ASME NM.1-20XX

Thermoplastic Piping Systems

ASME Standard for Nonmetallic Pressure Piping Systems

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CHAPTER 1

~~Introduction~~

Scope and Definitions

1-1 SCOPE

(a) This standard prescribes requirements for the design, materials, fabrication, erection, examination, testing, and inspection of thermoplastic piping systems.

(b) Thermoplastic piping as used in this standard includes pipe, flanges, bolting, gaskets, valves, fittings, special connecting components, and the pressure containing portions of other piping components, whether manufactured in accordance with Standards referenced in this standard or specially designed. It also includes hangers and supports and other equipment items necessary to prevent overstressing the pressure containing components.

1-2 GENERAL

(a) *Identification.* This Standard covers thermoplastic pressure piping systems.

(b) *Responsibilities*

(1) *Owner.* The owner of a thermoplastic piping system installation shall have overall responsibility for compliance with this Standard, and for establishing the requirements for design, construction, examination, inspection, and testing that will govern the entire fluid-handling or process installation of which the thermoplastic piping system is a part. The owner shall also be responsible for designating the fluid service.

(2) *Designer.* The designer shall be responsible to the owner for assurance that the engineering design of the thermoplastic piping system complies with the requirements of this Standard and with any additional requirements established by the owner.

(3) *Manufacturer, Fabricator, and Erector.* The manufacturer, fabricator, and erector of thermoplastic piping systems shall be responsible for providing materials, components, and workmanship in compliance with the requirements of this Standard and of the engineering design.

(4) *Owner's Inspector.* The owner's Inspector (see section 6-1) shall be responsible to the owner for ensuring that the requirements of this Standard for inspection, examination, and testing are met and with any additional requirements established by the owner.

(c) *Intent of the Standard*

(1) It is the intent of this Standard to set forth the requirements deemed necessary for safe construction of thermoplastic piping system installations. (Construction includes design, materials, fabrication, erection, inspection, examination, and testing.)

(2) This Standard is not intended to apply to the operation, examination, inspection, testing, maintenance, or repair of a thermoplastic piping system that has already been placed in service. The provisions of this Standard may be applied for those purposes, although other considerations may also apply.

(3) Engineering requirements of this Standard, while considered necessary and adequate for safe design, generally employ a simplified approach to the subject.

(-a) A designer capable of applying a more rigorous analysis than that included in this Standard shall have the latitude to do so; however, the approach shall be documented in the engineering design and its validity accepted by the owner.

(-b) The approach used shall provide details of design, construction, examination, inspection, and testing for the design conditions of section 2-1, with calculations consistent with the design criteria of this Standard.

(4) Thermoplastic piping systems shall conform to the specifications and standards listed in Table 4-2-1. Thermoplastic piping components neither specifically approved nor specifically prohibited by this Standard may be used provided they are qualified for use as set forth in applicable Chapters of this Standard.

(5) Where a thermoplastic piping system installation necessitates measures beyond those required by this Standard, such measures shall be specified in the engineering design and shall be implemented.

(6) Compatibility of materials with the intended fluid service and hazards inherent to the instability of contained fluids are not within the scope of this Standard.

(d) *General Requirements*

(1) The design and construction of a thermoplastic piping system shall take into consideration the limitations and conditions specific to the intended fluid service (e.g., temperature limits, necessary safeguarding), as these factors affect the selection and application of materials, components, and joints.

(2) A thermoplastic piping system shall meet the most restrictive requirements of each of its components.

(e) *Fluid Service*

(1) The fluid service requirements considered in the development of this Standard include those for nontoxic ~~fluids~~liquids (including slurries) and gases, and flammable or combustible liquids and gases, except as specified in Chapter 7.

(-a) The service temperatures and pressures for such applications are limited by the material properties and design of the specific ~~pipe material~~piping components selected for the given application.

(-b) When designing thermoplastic piping systems, the designer shall consider the degradation of material properties due to interaction with the process fluids. However, specific guidelines and requirements for, or limitations due to, interactions between the fluid and the pipe material are beyond the scope of this Standard.

(2) Except as specified in ~~Chapters~~Chapter 7~~ and 8~~, this Standard does not address the requirements for thermoplastic piping systems in Category M fluid service. The design, material, fabrication, examination, and testing requirements of such service are beyond those currently defined in this Standard.

1-2.1 Content and Coverage

(a) This Standard covers thermoplastic piping systems operating under pressure. ~~The temperatures limits for each thermoplastic material shall contain a maximum continuous-operating temperature and pressure and a maximum short-term operating temperature and pressure for a given time.~~

(b) Thermoplastic piping used in some applications may require special quality requirements and certification.

(c) This Standard covers thermoplastic piping that interconnects pieces or stages within a packaged equipment assembly.

(d) Exclusions. This Standard excludes the following:

(1) thermoplastic piping systems that meet all of the following:

(-a) The system has internal gauge pressures at or above zero but less than 0.105 ~~kPag~~MPag (15 psig).

(-b) The system handles fluid that is nonflammable, nontoxic, and not damaging to human tissues as defined in Section 1-3.

(-c) The system's design temperature ranges from −29°C (−20°F) through 100°C (212°F).

(2) power boilers in accordance with ASME Boiler and Pressure Vessel Code (BPVC), Section I, and boiler external piping that is required to conform to ASME B31.1.

~~(3) tubes, tube headers, crossovers, and manifolds of fired heaters that are internal to the heater enclosure.~~

~~(4~~ (3) pressure vessels, heat exchangers, pumps, compressors, and other fluid-handling or processing equipment, including internal piping and connections for external piping.

1-3 DEFINITIONS

Some of the common terms relating to thermoplastic piping are defined below. For terms related to thermoplastics but not defined here, definitions are in accordance with ASTM F412 and abbreviations are in accordance with ASTM D1600.

adhesive joint: a bonded joint made using an adhesive on the surfaces to be joined.

anchor: a rigid restraint providing substantially full fixation, permitting neither translation nor rotational displacement of the pipe.

assembly: the joining together of two or more piping components by bolting, solvent-cement welding, fusing, screwing, brazing, soldering, or cementing, or by use of adhesive or packing devices, as specified by the engineering design.

backup ring: a metallic or nonmetallic ring with bolt holes sized and located per the applicable flange standard. When the backup ring is used with a thermoplastic flange adapter, threaded fasteners are used to join and compress the two flange adapters (often used with a gasket) to create a leak-free connection.

base material: the material to be welded or otherwise fused.

bladder: a saclike device used in the flow-fusion or electrofusion welding process that, when pressurized, makes contact with the inner walls of the weld zone prior to the commencement of the weld process to ensure a bead-free weld zone on the inner diameter of the pipe.

bolt design stress: see *stress*.

bulk flow velocity: the instantaneous average speed of fluid through a pipe or fitting at a given point. It is stated disregarding laminar and turbulent flow effects that create different velocity zones within the cross section.

butt fusion: a type of joining of thermoplastic pipe, sheet, or other similar forms by heating the ends to be joined to a molten state and then rapidly pressing them together to form a homogeneous bond.

butt joint: a joint between two members aligned approximately in the same plane.

Category D: see *fluid service*.

engineering design: the detailed design governing a piping system, developed from process and mechanical requirements, conforming to the requirements of this Standard, and including all necessary specifications, drawings, and supporting documents.

erection: the complete installation of a piping system in the locations and on the supports designated by the engineering design and including any field assembly, fabrication, examination, inspection, and testing of the system as required by this Standard.

examination: quality control or nondestructive testing performed by the manufacturer, fabricator, or erector to verify conformance with requirements and specifications. Examples of examination are:

100% examination: complete examination of all of a specified kind of item in a designated lot of piping.

random examination: complete examination of a percentage of a specified kind of item in a designated lot of piping.

spot examination: a specified partial examination of each of a specified kind of item in a designated lot of piping.

examiner: a person who performs an examination.

expansion joint: a flexible piping component or assembly that absorbs seismic, thermal, and/or terminal movement.

fabrication: the preparation of piping for assembly, including cutting, threading, grooving, forming, bending, and joining of components into subassemblies. Fabrication can be performed in the shop or in the field.

fillet weld: a weld of approximately triangular cross section joining two surfaces approximately at right angles to each other in a lap joint, tee joint, or corner joint.

flammable: for the purposes of this Standard, a term used to describe a fluid that under ambient or expected operating conditions is a vapor or produces vapors that can be ignited and will continue to burn in air. The term thus can apply, depending on service conditions, to fluids defined for other purposes as flammable or combustible.

flange adapter: a thermoplastic component designed to attach to a thermoplastic pipe by solvent-cement welding or heat fusing. The component has a plain end or socket end on one side and a retaining lip on the other. It is used with a backup ring to make a thermoplastic lap-joint flange connection.

flared plastic face: sealing surface formed on a pipe spool or fitting by plastic deformation of the liner. Sometimes used synonymously with “flare.”

flaw: an imperfection or unintentional discontinuity that is detectable by a nondestructive examination.

flow-fusion welding (FFW): a thermoplastic welding process for sheets or pipe where the melt is constrained during the welding process.

fluid service: a general term concerning the application of a piping system, considering the combination of fluid properties, operating conditions, and other factors that establish the basis for design of the piping system.

Category D fluid service: a fluid service in which all of the following apply:

(a) The fluid handled is nonflammable, nontoxic, and not damaging to human tissues as defined in Section 1-3.

(b) The design gage pressure does not exceed 1035 kPa (150 psi).

(c) The design temperature ranges from −29°C (−20°F) through 186°C (366°F).

