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October 25, 2007

Mr. Eric M. Focht
Project Monitor
U.S. Nuclear Regulatory Commission - Research
11545 Rockville Pike
Rockville, MD 20852-2738

Sent via E-mail: emf1@nrc.gov

Subject: Letter Report on Task 2 on Contract Number DR-04-07-072
[Emc^2 Project Number 06-G44-02**]**

Dear Eric,

As required by the contract, attached is an updated revised DRAFT letter report for your review that constitutes our second deliverable on the above project on Task 2 – Evaluate the Acceptability of Existing Applicable Standards.

Please let me know if this is acceptable and we will submit a final copy.

Sincerely,

Kswamy

Dr. Prabhat Krishnaswamy
Vice-President.

cc: Mr. Joel D. Page, NRC-RES, jdp2@nrc.gov

Summary Report

on

Task 2 – Evaluate the Acceptability of Existing Applicable Standards

Objective:
The objective of this task is to evaluate existing standards on polyethylene (PE) piping with regard to their applicability to design, inspection, manufacturing, performance history, assembly, and material specifications in nuclear and/or non-nuclear safety-related applications.

Results:
There are four major standards organizations that develop standards and specifications that are relevant to PE piping:

- ASTM International (formerly American Society of Testing and Materials),
- American Society of Mechanical Engineers (ASME),
- International Standards Organization (ISO), and
- The Plastic Pipe Institute (PPI).

The first three organizations above are internationally recognized voluntary consensus standards bodies while the last is a trade association for the plastic pipe industry. PPI (www.plasticpipe.org) is responsible for determining the hydrostatic design basis for various plastic pipes (including various grades of PE resins) and also publishes handbooks and recommended best practices for the industry. These practices are adopted universally by the industry in North America in natural gas, sewer, water and other PE piping installations.

Specific to water piping the American Water Works Association (AWWA) has developed minimum requirement for PE water piping. And, specific to the natural gas distribution industry, additional standards and codes specifically have also been developed by the following:

- The US Department of Transportation (DOT),
- The American Gas Association (AGA),
- The American Petroleum Institute (API), and
- The Canadian Standards Association (CSA).

A list of relevant standards from the above organizations is provided in Attachment A. After a preliminary review of all the standards listed in Attachment A, it was decided that only those standards that are directly relevant to either non-safety or safety-related *nuclear* service water applications would be reviewed in detail. This is because the number of standards for PE piping are numerous and a detailed review of each of these would expand the scope of the effort relative to the objective of this task and would be unnecessary.

Of the standards listed in Attachment A, those that are critical to nuclear piping are reviewed below in two categories – Safety Related and Non-Safety Related with greater emphasis placed on the former.

<u>Standards Relevant to Class 3 Safety-Related Nuclear Piping Applications</u>

The ASME BVPC Section III has created a Special Working Group on Plastic Piping (SWG-PP) to develop Code Case(s) for HDPE Piping for Class 3 Service Water Piping. The SWG-PP has recently passed Code Case N-755 in January 2007 for safety-related PE piping. The US NRC voted negative on the ballot due to insufficient data to substantiate the criteria proposed in the CC. Attachment B provides a copy of the final document that will be published by ASME.

<u>*[NOTE: The standards provided in Attachments to this report were obtained by Emc^2 for use by the USNRC and contain copyrighted materials that may not be reproduced without permission of the organization responsible for its publication.]*</u>

Unlike other code cases from ASME, this is very comprehensive and attempts to address all technical issues relevant to the use of Polyethylene (PE) piping in safety-related applications. The overall goal of CC N-755 is to provide requirements for the design, procurement, fabrication, installation, examination and testing of PE material. This Section III Code Case covers <u>*ONLY*</u> the following:

- <u>*Buried*</u> straight PE pipe,
- Three-joint and five-joint mitered elbows (from PE pipe),
- Flanged Connections, and
- Butt fusion joints in PE piping.

Key issues addressed in CC N-755 relative to standards are summarized below by each Section of the code case:

<u>*- 1000 General Requirements:*</u> This section of the code case specifically restricts all PE piping in safety-related applications to an internal pressure not exceeding 150 psi and a maximum operating temperature that does not exceed 140 F.

This Section provides requirements for the Qualification of Suppliers of PE piping including surveying and auditing for the pipe manufacturer and resin supplier. The primary standard used for evaluating the quality system program in the supply chain is *ASTM D3350 - Standard Specification for Polyethylene Plastics Pipe and Fittings Materials*. The latest version of this standard is provided in Attachment C.

