*ID*) was calculated as follows:

$$ID = OD - 2(t) = 8.793 \text{ inches.}$$

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

$$Y_{max} = (0.05) \times ID = 0.440 \text{ inches.}$$

The sample was placed in a compression test apparatus and the force required to deflect the pipe 0.440 inches was found to be 1650 lbs.

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

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

Simplifying yields:

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

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

$$PS = \frac{F}{\Delta y} = \frac{1650}{\frac{8.052}{0.440}} = 466.1 \qquad \text{Eq. 6}$$

Substituting into Eq. 5 yields:

$$\Delta y = 0.00008876 \times (1.25W_e + W_l) \qquad \text{Eq. 7}$$

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

$$y = 0.00008876 \times [1.25(448) + 972]$$

$$y = 0.136 \text{ inches}$$

Percent Deflection = 0.136/8.793 *x* 100 = 1.6 percent

ACCEPTABLE

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

$$y = 0.00008876 \times [1.25(1{,}625) + 189]$$

$$y = 0.199 \text{ inches}$$

Percent Deflection = 0.199/8.793 *x* 100 = 2.3 percent

ACCEPTABLE

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

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

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

APPENDIX D: TOLERANCE

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 68 ± 9°F (20 ± 5°C).

APPENDIX E: SAMPLE LISTING

Polyethylene Pipe and Fittings

Polyethylene pipe should be installed and anchored according to the pipe manufacturer's instructions and FM Global Property Loss Prevention Data Sheets. For underground use only.

Nominal pipe size is the approximate outside diameter of the pipe. Refer to manufacturer's catalog for pipe inside diameter.

Product Designation	*O.D., Pipe Size, in.*	*Pressure Rating, bar (psi)*	*Remarks*
Pipe, Class 150	4, 6, 8, 10, 12, 14, 16 and 18	150 (1035)	a
Pipe, Class 200	4, 6, 8, 10, 12, 14, 16 and 18	200 (1380)	a
Class 150 Tees Molded IPS	2, 3, 4, 6	150 (1035)	a
Class 200, 90° Elbows Molded IPS	2, 3, 4, 6	200 (1380)	a
Class 200 Flange Adapter, Molded IPS	2, 3, 4, 6, 8, 10, 12, 14, 16, 18	200 (1380)	a
Class 150 Concentric Molded Reducer	3×2, 4×3, 6×4, 8×6, 10×8, 12×10, 14×12, 16×14, 18×16	150 (1035)	a
Class 150 Branch Saddle Reducing Tee	3×2, 4×2, 4×3, 6×2, 6×3, 6×4, 8×2, 8×3, 8×4, 8×6, 10×2, 10×3, 10×4, 10×6, 10×8, 12×2, 12×3, 12×4, 12×6, 12×8, 12×10, 14×2, 14×3, 14×4, 14×6, 14×8, 14×10, 16×2, 16×3, 16×4, 16×6, 16×8, 16×10, 16×12, 18×2, 18×3, 18×4, 18×6, 18×8, 18×10, 18×12	150 (1035)	a

a. Pipe and fittings may be directly connected together by the butt fusion process. Manufacturer fusion instructions must be strictly followed for a proper fusion joint. The pipe and fittings may also be joined to other FM Approved steel flanged pipe and fittings by using the listed flange adapters.

APPENDIX F: FIGURES

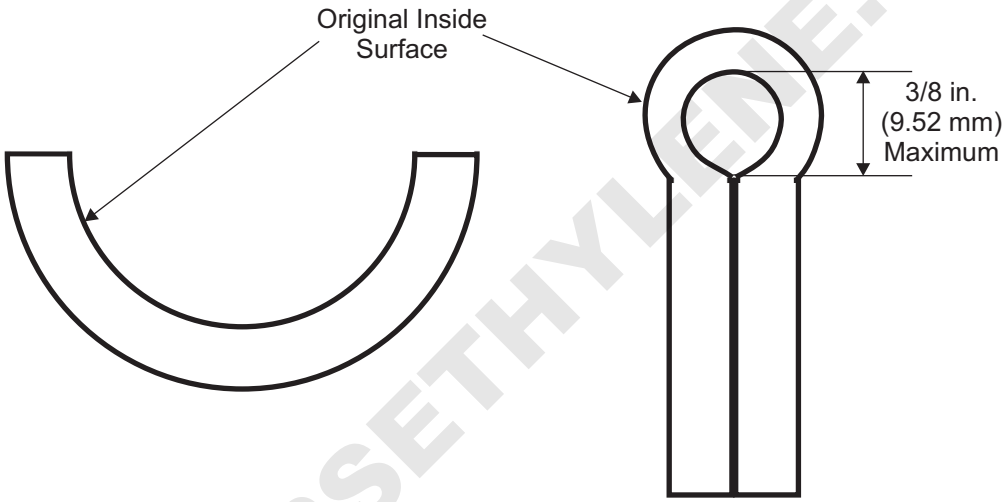

Figure F-1. Bend Back Test

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