Category M fluid service: a fluid service in which both of the ~~potential for personnel exposure~~following apply:

(a) the fluid is ~~judged to be significant and in which~~so highly toxic that a single exposure to a very small quantity of ~~a toxic~~the fluid, caused by leakage, can produce serious irreversible harm to persons on breathing or bodily contact, even when prompt restorative measures are taken~~.~~

(b) after consideration of piping design, experience, service conditions, and location, the owner determines that the requirements for Normal Fluid Service do not sufficiently provide the leak tightness required to protect personnel from exposure

Normal fluid service: a fluid service not subject to the requirements for Category D or Category M fluid service.

fusing: a permanent bond between thermoplastic piping components formed by heating the parts sufficiently to permit the commingling of the materials when the parts are pressed together.

fusing machine operator: person who uses and controls the equipment (including manual, semiautomatic, automatic machine styles) required to fuse thermoplastic piping components together. The fusing processes included are butt fusing, heated-tool butt welding, infrared welding, flow-fusion welding, socket fusion, socket-fusion welding, saddle fusion, electrofusion, electrofusion welding, and electrofusion saddle joining or welding.

Fusing Procedure Specification (FPS): a formal written document describing the process for joining thermoplastic piping components by fusion, which provides direction to the installer or fusion machine ~~operators~~operator for making sound and quality production fusion joints. See also *Procedure Qualification Record (PQR)* and *Joining Procedure Specification (JPS)*.

Fusion Performance Qualification (FPQ): a document that is intended to verify the ability of the fusing machine operator to produce a sound, fused joint when following a qualified Fusing Procedure Specification (FPS). See also *Performance Qualification Test Record (PQTR)*.

grounding lug: a connecting device to enable electrical continuity between metallic components of a thermoplastic-lined metallic piping system.

heat-fusion: a permanent bond between thermoplastic piping components formed by heating the parts sufficiently to permit the comingling of the materials when the parts are pressed together.

heat-joint: see heat-fusion.

high-speed tensile impact test: a method used to evaluate the mechanical properties of thermoplastic pipe (polyethylene and others) joined by heat fusing, in which a test sample under tension is exposed to a defined impact load.

high-vapor pressure application: a liquid-pipeline end use where the media transported are hydrocarbon liquids having a vapor pressure greater than 110 kPa (16 psi) absolute at 38°C (100°F), as determined by ASTM D323.

hot oiling: the activity of passing oil at an elevated temperature into a piping system for the purpose of removing paraffin and wax deposits from the pipe bore.

hydrostatic design basis (HDB): see *stress*.

hydrostatic design stress (HDS): see *stress*.

hydrostatic test (hydrotest): an evaluation procedure in which water is used as the medium to determine the pressure containment capabilities of a piping system or component.

imperfection: a condition of not being perfect; a departure of a quality characteristic from its intended condition.

inspection: to witness or verify compliance to the specified requirements.

Inspector: a person who witnesses or verifies compliance to the specified requirements.

pipe~~-supporting~~ support *elements:* fixtures and structural attachments as follows:

(a) fixtures are elements that transfer the load from the pipe or structural attachment to the supporting structure or equipment. They include, but are not limited to, hanging-type fixtures, such as hanger rods including parts, spring hangers, sway braces, counterweights, turnbuckles, struts, chains, guides, ~~and~~ anchors, and snubbers; and bearing-type fixtures, such as saddles, bases, rollers, brackets, and sliding supports.

(b) structural attachments are elements that are bolted or clamped to the pipe, such as clips, lugs, rings, clamps, clevises, straps, and skirts.

piping: assemblies of piping components used to convey, distribute, mix, separate, discharge, meter, control, or snub fluid flows. Piping also includes pipe-supporting elements but does not include support structures, such as building frames, bents, foundations, or any equipment excluded from this Standard [see para. 1-1(e)].

piping components: mechanical elements suitable for joining or assembly into pressure-tight fluid-containing piping systems. Components include pipe, piping subassemblies, tubing, fittings, flanges, gaskets, bolting, valves, and devices such as expansion joints, flexible joints, pressure hoses, traps, strainers, inline portions of instruments, and separators.

piping elements: any material or work required to plan and install a piping system. Elements of piping include design specifications, materials, components, supports, fabrication, examination, inspection, and testing.

piping installation: designed piping systems to which a selected standard edition ~~and addenda apply~~applies.

piping system: interconnected piping and components subject to the same set or sets of design conditions.

plastic: a material that contains a variety of semisynthetic or synthetic solids (polymers), is solid in its finished state, and, at some stage in its manufacture or processing, can be shaped by flow. The two general types of plastics are thermoplastic and thermosetting plastics.

pressure: an application of force per unit area; fluid pressure (an application of internal or external fluid force per unit area on the pressure boundary of piping components).

Procedure Qualification Record (PQR): a document listing all pertinent data, including the essential variables employed and the test results, used in qualifying the procedure specification. See also *Fusing Procedure Specification (FPS)* and *Joining Procedure Specification (JPS)*.

proof testing: process or method for determining design performance characteristics or quality of a component.

qualified life: the time duration that has been proven by qualification testing for a nonmetallic, reinforced, multilayered thermoplastic piping system. [See para. 8-3.2.1(c).]

reinforcing ring: a metallic or nonmetallic ring used to distribute the load from threaded fasteners used with thermoplastic flange adapters.

relining: a technique used to rehabilitate pipelines by pulling or inserting a pipe liner into the existing host piping system.

restraint: a device designed to prevent, resist, or limit movement of a piping system *sealing area:* the cross-sectional area of the molded or flared plastic face of thermoplastic-lined metallic piping, which has metallic backing that resists bolting stress.

sealing stress: the sustained pressure imparted by flange bolting necessary to effect a long-term leak-tight joint. It is normally less than seating stress, as long-term joint performance implies the initial seating stress has been previously applied.

seating stress: the initial pressure imparted by flange bolting necessary to effect a leak-tight seal. It is normally greater than sealing stress, due to the necessity of deforming sealing surface imperfections into the mating surface.

shall: an expression of a requirement.

should: an expression of a recommendation.

socket fusion: a fusion-joining method for assembly of certain thermoplastic fittings and pipe in which the pipe fits inside of the fitting. A metal socket mounted on a hot plate heats the outside circumference of the pipe along a defined length, which will vary depending on the size of pipe and fitting being fused. A metal spigot on the opposite side of the hot plate simultaneously heats the inside surface of the injection-molded fitting; the length of the heated region is the same as that for the pipe. Both fitting and pipe are heated for a set length of time, after which the heated socket or spigot tooling is removed and the pipe is pushed into the fitting to form a coalescent joint.

solvent-cement welding: a method for joining pipe and fittings made of certain thermoplastics [chlorinated ~~poly(vinyl~~polyvinyl chloride~~)~~ (CPVC), ~~poly(vinyl~~polyvinyl chloride~~)~~ (PVC), and acrylonitrile–butadiene–styrene (ABS)] in which a solvent cement containing chemical solvents is used, with or without primers, to dissolve the surfaces of the pipe's outer diameter and the fitting socket to fuse the surfaces together to form a pipe joint.

solvent-weld joint: a permanent bond between thermoplastic piping components formed by the use of solvent or solvent cement that forms an attachment between the mating surfaces.

Standard Fusing Procedure Specification (SFPS): see *Fusing Procedure Specification (FPS)*.

stress

bolt design stress: the design stress used to determine the required cross-sectional area of bolts in a bolted joint.

displacement stress: a stress developed by the self-constraint of the structure. It must satisfy an imposed strain pattern rather than being in equilibrium with an external load. The basic characteristic of a displacement stress is that it is self-limiting. Local yielding and minor distortions can satisfy the displacement or expansion conditions that cause the stress to occur. Failure from one application of the stress is not to be expected. Further, the displacement stresses calculated in this Standard are "effective" stresses and are generally lower than those predicted by theory or measured in strain-~~gage~~gauge tests.[1]

hydrostatic design basis (HDB): selected properties of plastic piping materials to be used in accordance with ASTM D2837 or ASTM D2992 to determine the hydrostatic design stress (see definition below) for the material.

hydrostatic design stress (HDS): the maximum continuous stress due to internal pressure to be used in the design of plastic piping, determined from the hydrostatic design basis by use of a service (design) factor.

sustained stress: a stress developed by an imposed loading that is necessary to satisfy the laws of equilibrium between external and internal forces and moments. The basic characteristic of a sustained stress is that it is not self-limiting. If a sustained stress exceeds the yield strength of the material through the entire thickness, the prevention of failure is entirely dependent on the strain-hardening properties of the material. A thermal stress is not classified as a sustained stress. Further, the sustained stresses calculated in this Standard are "effective" stresses and are generally lower than those predicted by theory or measured in strain-~~gage~~gauge tests.

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[1] Normally, the most significant displacement stress is encountered in the thermal expansion stress range from ambient to the normal operating condition. This stress range is also the stress range usually considered in a flexibility analysis. However, if other significant stress ranges occur, whether they are displacement stress ranges (such as from other thermal expansion or contraction events, or differential support movements) or sustained stress ranges (such as from cyclic pressure, steam hammer, or earthquake inertia forces), paras. 2-2.3.3 (b) and 2-3.3.1.3 may be used to evaluate their effect on fatigue life.

tensile test: a method used to determine the overall strength of a given object by fitting the object between two grips, one at each end, then slowly pulling the grips in opposite directions until the object breaks. This method provides information related the object's yield point, tensile strength, and ultimate strength.

thermoplastic: a plastic (polymer) that is capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.

thermosetting plastic: a resin and catalyst (polymer) capable of being changed into a substantially infusible or insoluble product when cured at room temperature, or by application of heat, or by chemical means.

tube or tubing: see *pipe*.

ultrasonic examination: a nondestructive method of evaluating or testing materials by introducing ultrasonic waves into, through or onto the surface of the article being examined and determining various attributes of the material from effects on the ultrasonic waves. Also known as ultrasonic testing (UT).

Vent: a small opening that allows air, gas, or the like to escape piping systems or a closed space. In thermoplastic-lined metal piping, it is the method of relieving pressure between the liner and the housing caused by permeation.

vent coupling: an accessory added to the vent hole to enable ducting of permeates.

visual examination: the observation of the portion of components, joints, and other piping elements that are or can be exposed to view before, during, or after manufacture, fabrication, assembly, erection, examination, or testing.