The rest of this section describes the procedures for product quality certification (PQC) for the procurement chain of PE piping that has to adhere to the *ASME-BVP Section III Subsection NCA – General Requirements for Division 1 and Division 2 (Piping) in Rules of Construction of Nuclear Power Plant Components*.

<u>*- 2000 Materials:*</u> The major requirements of this section are the following:

- Only PE materials with a cell classification of 445474C (or higher) per ASTM 3350-05 (or PE 4710 material per the Plastic Pipe Institute designation) are permitted to be used for Class 3 piping. The interpretation of the above cell classification is shown in Table 1 below.

Table 1 Interpretation of HDPE Cell Classification 445474C In Proposed Code Case N-755

Cell No.	Description
4	Density Range 0.948 to 0.955 gm/cc (59.182 to 59.618 lbs/ft^3) per ASTM D1505
4	Melt index of < 0.15 gm/10 min (0.00529 oz/10 min) per ASTM D1238
5	Flexural Modulus between 110 and 160 ksi (0.758 to 1.103 MPa) per ASTM D790
4	Tensile Strength between 3500 to 4000 psi (24.1 to 27.6 MPa) per ASTM D638
7	PENT Test Failure Time of > 500 hours per ASTM D 1473
4	Hydrostatic Design Basis of 1600 psi (11.03 MPa) per ASTM D2837
C	Black with 2% minimum carbon black

- All PE piping must meet the ASTM specifications below as appropriate
  - ASTM D-3035-03, Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
  - ASTM D-3261-03, Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing
  - ASTM D-3350-05, Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
  - ASTM F-714-03, Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter
  - ASTM F-1055- 98, Standard Specification for Electro fusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing
  - ASTM F-2206-02, Standard Specification for Fabricated Fittings of Butt-Fused Polyethylene (PE) Plastic Pipe, Fittings, Sheet Stock, Plate Stock, or Block Stock

  Each of the above ASTM specifications is comprehensive and contain within numerous other test methods and requirements. For completeness a copy of these standards in their entirety is provided in Attachment C.
- All external surfaces require visual examination prior to installation and any indentation more than 10% of the minimum wall thickness, regardless of wall thickness is unacceptable. *Further description of the allowable flaws/ defects including length and notch acuity (sharpness) is NOT provided for flaws up to 10% of the wall*,
- All transition flanges must have pressure rating equal to or higher than that for the piping,
- No repair allowed on piping from PE materials including mitered elbows that are damaged.

- 3000 Design: This is the most detailed part of the code case and describes the design rules for buried PE piping constructed of straight pipe, three and five-joint mitered elbows, fusion joints, and flanged connections. Without repeating what is in the Code Case (see Attachment B), the major issues addressed in the design rules include the following:

- Service Life: The maximum service life for PE piping is 50 years.
- Pressure Design: Pressure design of pipe based on a required minimum wall thickness and an allowable stress Table. Table 2 below (Table 3021-1 in CC N-755) provides these allowable stress values for various load durations and operating temperatures. *A key observation in the Table below is that the allowable stress is reduced from 840 psi to 430 psi for a 10 year life as the operating temperature is raised from 70 to 140 F*. *This fact coupled with an allowable flaw (of any length and notch acuity for all diameters and wall thickness) that is 10% of the wall or less as described above requires verification with experimental data*.

Table 2 – Allowable Stress S for PE (psi)

Temperature (^{o}F)	Load Duration (years)				
	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
$\leq$70	840	840	820	820	800
104	620	620	620	620	620
120	520	*	*	*	*
140	430	*	*	*	*

* - Values under Development

As a result of this issue the allowable stress values at 120 and 140 F for load duration exceeding 10 years (which were included in earlier versions of the code case) have yet to be defined in the above Table.

- Pressure Transients: The allowable stress levels due to pressure transients (spikes) cannot exceed 1.5 times the design pressure for Level B and 2 times the design pressure for Level C and D.
- Joints and Connections: PE piping may be connected using only butt joints and all connections to metallic piping must be flanged joints. The pressure rating of all fittings shall be equal to or greater than the attached straight pipe.
- Ring Deflection: The procedure to determine the maximum allowable ring deflection of pipe due to soil and surcharge loads is described including the value of elastic modulus to be used in the calculations. These modulus values are shown below in Table 3 (Table 3031-3 in the code case)

Table 3 Modulus of Elasticity of PE Pipe (ksi)

Load Duration	Temperature (^{o}F)			
	$\leq$73 ^{o}F	100 ^{o}F	120 ^{o}F	140 ^{o}F
< 10 h	110	100	65	50
10 h	58	47	31	24
100 h	51	42	27	21
1000 h	44	36	23	18
1 y	38	31	20	16
10 y	32	26	17	13
50 y	28	23	15	12

Two key observations to note in the above table are that the modulus decreases significantly with both time and temperature as is well established for viscoelastic materials such as PE. The value of short term modulus (< 10 hours) is reduced by 55% when the temperature is increased from 73 to 140 F, while the effect of load duration (creep over 50 years) reduces the modulus by 75% at 73 F. *At 140 F and for a 50 year life the effective modulus is 12 ksi which is only 11% of the short term modulus at 73 F! For continuously supported buried piping this may not be of concern, but for above ground piping the reduction in modulus needs to be addressed in designing supports*.

- Compression, Buckling: The design rules in the code case also include a limit on the compressive stresses in the sidewalls to 1000 psi. Calculation procedures for insuring failure against buckling of pipe due to external pressure and collapse due to negative internal pressure are also provided. Anchor requirements to resist buoyancy forces are prescribed in the code case.
- Longitudinal Stresses: Longitudinal stresses in PE piping due to internal pressure, applied axial forces and bending moments are restricted to the allowable stress values S (Table 2 above) for PE multiplied by a Design and Service Level Stress Factor k (greater than or equal to 1). *The basis for the stress factor 'k' as well as that for the stress indices used in the calculations need to be verified*. For short term loads (< 5 minutes) the allowable stress S value are higher than those in Table 2 and may equal 40% of the material tensile yield strength as determined using ASTM D638.
- Temperature Design: Since the effect of temperature on the mechanical properties of polymer such as PE is very significant, the following proposed design rules must be reviewed in critical detail:
    - The minimum operating temperature for PE is -50 F or the manufacturer's specification, whichever is higher. At these temperatures the failure mode of rapid crack propagation (brittle catastrophic failure) which is a design limit for PE gas piping is not an issue for PE materials.
    - For fully constrained conditions the net longitudinal tensile stress due to thermal expansion or contraction (due to differences between water and ground temperatures) is restricted to the allowable stress S in Table 2. An alternative procedure based on soil stiffness characteristics may be used to account for thermal expansion/contraction stresses which are limited to 1100 psi.
    - For any single non-repeated anchor movement, the total stress due to axial forces and moments is restricted to 2S.
- Seismic Design: Seismic stresses due to wave passage, soil movement and anchor motion effects resulting in an axial load and bending moment are restricted to 1100 psi. *The basis for selecting 1100 psi limit as well as the stress intensification factor needs to be verified*. Supplement 3 of CC N-755 provides a procedure for calculating seismic stresses and also an alternative strain based limit for seismic design of PE piping (Table A-1 Seismic Strain Limits in the code case).

- 4000 Fabrication and Installation: This section of the code case describes the requirements for installation of PE piping and fittings. The key technical issues covered include the following:

- Only butt fusion joining and flanged fittings are permitted in any installation; adhesive and threaded joints are not permitted.
- No repair of PE materials that have indentation exceeding 10% of the wall is permitted.
- The minimum bending radius of PE piping during installation is 30 times the diameter for DR 9 through DR 13.5. The basis for this bending radius needs to be reviewed and verified.
- Very detailed requirements are provided with regard to qualifying butt fusion joints (the only type of joining allowed for PE piping per CC N-755 is provided in Supplement 9 of Attachment B.
- Geometric dicontinuities at the fusion are addressed such that
    - Components of different OD's may not be fused together,
    - A maximum surface mismatch of 10% of the minimum wall thickness is permitted. The basis of the 10% value needs to be verified especially for large diameter (> 12 inches), and
    - Requirements for counterboring of the thicker pipe (smaller DR value) when two pipes of different thicknesses are fused
- Repair of fused joints is not permitted; they need to be cut out and replaced
- No permanent strain may be introduced during joint assembly; given that the material is viscoelastic, the definition of permanent strain needs to be clarified.
- For joining PE and metallic piping, only flanged connections are allowed.
- For support of piping point loads and loading over narrow areas must be avoided.