Welding Procedure Specification (WPS)

(a) formal written document describing the process for joining thermoplastic piping components by fusion, which provides direction to the installer or fusion machine ~~operators~~operator for making sound and quality production fusion joints. See also *Fusion Performance Qualification (FPQ)* and *Joining Procedure Specification (JPS)*.

(b) formal written document that lists the parameters to be used in construction of weldments in accordance with requirements of the ASME B31 Pressure Piping Code Sections, various ASME BPV Code Sections, and AWS B2.4.

1-4 ABBREVIATIONS

Unless otherwise noted, the abbreviations defined in Table 1-4-1 are used in this Standard to replace lengthy phrases in the text and in the titles of standards in Table 4-2-1. ~~Those marked with an asterisk (*) are in accordance with ASTM D1600. Those marked with a dagger (†) are in accordance with ASTM F412.~~

Table 1-4-1 Abbreviations

Abbreviation	Definition
ABS*†	Acrylonitrile–butadiene–styrene
CPVC*	Chlorinated ~~poly(vinyl chloride)~~ polyvinyl Chloride
NPS	Nominal pipe size
DR†	Dimension ratio
E-CTFE*	Ethylene–chlorotrifluoroethylene
EFW	Electrofusion welding
ETFE*	Ethylene–tetrafluoroethylene copolymer
FEP*	Perfluoro~~(ethylene–propylene)~~ -EthylenePropylene copolymer
FFW	Flow-fusion welding
FIPT	Female (internal) iron pipe thread
FPQ	Fusion Performance Qualification
FPS	Fusing Procedure Specification

HDB	Hydrostatic design basis stress
HDPE*†	High-density polyethylene
HDS†	Hydrostatic design stress
HFP	Hexafluoropropylene
I.D.	Inside diameter
IDR	Ratio of the inside diameter to the wall thickness of pipe
JPS	Joining Procedure Specification
LCL	Lower confidence limit pressure
MAOP	Maximum allowable operating pressure
MAOT	Maximum allowable operating temperature
MAWP	Maximum allowable working pressure
MDPE*†	Medium-density polyethylene
MOBR	Minimum operating bend radius
MPR	Maximum pressure rating
MRTPS	Multilayered, reinforced thermoplastic piping system
MSOP	Maximum sustained operating pressure
NPR	Nominal pressure rating
O.D.	Outside diameter
PA	Polyamide
PB*	Polybutylene
PE*	Polyethylene
PE-RT	Polyethylene~~, raised temperature~~ of Raised Temperature
PEX	Cross-linked polyethylene
PFA*	Perfluoro~~(alkoxyalkane)~~ Alkoxyalkane
PP*	Polypropylene
PQR	Procedure Qualification Record
PQTR	Performance Qualification Test Record
PR†	Pressure rating
PTFE*	Polytetrafluoroethylene
PTFE-M	Modified PTFE
PVC*	~~Poly(vinyl~~Polyvinyl chloride~~)~~
PVC-O	Oriented ~~poly(vinyl chloride)~~polyvinyl Chloride
PVDF*	~~Poly(vinylidene fluoride)~~Polyvinylidene Fluoride
PVDF-C	~~Poly(vinylidene~~Polyvinylidene fluoride~~)~~ copolymer
PVVE	Perfluoroalkyl vinyl ether
RPM	Reinforced plastic mortar
RTP	Reinforced thermosetting plastic
RTR	Reinforced thermosetting resin
SDR†	Standard dimension ratios
SIDR†	Standard inside diameter dimension ratio
SPIG	Spigot end
WPS	Welding Procedure Specification

GENERAL NOTE: Abbreviations marked with an asterisk (*) are in accordance with ASTM D1600. Those marked with a dagger (†) are in accordance with ASTM F412.

1-5 STATUS OF APPENDICES

Table 1-5-1 indicates for each Appendix of this Standard whether it contains requirements, guidance, or supplemental information. See the first page of each Appendix for details.

Table 1-5-1 Status of Appendices

Mandatory Appendix	Title	Status
I	~~Fusing~~Fusing and Electrofusing of Polyamide-11 Thermoplastic Piping; and Fusing of Polypropylene, Polyvinylidene Fluoride, and Polytetrafluoroethylene Plastic Liners of Lined Steel Pipe	Requirements
II	Threaded Thermoplastic Connections	Requirements
III	Acceptance Criteria for Thermoplastic Joints	Requirements
IV	Stress Intensification Factors and Flexibility Factors	Requirements
V	One-Piece Thermoplastic ~~One-Piece~~ Flanges	Requirements

Nonmandatory Appendix		
A	~~Lap Joint~~ Components for Thermoplastic Lap-Joint Flange Connections ~~(LJTF), Backup Rings, and Components~~	Guidance
B	Design ~~Rules~~Requirements for Buried Piping	Guidance
C	Pressure Surge from Fluid Transient	Guidance
D	Multilayered Reinforced Thermoplastic Piping System(s) Operation, Maintenance, and Repair	Guidance

Chapter 2

Design

2-1 Design Conditions

2-1.1 General

(a) The piping capacity of many nonmetallic materials degrades under load with time. Therefore, the procurement documents shall specify a design life for the piping system.

(b) If the mechanical properties of the nonmetallic material under consideration vary or degrade with time, the mechanical properties used in design shall be consistent with the load duration and design life of the piping system. Therefore, care shall be taken in selecting the appropriate materials properties for a given loading.

NOTE: The physical properties for thermoplastic materials are provided in ASME NM.3.3. ~~Refer to ASME NM.3.3 for long- and short-term properties of thermoplastic materials.~~

2-1.2 Pressure, Temperature, and Other Loads

2-1.2.1 General

(a) These design conditions define the pressures, temperatures, and various loads applicable to the design of thermoplastic piping systems.

(b) Piping systems shall be designed for the most severe condition of coincident pressure, temperature, and loading, except as herein stated. The most severe condition shall be that which results in the greatest required pipe wall thickness and the highest flange rating.

2-1.2.2 Pressure

All pressures referred to in this Standard are expressed in ~~kilopascals~~megapascals (MPa) above atmospheric pressure [~~kPa~~MPa (gage)] [pounds per square inch, (psig)], unless otherwise stated.

(a) *Internal Design Pressure.* The internal design pressure shall be no less than the maximum sustained operating pressure (MSOP) within the piping system, including the effects of static head.

(b) External Design Pressure. Piping subject to external pressure shall be designed for the maximum differential pressure anticipated during operating, shutdown, or test conditions.

(c) Pressure Cycling. The Standard does not explicitly address the contribution of fatigue caused by pressure cycling. Special consideration may be necessary where piping systems are subjected to pressure cycling.

2-1.2.3 Temperature

(a) All temperatures referred to in this Standard are the average material temperatures of the respective materials expressed in degrees Celsius (°C) (Fahrenheit, °F), unless otherwise stated.

(b) The piping shall be designed for a material temperature representing the maximum sustained condition expected. The design temperature shall be assumed to be the same as the fluid temperature unless calculations or tests support the use of other data, in which case the design temperature shall not be less than the average of the fluid temperature and the outside wall temperature.

(c) Where a fluid passes through heat exchangers in series, the design temperature of the piping in each section of the system shall conform to the most severe temperature condition expected to be produced by the heat exchangers in that section of the system.

(d) For outdoor exposed pipe subjected to solar thermal heating, the evaluation of such heating effects shall be considered.

(e) Minimum material temperatures shall consider the minimum fluid temperature ~~or~~and minimum one day meteorological conditions for the site.

(1) The pipe material shall not be used at a temperature below the manufacturer's minimum temperature limit.

(2) See ASME NM.3.3, as available, for maximum and minimum design temperatures for the various materials~~.~~

2-1.2.4 Ambient Influences

(a) Cooling Effects on Pressure. Where the cooling of a fluid can reduce the pressure in the piping to below atmospheric, the piping shall be designed to withstand the external pressure or provision shall be made to break the vacuum.

(b) Fluid Expansion Effects. Where the expansion of a fluid can increase the pressure, the piping system shall be designed to withstand the increased pressure or provision shall be made to relieve the excess pressure.

2-1.2.5 Dynamic Effects

(a) Impact. Impact forces caused by all external and internal conditions shall be considered in the piping design. One form of internal impact force is due to the propagation of pressure waves produced by sudden changes in fluid momentum. This phenomenon is often called water or steam "hammer" and can be caused by the rapid opening or closing of a valve in the piping system. The pipe wall thickness determination shall include consideration of these pressure increases. Nonmandatory Appendix C provides guidance on the design for pressure surges. The designer should be aware that propagation of pressure waves is only one example of impact loading and that other causes exist.

(b) Wind. Exposed piping shall be designed to withstand wind loadings. The analysis considerations and loads may be as described in ASCE/SEI 7, or authoritative local meteorological data may be used to define or refine the design wind forces. Where local jurisdictional rules covering the design of building structures are in effect and specify wind loadings for piping, these values shall be considered the minimum design values. Wind and earthquake loads may be considered as not acting concurrently.

(c) Earthquake (Seismic) Loads. The effect of earthquakes shall be considered in the design of piping, piping supports, and restraints. The earthquake loads may be as defined in ASCE/SEI-7, or authoritative local seismological data may be used to define or refine the design earthquake forces~~.~~ and building displacement effects as applicable to the seismic design requirements of the local building Codes. Where local jurisdictional rules covering the design of building structures are in effect and specify earthquake (seismic) loadings for piping, these values shall be considered the minimum design values. Earthquake (seismic) inertial effects and anchor motion effects shall be considered where required by local building codes. Earthquake and wind loads may be considered as not acting concurrently

(d) Vibration. The designer shall consider vibration when determining the arrangement and support of piping.

2-1.2.6 Weight Effects

The following weight effects combined with loads and forces from other causes shall be taken into account in the design of piping. When evaluating sustained loads on the pipe, the sum of the dead loads and live loads shall always be considered together.