As stated above Supplements 9 of CC N-755 (Attachment B) provides detailed requirements for the butt fusion process including

- Fusion General Requirements including
    - Proper bead configuration during fusing without evidence of cracks or incomplete fusion
    - Joints cannot be visually mitered (angled or offset) with a limitation on ovality of 10% of the minimum wall thickness. This value of 10% of minimum wall needs to be validated particularly for larger diameter piping
    - Use of a mandatory automated computer data logger during fusion that records all the essential variable during fusion including
        - Heater Surface temperature
        - Interfacial Pressure
        - Gauge Pressure during the heat cycle
        - Gauge Pressure during the fusion/cool cycle
        - Time during the heat cycle
        - Time during the fusion/cool cycle
        - Heater removal time.
    - For Testing of fusion joints there are three methods specified including
        - High Speed Tensile Test of a full-thickness specimen machined from four locations 90-degrees apart along a butt fusion in the

axial orientation and is tested at 6 in/sec for thicknesses 1.25 inches or less and at 4 in/sec for thicknesses greater than 1.25 inches. The test is conducted at 73 F. A joint passes if the failure in the tensile test occurs outside the fusion region.

- Sustained Pressure Test of 8” DR11 piping per ASTM D-3035-03a (see Attachment B) where the minimum time to failure is met at the elevated temperature (80 C).
- Free Bend (or Bend back) tests: This test involves machining two rectangular straps across the butt joint 180-degres apart and then bending the straps backwards in both directions (so that in one case the inside pipe surfaces is in tension while in the other the outside surface is in tension) so that the ends of the straps touch one another. The joint is deemed to pass if no cracks or fracture appear in the joint region during this test.

- Fusion Procedure Qualification is specified per the plastic pipe industry document PPI TR-33/2001 (which has been included in Attachment 4). For procedures that deviate from this document a qualification process has been defined using the essential variables in fusion.
- A detailed appendix Article III in CC N-755 provides the requirements for Fusion Machine Operator performance qualification and training.

- 5000 Examination: One of the key points to note regarding the fusion procedure is that all examination and inspection requirement is visual. *No volumetric examination of butt joints is deemed necessary primarily because the industry research has indicated that no NDE method has the required level of reliability.*

- 6000 Testing: The requirements for hydrostatic testing of the installed system is as follows - The pressure in the test section shall be gradually (minimum rate of 5 psig/min not to exceed a maximum rate of 20 psig/min) increased to the specified test pressure (which is 1.5 times the design pressure plus 10 psi) and held for 4 hours. Make up water may be added to maintain test pressure during this time to allow for initial expansion. Following the 4 hour initial pressurization period, the test pressure shall be reduced by 10 psig and the system monitored for another 1 hour. Make up water may no longer be added to maintain pressure. Each joint shall be examined. If no visual leakage is observed and the pressure remains within 5% of the test pressure for the 1 hour, the pipe section under test is considered acceptable.

In addition to CC N-755 and its requirements the following standards are also of critical interest in evaluating PE piping for Class 3 safety-related applications –

1. ASTM F1473-07 Standard Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins. This test method provides a laboratory coupon type method to evaluate the slow crack growth resistance of PE piping and resins under accelerated tests conditions.
2. F1474-98 Standard Test Method for Slow Crack Growth Resistance of Notched Polyethylene Plastic Pipe. This test method has been withdraw by ASTM, but the

ISO version of this method is still available and describes accelerated testing of notched PE piping to evaluate slow crack growth resistance and thereby predict service life.

3. ASTM D2657-07 Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings. This standard provides an ASTM adoption of the PPI Technical Report on the procedure for butt fusion of PE piping.

A copy of each of the above standards is also provided in Attachment C.

Standards Relevant to Non-Safety-Related Nuclear Piping Applications

PE piping has been used in non-safety related nuclear power plant applications for over 10 years by Duke Energy at its Catawba, SC plant. These piping systems were designed, manufactured, installed, and tested prior to the developments of the requirements in CC N-755 (Attachment B). The systems operated by Duke Energy, though not-safety critical, are nevertheless absolutely essential for the successful operation of the power plant. The standards used to design non-safety piping meet the requirements of ASME B31.1 Power Piping.

The key issues addressed in ASME B31.1 for the use of plastic piping in water applications are as follows:

- The maximum operating temperature for all plastic piping is 140 F.
- The maximum operating pressure is 150 psi.
- There is a non-mandatory Appendix III to B31.1 that provides the "Rules for Non-Metallic Piping" for water service only and includes the following for PE piping
    - The design of piping systems must include at least the following
        - Short term and long term tensile, compressive, flexural and shear strength and modulus at the design temperature
        - Creep characteristics under service conditions
        - Design stress and its basis
        - Coefficient of thermal expansion
        - Ductility and plasticity
        - Impact and thermal shock properties
        - Temperature limits for service
        - Transition temperatures for materials
        - Toxicity of material, porosity and permeability
        - Methods of making joints
        - Deterioration in service environments, and
        - Effect of UV/solar radiation on properties
    - The Hydrostatic Design Stress (HDS) and recommended temperature limit for PE Piping is provided in the Table below

Material		Temperature Limits			Hydrostatic Design Stress		
		Minimum	Maximum		73 F	100 F	180 F
		deg F	deg F		psi	psi	psi
PE 2306		-30	140		630	400	
PE 3306		-30	140		630	500	
PE 3406		-30	140		630	500	250
PE 3408		-30	140		800		

- The coefficient of thermal expansion for PE to be used for piping design is specified as 90.0 x 10^{-6} in/in/F for a temperature range of 70 to 120 F.
- The modulus of elasticity to be used for design is 130 ksi at 73.4 F.

- *The most severe conditions of coincident pressure (stress) and temperature must be used to determine the design conditions*.
- Piping support for above ground applications are to follow manufacturer's recommendations.

Attachment A

List of Relevant Standards for Polyethylene Pipe

ASTM Standards

1. D1598-02 Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure.
2. D1599-99e1 Standard Test Method for Resistance to Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings.
3. D2104-03 Standard Specification for Polyethylene (PE) Plastic Pipe.
4. D2122-98e1 Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings.
5. D2239-03 Standard Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter.
6. D2321-00 Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications.
7. D2412-02 Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.
8. D2444-99 Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight).
9. D2447-03 Standard Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter.
10. D2513-03b Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings.
11. D2657-03 Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings.
12. D2683-98 Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing.
13. D2749-02 Standard Symbols for Dimensions of Plastic Pipe Fittings. – as stated in the title, this standard provides accepted symbols used in the industry to represent pipe fitting dimensions.
14. D2774-01 Standard Practice for Underground Installation of Thermoplastic Pressure Piping.
15. D2837-02 Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials.
16. D3035-03 Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter.
17. D3261-03 Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing.
18. F412-01ae1 Standard Terminology Relating to Plastic Piping Systems.
19. F645-02 Standard Guide for Selection, Design, and Installation of Thermoplastic Water-Pressure Piping Systems.
20. F714-03 Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter.
21. F725-03e1 Standard Practice for Drafting Impact Test Requirements In Thermoplastic Pipe And Fittings Standards,

22. F948-94(2001)e1 Standard Test Method for Time-to-Failure of Plastic Piping Systems and Components Under Constant Internal Pressure With Flow.
23. F1055-98e1 Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing.
24. F1248-96(2002)e1 Standard Test Method for Determination of Environmental Stress Crack Resistance (ESCR) of Polyethylene Pipe.
25. F1290-98a Standard Practice for Electrofusion Joining Polyolefin Pipe and Fittings.
26. F1473-01e1 Standard Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins.
27. F1588-96(2002) Standard Test Method for Constant Tensile Load Joint Test (CTLJT).
28. F1668-96(2002) Standard Guide for Construction Procedures for Buried Plastic Pipe.
29. F1804-03 Standard Practice for Determining Allowable Tensile Load for Polyethylene (PE) Gas Pipe During Pull-In Installation.
30. F1924-01e1 Standard Specification for Plastic Mechanical Fittings for Use on Outside Diameter Controlled Polyethylene Gas Distribution Pipe and Tubing.
31. F1948-99ae1 Standard Specification for Metallic Mechanical Fittings for Use on Outside Diameter Controlled Thermoplastic Gas Distribution Pipe and Tubing.
32. F1962-99 Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings.
33. F2018-00e1 Standard Test Method for Time-to-Failure of Plastics Using Plane Strain Tensile Specimens.
34. F2136-01e1 Standard Test Method for Notched, Constant Ligament-Stress (NCLS) Test to Determine Slow-Crack-Growth Resistance of HDPE Resins or HDPE Corrugated Pipe.
35. F2160-01 Standard Specification for Solid Wall High Density Polyethylene (HDPE) Conduit Based on Controlled Outside Diameter (OD).
36. F2164-02 Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Hydrostatic Pressure.
37. F2176-02 Standard Specification for Mechanical Couplings Used on Polyethylene Conduit, Duct and Innerduct.
38. F2206-02 Standard Specification for Fabricated Fittings of Butt-Fused Polyethylene (PE) Plastic Pipe, Fittings, Sheet Stock, Plate Stock, or Block Stock.
39. F2231-02e1 Standard Test Method for Charpy Impact Test on Thin Specimens of Polyethylene Used in Pressurized Pipes.