(a) Live Load. The live load shall consist of the weight of the fluid transported. Snow and ice loads shall be considered in localities where such conditions exist.

(b) Dead Load. The dead load shall consist of the weight of the piping components, insulation, protective lining and coating, and other superimposed permanent loads.

(c) Test or Cleaning Fluid Load. The test or cleaning fluid load shall consist of the weight of the test or cleaning fluid.

(d) Buried Piping System Load. For buried piping application, additional design loads (backfill, soil cover and burial depth, soil type, compaction, and surcharge loads) shall be considered. (See para. 2-3.3.2.)

2-1.2.7 Thermal Expansion and Contraction Loads

The design of thermoplastic piping systems shall take account of the forces and moments resulting from thermal expansion and contraction, and from the effects of expansion joints. Thermal expansion and contraction shall be provided for, preferably by elbows, offsets, or changes in direction of the pipeline. Hangers and supports shall permit expansion and contraction of the piping between anchors. Expansion joints and flexibility devices may be used if approved by the owner.

2-1.2.8 Building Settlement Effects

Building settlement displacements shall be considered to account for the ~~extent~~fact that further settlement of the buildings may occur following initial construction. If the actual amount of building settlement is unknown, then the total calculated vertical displacements shall be used.

2-2 Design Criteria

2-2.1 General

These criteria cover pressure–temperature ratings for standard and specially designed components, allowable stresses, stress limits, and various allowances to be used in the design of piping and piping components.

2-2.2 Pressure–Temperature Ratings for Piping Components

2-2.2.1 Components Having Specific Ratings

(a) Pressure–temperature ratings for certain piping components have been established and are contained in some of the specifications listed in section 4-5. Where piping components have established pressure–temperature limits permitted by this Standard, the pressure–temperature ratings between those established limits and the upper material temperature limits may be determined in accordance with the requirements of this Standard, but such extensions are subject to restrictions, if any, imposed by the standards listed in Table 4-2-1.

(b) Standard components may not be used at conditions of pressure and temperature that exceed the limits imposed by this Standard.

2-2.2.2 Components Not Having Specific Ratings

(a) Unless limited elsewhere in this standard, piping components that do not have specific pressure–temperature ratings shall be rated for the same allowable pressures as the thermoplastic pipe, as determined in paras. 2-3.1 and 2-3.2 for material having the same allowable stress.

(b) Piping components for which allowable stresses have been developed in accordance with para. 2-2.3, but that do not have established pressure ratings, shall be rated by requirements for pressure design in para. 2-3.2, modified as applicable by other provisions of this Standard.

(c) Methods of manufacturer or design of components not covered by this Standard or not listed in referenced standards shall comply with the requirements of paras. 2-3.1 and 2-3.2 and other applicable requirements of this Standard for design conditions involved.

(d) Where components other than those discussed in (a) through (c), such as pipe or fittings not assigned pressure–temperature ratings in an American National Standard, are used, the manufacturer's recommended pressure–temperature shall not be exceeded.

2-2.2.3 Ratings: Normal Operation

A piping system shall be considered safe for operation if the maximum sustained operating pressure and temperature that may act on any ~~part or~~ component of the system does not exceed the maximum pressure and temperature allowed by this Standard for that particular ~~part or~~ component. The design pressure and temperature shall not exceed the pressure–temperature rating for the particular component and material as defined in the applicable specification listed in Table 4-2-1.

2-2.2.4 Ratings: Allowance for Variation ~~From~~from Normal Operation

(a) The maximum internal pressure and temperature allowed shall include considerations for occasional loads and transients of pressure and temperature. Since variations in pressure and temperature inevitably occur, the piping system, except as limited by component standards referred to in para. 2-2.2.1 or by manufacturers of components referred to in para. 2-2.2.2, shall be considered safe for occasional short operating periods at higher than design pressure or temperature. For such variation, either pressure or temperature, or both, may exceed the design values provided the computed stress (hoop or axial) does not exceed the maximum allowable stress from ASME NM.3.3 for the coincident temperature for the transient conditions by

(1) 10% if the event duration occurs for no more than 8 h at any one time and not more than 800 h per year, or

(2) 20% if the even duration occurs for not more than 1 h at any one time and not more than 80 h per year

(b) The safe pressure–temperature ratings can be impacted by specific chemical fluid services (i.e., applications that use fluids other than water). Designers shall consult manufacturers or review previous successful service applications to determine the impact of chemical service on the pressure–temperature rating. See para. 2-2.3.2 for service factor considerations for different applications.

2-2.2.5 Ratings at Transitions. Where two piping systems operating at different design conditions are connected, a division valve shall be provided having a pressure–temperature rating equal to or exceeding the more severe conditions.

2-2.3 Allowable Stress Values and Other Stress Limits for Piping Components

2-2.3.1 Allowable Stress Values

Allowable stress values for thermoplastic pipe materials are based on time durations and temperature and are provided in ASME NM.3.3. The basis for the allowable stress limits is also given in ASME NM.3.3.

2-2.3.2 Service Factors for Different Applications

The allowable stress values in ASME NM.3.3 are listed for each material based on general industrial applications that use water as a working fluid. Other service factors are provided for other fluids. Where certain industries are governed by federal or local regulations that require the use of lower values for the design factors than those used in ASME NM.3.3, the allowable stress values from ASME NM.3.3 shall be multiplied by the ratio of the required service factor over the service factor used in ASME NM.3.3, as follows:

$$S_{specific} = S_{NM\,3.3} \frac{Servicefactor_{specific}}{Designfactor_{NM\,3.3}} \qquad (2\text{-}2\text{-}1)$$

where

$S_{NM.3.3}$ = S value given in ASME NM.3.3, MPa (psi)

$$N = N_e + N_1\left(\frac{\Delta T_1}{\Delta T_E}\right)^{5.0} + N_2\left(\frac{\Delta T_2}{\Delta T_E}\right)^{5.0} + \cdots, + N_n\left(\frac{\Delta T_n}{\Delta T_E}\right)^{5.0} \qquad (2\text{-}2\text{-}5)$$

where

$N_1, N_2, \ldots N_n$ = number of cycles at letter temperatures changes, $\Delta T_1, \Delta T_2, \ldots, \Delta T_n$

N_e = number of cycles at maximum temperature change ΔT_E

$\Delta T_1, \Delta T_2, \ldots, \Delta T_n$ = the lower temperature changes experienced by the pipe, °C (°F)

ΔT_E = maximum temperature change experience by the pipe, °C (°F)

The maximum number of permitted equivalent full-range temperature cycles, N, shall be 100,000.

(2) *Materials Other Than HDPE.* The total number of thermal cycles shall be the sum of the cycles of each temperature change, $\Delta T_E, \Delta T_1, \Delta T_2, \ldots, \Delta T_n$.

$$N = N_E + N_1 + N_2 + \ldots + N_n \qquad (2\text{-}2\text{-}6)$$

where $\Delta T_E, \Delta T_1, \Delta T_2, \ldots, \Delta T_n$ and $N_E, N_1, N_2, \ldots, N_n$ are as defined (1) above.

2-2.3.4 Limits of Calculated Stresses Due to Occasional Loads

(a) *During Operation*. The sum of the longitudinal stresses produced by internal pressure, live and dead loads, other sustained loads, and occasional loads shall meet the requirements of para. 2-3.3.1.2.

(b) *During Test*. During pressure tests performed in accordance with section 6-6, the circumferential (hoop) stress shall not exceed 150% of allowable stress value given in ASME NM.3.3 at test temperature. In addition, the sum of longitudinal stresses due to test pressure, live and dead loads, and sustained loads at the time of test, excluding occasional loads, shall not exceed 120% of allowable stress value given in ASME NM.3.3 at test temperature.

If any ~~subjected~~ piping system or portion thereof is subjected to pressure or stress levels beyond these limits during the pressure testing, it shall be removed and replaced.

2-2.4 Design Allowances

2-2.4.1 Corrosion or Erosion

When corrosion or erosion is expected to occur, an increase in wall thickness of the piping shall be provided over that required by other design requirements. This allowance, in the judgment of the designer, shall be consistent with the expected life of the piping.

2-2.4.2 Threading

The allowances required for threading shall be determined in accordance with Mandatory Appendix II.

2-2.4.3 ~~Joint Efficiency Factors~~ ~~UNDER DEVELOPMENT~~

~~2-2.4.4~~ Mechanical Strength

Where enhancement of mechanical strength is necessary to prevent damage, collapse, excessive sag, or buckling of pipe due to superimposed loads ~~from supports or other causes~~, the wall thickness of the pipe should be increased. If this is impractical or would cause excessive local stresses, then the superimposed loads ~~or other causes~~ shall be reduced or eliminated by other design methods.

2-2.4.~~5~~4 Material Quality Factors. Factors for the quality of material made to various manufacturing methods shall be reflected in the allowable design stress.

2-3 Pressure Design of Piping Components

2-3.1 Criteria for Pressure Design of Piping Components

The design of piping components shall consider the effects of pressure and temperature, in accordance with paras. 2-3.2.1 through 2-3.2.8, including the consideration of variations and allowances permitted by paras. 2-2.2.4 and 2-2.4. In addition, the mechanical strength of the piping system shall be determined adequate in accordance with para. 2-3.3 under other applicable loadings, including, but not limited to, those loadings and conditions defined in sections 2-1 and 2-2.

2-3.2 Pressure Design of Components

2-3.2.1 Straight Pipe

2-3.2.1.1 Straight Pipe under Internal Pressure

(a) The minimum required wall thickness of straight pipe sections for pressure design shall be determined by the following:

(1) For O.D.-controlled pipe

$$t_{\min} = \frac{P_D D}{(2S + P_D)} + A \qquad \text{(2-3-1)}$$

(2) For I.D.-controlled pipe

$$t_{\min} = \frac{P_D d + 2SA + PA}{(2S - P_D)} \qquad \text{(2-3-2)}$$

where

A = an allowance to be determined by the designer for threading, grooving, erosion, or other wall loss mechanisms

D = specified or actual outside diameter

d = specified or actual inside diameter

P_D = design pressure

When the pipe is subjected to scratches, dents, or other damage during construction, the remaining pipe wall thickness shall be greater than or equal to $t_{\min}$ plus any erosion or other required allowance.

(b) The maximum allowable working pressure, P_a, shall be determined as follows:

(1) For O.D.-controlled pipe

$$P_a = \frac{2S(t - A)}{(D - (t - A))} \qquad \text{(2-3-4)}$$

(2) For I.D.-controlled pipe

$$P_a = \frac{2S(t-A)}{(d-(t-A)+2t)} = \frac{2S(t-A)}{d+A+t} \quad (2\text{-}3\text{-}5)$$

where t = minimum wall thickness from the standard to which the pipe was made, accounting for manufacturing tolerances, or the minimum measured wall thickness.

2-3.2.1.2 Straight Pipe under External Pressure

~~The requirements for the external design of aboveground straight pipe are under development.~~ See Nonmandatory Appendix B for recommended requirements for external pressure design of buried piping systems.

2-3.2.1.3 Allowable Pressure Due to Pressure Spikes

~~(a)~~ *HDPE*

(1) The sum of the maximum anticipated operating pressure plus the maximum anticipated occasional pressure spikes shall be not greater than $1.5P_D$.

(2) The maximum permitted duration of the pressure spike is 15 min, and the total duration of the pressure spikes shall be less than 20 h/yr.

~~(b) *Materials Other Than HDPE*~~

~~UNDER DEVELOPMENT~~

2-3.2.2 Joints or Fittings

This paragraph provides the design requirements and limitations for joints or fittings in thermoplastic piping systems.

(a) *General Requirements for All Thermoplastics*

(1) See Chapter 5 for allowable joining methods for each type of listed thermoplastic.

(2) The piping components permitted in section 2-3 shall be designed to withstand a pressure greater than or equal to the design pressure of the attached pipe.

(3) See Mandatory Appendix II for requirements on threaded thermoplastic connections.

(4) See Mandatory Appendix III for acceptance criteria for thermoplastic joints.

(5) See Mandatory Appendix V and Nonmandatory Appendix A for requirements and information on thermoplastic flanges and flange connections.

(b) *Requirements Specific to HDPE.* Pipe fittings including the design of electro-fusion fittings shall be designed to withstand a pressure greater than or equal to the design pressure, P_D, of the attached HDPE pipe.

(1) The pressure rating (PR) of the fitting shall be determined by testing or by the following calculation:

$$PR = GSR\left(\frac{2S}{(DR-1)}\right) \geq P_D \quad [2\text{-}3\text{-}6(a)]$$

where GSR is the geometric shape rating factor per Table 2-3-1~~.~~ and DR is the dimensional ratio (D/t).

(2) For components of different DRs, the item with the smaller DR shall be counterbored and tapered to equal the wall thickness of the item with the larger DR or its outside diameter shall be machined and tapered to equal the wall thickness of the item with the larger DR and shall comply with Figure 2.3-1, illustration (a) or illustration (b), as applicable. This requirement shall be identified on the design and fabrication drawings.

Table 2-3-1 Geometric Shape Ratings (GSR) for HDPE fittings

Fitting Description	GSR [Note (1)]
Straight pipe	1.0
Molded flange adapters	1.0
Machined flange adapters	1.0
Molded fittings	1.0
Concentric conical monolithic reducer (machined or molded) [Note (2)]	1.0
Thrust collar (machined or molded)	1.0
Fabricated ~~Elbow~~Tee equal outlet (two DR less than pipe) DR 5 to DR 9	~~UNDER DEVELOPMENT~~ 0.65
~~Fabricated Tee~~	
Mitered ~~Fittings~~Elbows [Note (3)] (from one to five segments) DR 5.6 to DR 9	~~UNDER DEVELOPMENT~~ 0.80
Mitered Elbows [Notes (1) & (3)] (from one to five segments) DR 9.5 to DR 13.5 (segments less than or equal to 22.5 deg. directional changes per fusion)	~~UNDER DEVELOPMENT~~ 0.75

NOTES:
(1) Alternatively, the GSR factor may be determined by dividing the pressure rating determined by calculation or testing by the pressure rating of the pipe used to make the fitting.
(2) Pressure ratings for concentric conical monolithic reducers shall be based on the minimum dimensional ratio (DR). In a reducer, the wall thickness will vary from the greatest diameter to the smallest diameter. Since the DR is the ratio of the diameter to the minimum wall thickness, the pressure rating of the reducer shall be based on the section of the reducer with the highest DR (lowest pressure rating).
(3) Pressure ratings for all mitered fittings shall be determined using eq. (2-3-6 (a)) with an appropriate GSR factor. The equation has values suitable for HDPE mitered elbows. Alternatively, the manufacturer's pressure ratings may be used if they are backed by test data.

(c) *Materials Other Than HDPE*. Tables 2-3-2 and 2-3-3 list the design factors (DF) and pressure ratings for non-HDPE thermoplastic molded fittings made in compliance with referenced specifications. Alternatively, the manufacturer's pressure rating may be used if it is backed by test data. The pressure rating (PR) for other thermoplastic piping components shall be determined by testing or by the following calculation:

$$PR = DF\left(\frac{2S}{(D/t-1)}\right) \geq P_D \qquad [2\text{-}3\text{-}6(b)]$$

Table 2-3-2 Design Factor (DF)

Fitting Description	DF	Reference Specifications
PVC Schedule 40		
Straight pipe	1.0	~~ASTM D1785/~~ASME SD-1785
Molded fittings, solvent weld	0.6	~~ASTM D2466/~~ASME SD-2466
Molded fittings, threaded (Threads are actually Sch. 80)	0.5	~~ASTM D2464/~~ASME SD-2464 ~~ASTM D2467/~~ASME SD-2467
PVC Schedule 80		
Straight pipe	1.0	~~ASTM D1785/~~ASME SD-1785
Molded fittings, solvent weld	0.6	~~ASTM D2467/~~ASME SD-2467
Molded fittings, threaded	0.5	~~ASTM D2464/~~ASME SD-2464 ~~ASTM D2467/~~ASME SD-2467
CPVC Schedule 40		
Straight pipe	1.0	~~ASTM F441/~~ASME SF-441
Molded fittings, solvent weld	0.6	~~ASTM F438/~~ASME SF-438
CPVC Schedule 80		
Straight pipe	1.0	~~ASTM F441/~~ASME SF-441
Molded fittings, solvent weld	0.6	~~ASTM F439/~~ASME SF-439
Molded fittings, threaded	0.5	~~ASTM F437/~~ASME SF-437
ABS Pressure Piping Components		
Straight pipe	1.0	ASTM ~~FD2661~~F2661, F2806, F2969
Molded fittings, solvent weld	0.6	ASTM D2235, F2135
Molded fittings, threaded	0.5	ASTM D3311, F1498

Table 2-3-3 Pressure Rating (PR) at 23ºC (73ºF)

Fitting Description	PR, MPa (psi)	Reference Specification
PVC Schedule 40		
Molded unions	1.034 (150)	~~ASTM F1970/~~ASME SF-1970
Molded wyes	1.034 (150)	~~ASTM F1970/~~ASME SF-1970
PVC Schedule 80		
Molded flange adapters	1.034 (150)	~~ASTM F1970/~~ASME SF-1970
Molded unions	1.034 (150)	~~ASTM F1970/~~ASME SF-1970
Molded wyes	1.034 (150)	~~ASTM F1970/~~ASME SD-1970
CPVC Schedule 40		
Molded unions	1.034 (150)	~~ASTM F1970/~~ASME SF-1970
Molded wyes	1.034 (150)	~~ASTM F1970/~~ASME SF-1970
CPVC Schedule 80		
Molded flange adapters	1.034 (150)	~~ASTM F1970/~~ASME SF-1970
Molded unions	1.034 (150)	~~ASTM F1970//~~ASME SF-1970
Molded wyes	1.034 (150)	~~ASTM F1970/~~ASME SF-1970
ABS Pressure Piping Components		
Molded flange adapters	1.034 (150)	ASTM D2235, F2135

GENERAL NOTE: Appropriate derating factor shall be applied for higher temperature applications or services.

~~**2-3.2.2.1 Mechanical Joints.** UNDER DEVELOPMENT.~~

2-3.2.3 Intersections

(a) *HDPE.* Fabricated intersections and molded tees as provided in para. 2-3.2.2 may be used. For electrofusion saddle fittings, the ratio of OD_{branch}/OD_{run} shall be less than 0.6 per Mandatory Appendix IV, Table IV-1.

(b) *Materials Other Than HDPE.* Molded intersections may be used. Fabricated intersections may be used if their use is backed by test data.

2-3.2.4 Design of Mitered Elbows

~~(a)~~ *HDPE*

(1) The design pressure rating of the mitered elbow, P_m, shall be calculated as the lesser of eqns. (2-3-7) and (2-3-8) (see Figure 2-3-1) or as determined by testing per para. 2-3.2.2(b)(1).

$$P_m = \frac{St_{elbow}}{r_2}\left(\frac{t_{elbow}}{t_{elbow} + 0.622 \tan\theta\sqrt{t_{elbow} r_2}}\right) \qquad (2\text{-}3\text{-}7)$$

or

$$P_m = \frac{St_{elbow}}{r_2}\left(\frac{R_1 - r_2}{R_1 + 0.5r_2}\right) \quad (2\text{-}3\text{-}8)$$

where

R_1 = centerline radius of mitered elbow, mm (in.); see Figure 2-3-1, illustrations (a) and (b)

r_2 = radius of curvature at the end of a tapered transition joint, mm (in.)

t_{elbow} = minimum (mitered segment) wall thickness for fabricated elbows, mm (in.)