ISO Standards

40. ISO - 9080 Thermoplastics pipes and fittings for the transport of fluid – Methods of extrapolation of hydrostatic stress rupture data to determine the long-term hydrostatic strength of thermoplastics pipe materials.
41. ISO - 4427 Polyethylene (PE) pipes for water supply.
42. 4437 Buried polyethylene (PE) pipes for the supply of gaseous fuels – Metric series – Specifications.

43. ISO - 12162 Thermoplastics materials for pipes and fittings for pressure applications – Classification and designation – Overall service (design) coefficient.
44. ISO 13477:1997 Ed. 1, Thermoplastics pipes for the conveyance of fluids -- Determination of resistance to rapid crack propagation (RCP) -- Small-scale steady-state test (S4 test).
45. ISO 13478:1997 Ed. 1, Thermoplastics pipes for the conveyance of fluids -- Determination of resistance to rapid crack propagation (RCP) -- Full-scale test (FST).

[*Note: There are numerous other ISO Standards that are "equivalent" to the ASTM standards listed above and are referenced in the relevant ASTM documents*].

ASME Standards

46. ASME Code for Pressure Piping, B31.1 Power Piping.
47. ASME Code for Pressure Piping, B31.8 Process Piping.

Plastic Pipe Institute
Technical Reports (TR) & Technical Notes (TN)

48. TR-3 Policies and Procedures for Developing Hydrostatic Design Bases (HDB), Pressure Design Bases (PDB), Strength Design Bases (SDB), and Minimum Required Strengths (MRS) Ratings for Thermoplastic Piping Materials for Pipe.
49. TR-4 PPI Listing of Hydrostatic Design Bases (HDB), Strength Design Bases (SDB), Pressure Design Bases (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe.
50. TR-7 Recommended Methods for Calculation of Nominal Weight of Solid Wall Plastic Pipe.
51. TR-9 Recommended Design Factors for Pressure Applications of Thermoplastic Pipe Materials.
52. TR-11 Resistance of Thermoplastic Piping Materials to Micro- and Macro Biological Attack.
53. TR-14 Water Flow Characteristics of Thermoplastic Pipe.
54. TR-18 Weatherability of Thermoplastic Piping Systems.
55. TR-19 Thermoplastic Piping for the Transport of Chemicals.
56. TR-21 Thermal Expansion and Contraction in Plastics Piping Systems.
57. TR-30 Investigation of Maximum Temperatures Attained by Plastic Fuel Gas Pipe Inside Service Risers.
58. TR-33 Generic Butt Fusion Joining Procedure for Polyethylene Gas Pipe.
59. TN-5 Equipment used in the Testing of Plastic Piping Components and Materials.
60. TN-7 Nature of Hydrostatic Stress Rupture Curves.
61. TN-11 Suggested Temperature Limits for the Operation and Installation of Thermoplastic Piping in Non-Pressure Applications.
62. TN-13 General Guidelines for Butt, Saddle and Socket Fusion of Unlike Polyethylene Pipes and Fittings.
63. TN-14 Plastic Pipe in Solar Heating Systems.

64. TN-161 Rate Process Method for Projecting Performance of Polyethylene Piping Components.
65. TN-18 Long-Term Strength (LTHS) by Temperature Interpolation.
66. TN-19 Pipe Stiffness for Buried Gravity Flow Pipes.
67. TN-20 Special Precautions for Fusing Saddle Fittings to Live PE Fuel Gas Mains Pressurized on the Basis of a 0.40 Design Factor.
68. TN-21 PPI PENT test investigation.
69. TN-23 Guidelines for Establishing the Pressure Rating for Multilayer and Coextruded Plastic Pipes.

Standards by Other Organizations for Safety-Related Gas Piping

70. US Federal Government Regulation, Title 49, CFR part 172, Transportation of Natural Gas and Other Gas by Pipe Line.
71. AWWA C906 Polyethylene (PE) Pressure Pipe and Fittings, 4 inch through 63 inches, for Water Distribution.
72. American Gas Association, AGA Plastic Pipe Manual for Service.
73. American Petroleum Institute (API), API Spec 15LE Specification for Polyethylene Line Pipe.
74. Canadian Standards Association (CSA), B137.4 Polyethylene Piping Systems for Gas Services.