θ = angle of miter cut, deg; see Figure 2-3.2.4-1, illustrations (a) and (b)
= 22.5 deg max.

P_m shall be greater than or equal to P_D.

(2) Alternatively, the pressure rating for HDPE mitered fittings may be determined by testing as provided in ~~ASTM F2206 (~~ASME SF-2206~~)~~.

(3) The maximum DR permitted for HDPE mitered elbow segments shall be determined by the pressure rating.

(4) The minimum fabricated wall thickness of the monolithic reinforced sections of the mitered elbow shall be > $1.25t_{\mathrm{min}}$ of the attached straight pipe. The additional monolithic wall thickness shall be provided by enlarging the pipe O.D. while maintaining the pipeline I.D., or by reducing the pipe I.D. while maintaining the pipeline O.D.

NOTE: If a mitered fitting design has been tested as required in ~~ASTM F2206 (~~ASME SF-2206~~)~~, a wall thickness > $1.25t_{\mathrm{min}}$ may not be required, provided the owner approves the thickness and it has been verified by test data.

(5) The fabricated tolerance of the fitting angular direction shall be +3 deg. Mitered joints of 3 deg or less (angle α_{elb} in Figure 2-3-2) shall not require redesign consideration as mitered elbows.

(6) HDPE mitered elbows shall comply with the following requirements, except the wall thickness shall be determined as outlined in (3) above:

(-a) The angle θ in Mandatory Appendix IV, Table IV-1 shall not be more than 22.5 deg.

(-b) The centerline distance shall be in accordance with the Mandatory Appendix IV, Table IV-1.

(-c) The segments of the n miter bends shall be joined by butt fusion joints.

~~(b) *Materials Other Than HDPE*. UNDER DEVELOPMENT.~~

2-3.2.5 Attachments

(a) External and internal attachments to piping shall be designed so as not to cause flattening of the pipe, excessive localized bending stresses, or harmful thermal gradients in the pipe wall.

(b) Such attachments shall be designed to minimize stress concentrations in applications where the number of stress cycles, due either to pressure or thermal effect, is relatively large for the expected life of the equipment.

2-3.2.6 Closures

(a) General. Closures shall be made by use of closure fittings, such as threaded or bonded plugs and caps, manufactured in accordance with standards listed in Table 4-2-1, and used within the specified pressure–temperature ratings~~, and in accordance with the following:~~.

~~(1) Flat caps are not permitted.~~

~~(2) Openings in closures are not permitted. See para. 2-3.2.6.1.~~

(b) Openings in Closures

(1) A closure with a threaded or socketed opening shall be designed as a reducer or reducer bushing.

(2) Secondary drill and tap of a threaded or bonded plug or cap is not permitted.

2-3.2.7 Pressure Design of Flanges and Blanks

(a) Flanges — General. See Mandatory Appendix V and Nonmandatory Appendix A.

(b) Blind Flanges. Blind flanges shall be made of materials per ASME B16.5.

~~*(c) Blanks.* UNDER DEVELOPMENT.~~

~~**2-3.2.8 Other Pressure-Retaining Fittings or Components.** UNDER DEVELOPMENT.~~

2-3.3 Analysis of Piping Components

(a) To validate a design under the rules in this paragraph, the complete piping system shall be evaluated between anchors for the effects of thermal expansion, weight, other sustained loads, and ~~other~~ occasional loads.

(b) Each component in the system shall meet the limits in this paragraph. Equations (2-3-9) and (2-3-10) may not apply for bellows and expansion joints.

(c) When evaluating piping stresses in the vicinity of expansion joints, consideration shall be given to actual cross-sectional areas that exist at the expansion joint.

2-3.3.1 Aboveground Pipe

2-3.3.1.1 Stress Due to Sustained Loads. Longitudinal stresses in the pipe caused by applied pressure and bending loads in thermoplastic pipe shall satisfy the following equation:

2-3.3.1.3 Stress Due to Displacement and Thermal Expansion Load Ranges

(a) Cyclic secondary longitudinal loads shall include, but are not limited to, the effects of thermal expansion, seismic anchor motions~~,~~ (if not included in Equation (2-3-10)), and vibrations.

(b) The bending stresses in the thermoplastic pipe caused by applied cyclic secondary loads shall satisfy the following equation:

$$\frac{i \cdot M_C}{Z} \leq S_A \qquad (2\text{-}3\text{-}12)$$

where

M_c = range of resultant cyclic secondary moment load the cross section, if any

S_A = allowable fatigue stress, MPa (psi), from ASME NM.3.3 at the given temperature and for the given number of equivalent cycles as determined in para. 2-2.3.3(b)

2-3.3.1.4 Stress Due to ~~Nonrepeated~~Non-repeated Secondary Loads

(a) Noncyclic secondary longitudinal loads shall include, but are not limited to, the effects of ~~nonrepeated~~non-repeated anchor motions and ground settlement.

(b) The bending stresses in the thermoplastic pipe caused by applied noncyclic secondary axial and longitudinal loads shall meet the following equation:

$$\frac{i \cdot M_D}{Z} \leq 2 \cdot S_h \qquad (2\text{-}3\text{-}13)$$

where

M_D = noncyclic secondary resultant moment loading on the cross section

2-3.3.2 Buried Pipe

(a) The design loads for buried piping systems shall include, but are not limited to, soil loads, wheel loads, other surcharge loads, external pressure loads, negative pressure loads, groundwater pressure, flotation loads, frost heave, soil settlement, and earthquake loads, as applicable.

(b) An acceptable method for the design of buried pipe is provided in Nonmandatory Appendix B.

2-3.3.3 Determination of Section Modulus

(a) For intersections, the section modulus used to determine stresses shall be the effective section modulus.

(1) For the run pipe

$$Z = \frac{\pi({D_{oh}}^4 - {d_h}^4)}{32 D_{oh}} \qquad (2\text{-}3\text{-}14)$$

Where:

D_{oh}: Outside diameter of header

d_h: Inside diameter of header

(2) For the branch pipe

$$Z = \frac{\pi(D_{ob}{}^4 - d_b{}^4)}{32D_{ob}} \qquad (2\text{-}3\text{-}15)$$

Where:

D_{ob}: Outside diameter of the branch pipe

d_b: Inside diameter of the branch pipe

(b) For components and joints other than intersections, the section modulus used to determine stresses shall be the classic section modulus.

$$Z = \frac{2I}{D} \qquad (2\text{-}3\text{-}16)$$

2-4 Other Design Considerations

2-4.1 Design of Pipe Support Elements

Pipe support elements (e.g. anchors, guides, and supports) shall be selected and applied to comply with the principles and requirements of this section.

2-4.1.1 General

(a) Thermoplastic piping shall be supported, guided, and anchored in such a manner as to prevent damage to the piping.

(b) Point loads and narrow areas of contact between piping and supports shall be avoided.

(c) ~~Support~~Pipe support elements shall be designed to avoid pinpoint stresses, since thermoplastic piping is less rigid than metallic pipes.

(d) Local stresses at points of support, including clamping forces, shall be considered.

(e) Padding compatible to direct contact with the piping material shall be placed between piping and supports where damage to piping can occur.

(f) Where pipe support elements contact the pipe, the ~~stress~~ load shall be distributed over the pipe using sleeves, wraps, etc.

(1) U-bolts ~~should~~shall not be used.

~~(2) Care should be taken to ensure contact with the plastic pipe does not damage the pipe.~~

(g) Due to the high thermal expansion and contraction properties of thermoplastic materials, thermoplastic piping can move considerably more than metallic pipes.

(1) These movements shall not be restricted in a manner that will cause excessive pipe stresses.

(2) Anchors and guides ~~shall~~may be used to direct the pipe to expand and contract into portions of the system which are designed to absorb them.

(h) Valves and equipment that would transmit excessive loads to the piping shall be independently supported to prevent such loads.

(i) Considerations shall be given to mechanical guarding in traffic areas.

(j) Manufacturer's recommendations for support shall be considered.

2-4.1.2 Anchors

(a) A thermoplastic piping system shall have sufficient pipe anchors or restraints to ensure that the system can withstand the effects of fluid transients caused by the closure or opening of quick-acting valves.

(b) Valves should normally be anchored to absorb the handwheel or operator loads required to operate the valves.

(c) Anchors should be carefully placed so as not to excessively decrease the piping system's flexibility or ability to absorb expansion movement due to temperature variation.

2-4.1.3 Guides

(a) Guides which are used to control movement of pipe caused by thermal expansion and contraction or vibrations shall not excessively restrict movement in the unrestrained direction.

(b) Metal guides, if used, shall be lined with suitable materials (wear resistant and/or flexible) to prevent damage to the pipe surface.

2-4.1.4 Supports

(a) Supports shall be spaced to limit excessive sag or deformation at the design temperature and within the design life of the piping system.

(b) Decreases in the modulus of elasticity with increasing temperature and creep of pipe material with time shall be considered when determining pipe support requirements.

(c) The thermal expansion of the piping system shall be considered in the design and location of supports.

(d) Where axial restraint is required, positive stops, such as shear collars, shall be provided as axial restraint. Frictional forces from clamping pressure shall not be considered an anchor mechanism unless specifically recommended by the manufacturer.

2-4.1.5 Thrust Collars for HDPE

(a) The shear stress in the thrust collar due to applied primary loads shall satisfy the following equation:

$$\tau_i = \frac{F_i}{A_S} < 0.8 S_h \qquad (2\text{-}4\text{-}1)$$

where

A_s = shear area of the thrust collar at the interface at the surface of the pipe, mm^2 (in.^{2})

F_i = axial force due to the maximum of simultaneously occurring applied loads, N (lb)

τ_i = shear stress in the interface of the thrust collar and the pipe due to the applied primary loads, MPa (psi)

(b) If other bonded or welded attachments to pipe are used, the design shall consider pipe wall bending stresses due to eccentricity of the loads from the restraint points on the pipe, in addition to shear stresses.

2-4.2 Moduli of Elasticity

(a) The moduli of elasticity to be used in the analysis of any given loading condition shall be taken from ASME NM.3.3 for the appropriate material, temperature, and where appropriate, load duration.

(b) The mechanical properties of some materials vary depending on the duration of the applied load. This load-based variation shall be considered in the design to ensure that the mechanical properties of the chosen material for a given analysis are consistent with the anticipated load duration.

– (1) ~~The elastic~~ For HDPE piping, the modulus ~~of a material can vary significantly depending on the load duration.~~

~~– (2) Care shall be taken in selecting the appropriate modulus of elasticity, E,~~ used for ~~a given loading.~~

~~– (3) Durations for given loadings should be selected from ASME NM.3.3.~~

~~(-a) The modulus~~thermal expansion analysis shall be selected to be consistent with the duration of the application of the thermal expansion load~~ for HDPE piping~~.

~~(-b~~(2) For seismic loads on HDPE piping, the moduli of elasticity from ASME NM.3.3 based on half hour durations shall be increased by 25% (see ASME PVP2012-78777).

Chapter 3

~~Thermoplastic~~ Materials

3-1 GENERAL

Chapter 3 contains limitations and required qualifications for thermoplastic materials based on their properties. Use of these materials in piping systems is also subject to requirements and limitations in other parts of this Standard.

3-2 Materials and Specifications

3-2.1 Listed Materials

Material meeting the following requirements shall be considered listed and acceptable material:

(a) thermoplastic materials listed in ASME NM.3.3

(b) thermoplastic materials not listed in ASME NM.3.3, but not specifically prohibited by this Standard, provided they satisfy one of the following requirements:

(1) The materials are referenced in other parts of this Standard and shall be used only within the scope of and in the product form permitted by the referencing text.

(2) The materials shall comply with the requirements of ASME NM.3.3, Mandatory Appendix 12 for the listing of new thermoplastic materials.

(c) thermoplastic materials for pressure pipe

(1) polyolefin: PE, PP

(2) vinyl: PVC, CPVC

(3) fluorinated: PVDF

(4) polyamide: PA 11

(5) ABS

(d) thermoplastic material for linings

(1) polyolefin: PE, PP

(2) fluorinated: PVDF, PTFE, FEP, PFA, ETFE, ECTFE

3-2.2 Unlisted Materials

Thermoplastic materials other than those meeting the requirements of para. 3-2.1 shall be considered unlisted thermoplastic materials. Unlisted thermoplastic materials shall be used only if they satisfy all of the following requirements:

(a)-The materials shall comply with the requirements of ASME NM.3.3, Mandatory Appendix 12 for the listing of new thermoplastic materials.

(b) The designer shall document the owner’s acceptance for use of unlisted thermoplastic materials.

(c) All other requirements of this Standard are satisfied.

(d) Unlisted materials shall meet a published specification covering chemistry, physical and mechanical properties, method and process of manufacture, and quality control.

(e) Unlisted materials shall be qualified for service within a stated range of minimum and maximum temperature and pressure based upon data associated with successful experience, tests, or analysis, or a combination thereof.

3-2.3 Unknown Thermoplastic Materials

Thermoplastic materials of unknown specification shall not be used for pressure-containing piping system components.

3-2.4 Size or Thickness

Materials outside the limits of size or thickness given in any specification listed in this Standard (see Table 4-2-1) may be used, if the material is in compliance with the other requirements of the specification, and no other similar limitation is given in the requirements for construction.

3-2.5 Limitations on Materials

(a) A listed thermoplastic material for pressure pipe shall not be used at a design temperature above the maximum temperature at which the allowable stress value has been determined for the material (see ASME NM.3.3).

(b) The designer shall verify that thermoplastic materials which meet other requirements of the Standard are suitable for service throughout the operating temperature range.

(c) Thermoplastic materials for use at temperatures below those recommended by the manufacturer shall be tested to determine that they are suitable for use in standard piping. The designer shall have test results at or below the lowest design temperature to ensure that the thermoplastic materials are suitable for the intended application at the design minimum temperature.

3-2.6 Marking of Thermoplastic Materials or Products

Thermoplastic materials or products marked as meeting the requirements of a material specification or multiple specifications shall be acceptable provided:

(a) one of the markings includes the thermoplastic material specification, and type of thermoplastic material is permitted by this Standard

(b) the appropriate allowable stress from ASME NM.3.3 for the specified type of thermoplastic material is used

(c) all other requirements of this Standard are satisfied

3-3 Other Thermoplastic Composite Materials

(a) Requirements for metallic and thermoplastic material combinations (e.g., metallic lined piping with thermoplastics) are listed in Chapter 7.

(b) Requirements for metallic, nonmetallic and thermoplastic material combinations (e.g., multilayer reinforced, fiberglass reinforced) are listed in Chapter 8.

(c) Combination of any of the above materials are listed in Chapter 8.

~~Requirements for the following composites (e.g., multilayer reinforced, fiberglass reinforced) are not included in this Chapter:~~

~~(a) metallic and thermoplastic material combinations — see Chapter 7~~

~~(b) nonmetallic and thermoplastic material combinations~~

~~(c) metallic, nonmetallic, and thermoplastic material combinations — see Chapter 8~~

~~(d) thermoplastic material combinations~~

~~(e) combinations of any of the above — see Chapter 8~~

CHAPTER 4
Standards for Piping Components

4-1 General ~~Requirements~~

(a) Standard Piping Components. Components that ~~complies~~comply with one or more standards listed in Table 4-2-1 or ASME NM.3.1.

(b) Nonstandard Piping Components. Piping components that do not comply with *one or more* standards listed in Table 4-2-1; however, they shall meet the pressure design and other requirements of this Standard.

4-2 Reference Documents

4-2~~-~~.1 Standards and Specifications

The standards and specifications listed in Table 4-2-1 are incorporated into this Standard by reference. These documents contain references to other codes, standards, and specifications for thermoplastic piping and components (including metallic and nonmetallic backup rings) and metals lined with thermoplastics. Any codes, standards, and specifications not explicitly listed in Table 4-2-1 shall be used only in the context of the listed standard or specification in which they appear. As it is not practical to refer to a specific edition of each standard or specification throughout the text of this Standard, the approved editions are shown in Table 4-2-1. Additional ASTM standards adopted by ASME will appear in ASME NM.3.1 and will be added to ASME NM~~-~~.1 in future editions.

The names and addresses of the organizations from which the referenced standards and specifications can be procured are shown in Table 4-2-2.

4-2.2 Additional References

The following are additional publications ~~are~~ referenced in this standard and may be used for guidance:

Munson, Adams, Nickhols, "Determination of Tensile Elastic Modulus in High Density Polyethylene Piping at Seismic Strain Rates", Paper No. PVP2012-78777, pp. 217-228; 12 pages.

Publisher: ASME

Guidance for Field Hydrostatic Testing of High Density Polyethylene Pressure Pipelines: Owner's Consideration, Planning, Procedures, and Checklists

Material Handling Guide, Chapter 2, Inspections, Tests and Safety Considerations

Publisher: Plastics Pipe Institute

ASTM D2774	Standard Practice for Underground Installation of Thermoplastic Pressure Piping
ASTM D2837	Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials
ASTM D3139	Standard Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals
~~ASTM D3311~~	~~Standard Specification for Drain, Waste, and Vent (DWV) Plastic Fittings Patterns~~
ASTM D4218	Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle Furnace Method
ASME SF477	Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe
~~ASTM F2135~~	~~Standard Specification for Molded Drain, Waste, and Vent (DWV) Short-Pattern Plastic Fittings~~
AWS B2.4	Specification for Welding Procedure and Performance Qualification for Thermoplastics
AWWA C207	Steel Pipe Flanges for Waterworks Service, Sizes 4 In. Through 144 In. (100 mm Through 3,600 mm)
~~BS~~ EN 12814-3-2014	Testing of welded joints in thermoplastics semi-finished products. Tensile creep test
CSA Z662	Oil and Gas Pipeline Systems
DVS 2207-1	Welding of thermoplastics- Heated element welding of pipes, piping parts and panels made out of polyethylene
DVS 2207-5	Welding of Thermoplastics –Welding of PE Casting Pipes- Fitting and isolating Valves
DVS 2207-6	Welding of Thermoplastics- Non-contact heated tool butt welding of pipes, pipeline components and sheets –Methods-Equipment-Parameters
DVS 2207-11	Welding of thermoplastics- Heated element welding of pipes, piping parts and panels made of PP
DVS 2207-15	Welding of thermoplastics- Heated element welding of pipes, piping parts and panels made of PVDF
DVS 2210-1	Industrial Piping Made Of Thermoplastics - Planning And Execution - Above-Ground Pipe Systems
DVS 2212-1	Qualification testing of plastic welders; Qualification Test Groups I and II
EN 1092-1-2002	Flanges and their joints- Circular flanges for pipes, valves, fittings and accessories, PN designated- Part 1: Steel flanges
EN 12814-7-2002	Testing of welded joints of thermoplastics semi-finished products - Tensile test with waisted test specimens
EN 13067-2003	Plastics welding personnel - qualification testing of welders - thermoplastics welded assemblies
EN 13100-1	Non-destructive testing of welded joints of thermoplastics semi-finished products - Part 1: Visual examination
ISO 161/1 -1978	Thermoplastic pipes for the transport of fluids-nominal outside diameters and nominal pressures-Part 1: Metric series
ISO 7005-1 - 1992	Pipe Flanges: Part 1: Steel flanges for industrial and general service piping systems
PPI TR-3	Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Materials
PPI TR-4 HDB/HDS/SDB/PDB/ MRS Listed Materials	PPI Listing of Hydrostatic Design Basis (HDB), Hydrostatic Design Stress (HDS), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe
PPI TR-45	Butt Fusion Joining Procedure for Field Joining of ~~Polyamid~~Polyamide-11 (PA-11) Pipe

ABS Standards

ASTM D1527	Standard Specification for ABS Plastic Pipe, Sch. 40 and 80
ASTM D2235	Standard Specification for Solvent Cements for ABS Plastic Pipe and Fittings
ASTM D2282	Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR)
ASTM D2468	Standard Specification for Socket-Type ABS Plastic Pipe Fittings, Sch. 40

ASTM D2661	Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe and Fittings
ASTM D3965	Standard Classification System and Basis for Specifications for Rigid Acrylonitrile-Butadiene-Styrene (ABS) Materials for Pipe and Fittings
ASTM F2629	Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) IPS Dimensioned Pressure Pipe
	CPVC Standards
ASME SD1784	Specification for Rigid ~~Poly(Vinyl~~PolyVinyl Chloride~~)~~ (PVC) Compounds and Chlorinated ~~Poly(Vinyl~~PolyVinyl Chloride~~)~~ (CPVC) Compounds
ASME SD2846	Specification for Chlorinated ~~Poly(Vinyl~~PolyVinyl Chloride~~)~~ (CPVC) Plastic Hot – and Cold-Water Distribution Systems
ASME SF437	Specification for Threaded Chlorinated ~~Poly(vinyl~~Polyvinyl Chloride~~)~~ (CPVC) Plastic Pipe Fittings, Schedule 80
ASME SF438	Specification for Socket-Type Chlorinated ~~Poly(vinyl~~Polyvinyl Chloride~~)~~ (CPVC) Plastic Fittings, Schedule 40
ASME SF439	Specification for Socket-Type Chlorinated ~~Poly(vinyl~~Polyvinyl Chloride~~)~~ (CPVC) Plastic Fittings, Schedule 80
ASME SF441	Specification for Chlorinated ~~Poly(vinyl~~Polyvinyl Chloride~~)~~ (CPVC) Plastic Pipe, Schedule 40 and 80)
ASME SF442	Specification for Chlorinated ~~Poly(vinyl~~Polyvinyl Chloride~~)~~ (CPVC) Plastic Pipe, (SDR-PR)
ASME SF493	Standard Specification for Solvent Cement for Chlorinated Poly(vinyl Chloride) (CPVC) Plastic Pipe and Fittings
ASME SF1970	Specification for Special Engineered Fittings, Appurtenances or Valves for use in ~~Poly (Vinyl~~Polyvinyl Chloride~~)~~ (PVC) or Chlorinated ~~Poly (Vinyl~~Polyvinyl Chloride~~)~~ (CPVC) Systems
CSA B137.6	Chlorinated Polyvinylchloride (CPVC) pipe tubing and fittings for hot and cold water distribution systems
	PE Standards
API 15LE	PE Line Pipe
ASME SD2239	Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter
ASME SD2513	~~Standard~~ Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings
ASME SD2609	Specification for Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe
ASME SD2683	Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing
ASME SD2737	Specification for Polyethylene (PE) Plastic Tubing
ASME SD3035	Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
ASME SD3261	Specification for Butt heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing
ASME SD3350	Specification for Polyethylene Pipe and Fittings Materials
ASME SD4976	Specification for Polyethylene Plastics Molding and Extrusion Materials
ASME SF714	Specification for Polyethylene (PE) plastic pipe (SDR-PR) Based on Outside Diameter
ASME SF1055	Specification for Electrofusion Type Polyethylene Plastic Fittings for Outside Dimension Controlled Polyethylene Pipe and Fittings
ASME SF1924	Specification for Plastic Mechanical Fittings of Use on Outside Controlled Polyethylene Gas Distribution Pipe and Tubing
ASTM SF2164	Standard Practice for Field Leakage Testing of Polyethylene (PE) and Cross-linked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure

ASME SF2206	Specification for Fabricated Fittings of Butt Fused Polyethylene (PE) Plastic Pipe, Fittings, Sheet Stock, Plate Stock, or Block Stock
ASTM ~~S~~F2435	Standard Specification for Steel Reinforced Polyethylene (PE) Corrugated Pipe
ASME SF2619	Specification for High-density Polyethylene (PE) Line Pipe
ASTM ~~S~~F2620	Standard Specification for Butt Fusion of Polyethylene Pipe and Fittings
ASME SF2880	Specification for Lap Joint Type Flange Adapters for Polyethylene Pressure Pipe in Nominal Pipe Sizes ¾ in. to 65 in.
ASTM SF3123	Standard Specification for Metric Outside Diameter Polyethylene (PE) Plastic Pipe (DR-PN)
AWWA C901	Polyethylene (PE) Pressure Pipe, Tubing and Fittings, ¾ in to 3 in. for water service
AWWA C906	Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 63 in., for Water Distribution
AWWA Manual M55	PE Pipe Design and Installation
ISO 13953-2001	Polyethylene(PE) pipes and fittings - Determination of the tensile ~~strengt~~strength and failure mode of test pieces from a butt-fused joint
PPI TN-38	Bolt Torque for Polyethylene Flanged Joints
	PE-RT Standards
ASME SF2623	Specification for Polyethylene of Raised Temperature (PE-RT) SDR 9 Tubing
ASTM SF2735	Standard Specification for Plastic Insert Fittings For SDR9 Cross-linked Polyethylene (PEX) and Polyethylene of Raised Temperature (PE-RT) Tubing
ASME SF2769	Specification for Polyethylene of Raised Temperature (PE-RT) Plastic Hot and Cold-Water Tubing and Distribution Systems
CSA B137.18	Polyethylene of Raised Temperature (PE-RT) tubing systems for pressure applications.
	PP Standards
ASME SD4101	Specification for Polypropylene Injection and Extrusion Materials
ASTM ~~S~~D5857	Standard Specification for Polypropylene Injection and Extrusion Materials Using ISO Protocol and Methodology
ASME SF2389	Specification for Pressure Rated Polypropylene (PP) Piping Systems
CSA B137.11	Polypropylene (PP-R) pipe and fittings for pressure applications
	PVC Standards
ASME SD1785	Specification for Rigid ~~Poly(vinyl~~Polyvinyl Chloride~~)~~ (PVC) Plastic Pipe, Schedules 40, 80, and 120
ASME SD2152	Standard Test Method for Degree of Fusion of Extruded ~~Poly(vinyl~~Polyvinyl Chloride~~)~~ (PVC) Pipe and Molded Fittings by Acetone Immersion
ASME SD2241	Specification for ~~Poly(vinyl~~Polyvinyl Chloride~~)~~ (PVC) Pressure Rated Pipe (SDR Series)
ASME SD2464	Specification for Threaded PVC Plastic Pipe Fittings, Sch. 80
ASME SD2466	Specification for ~~Poly(vinyl~~Polyvinyl Chloride~~)~~ (PVC) Plastic Pipe Fittings, Schedule 40
ASME SD2467	Specification for Socket-Type ~~Poly(vinyl~~Polyvinyl Chloride~~)~~ (PVC) Plastic Pipe Fittings, Schedule 80
ASTM D2564	Standard Specification for Solvent Cements for Poly(vinyl Chloride) (PVC) Plastic Piping Systems
ASTM D2672	Standard Specification for Joints for IPS PVC Pipe Using Solvent Cement
ASTM D2855	Standard Practice for Two-Step (Primer and Solvent Cement) method of Joining Standard Practice for the Two-Step (Primer and Solvent Cement) Method of Joining Poly (Vinyl Chloride) (PVC) or Chlorinated Poly (Vinyl Chloride) (CPVC) Pipe and Piping Components with ~~Tampered~~Tapered Sockets
~~ASTM F656~~	~~Standard~~

ASME SD1784	Specification for ~~Primers for Use in Solvent Cement Joints of~~Rigid Poly(Vinyl Chloride) (PVC) ~~Plastic Pipe~~Compounds and ~~Fittings~~Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
ASME SF1970	Specification for Special Engineered Fittings, Appurtenances or Valves for use in Poly (Vinyl Chloride) (PVC) or Chlorinated Poly (Vinyl Chloride) (CPVC) Systems
AWWA C900	Polyvinyl Chloride (PVC) Pressure Pipe, 4 inch through 12" for Water
AWWA C905	Polyvinyl Chloride (PVC) Water Transmission Pipe, Nominal Diameters 14 in. Through 36 in.
AWWA Manual M23	PVC Pipe – design and installation

PVCO Standards

ASME SF1483	Specification for Oriented Polyvinylchloride (PVCO) Pressure
AWWA C909	Molecularly Oriented Polyvinylchloride (PVCO) Pressure Pipe 4 in. through 24in (100mm – 600mm) for Water Distribution
CSA B137.3.1	Molecularly Oriented Polyvinylchloride (PVCO) Pipe for Pressure Applications

PVDF Standards

ASTM~~ASME~~ D3222	Standard Specification for Unmodified ~~Poly(Vinylidene~~Polyvinylidene Fluoride~~)~~ (PVDF) Molding Extrusion and Coating Materials
ASME SD5575	Classification System for Copolymers of Vinylidene Fluoride (VDF) with Other Fluorinated Monomers
ASTM D6713	Standard Specification for Extruded and Compression Molded Shapes Made from Poly(Vinylidene Fluoride) (PVDF)
ASME SF1673	Specification for PVDF Corrosive Waste Drainage Systems
CSA B181.3	Polyolefin and Polyvinylidene Fluo~~u~~ride (PVDF) laboratory drainage systems

Standards for Metals Lined With Thermoplastics

~~ASTM F1545~~ASME SF1545	~~Standard~~ Specification for Plastic-Lined Ferrous Metal Pipe, Fittings, and Flanges

PA Standards

~~ASTM D1733~~ASME SF1733	~~Standard~~ Specification for Butt Heat Fusion Polyamide(PA) Plastic Fitting for Polyamide(PA) Plastic Pipe and Tubing
ASTM F1973	Standard Specification for Factory Assembled Anodeless Risers and Transition Fittings in Polyethylene (PE) and Polyamide 11 (PA11) and Polyamide 12 (PA12) Fuel Gas Distribution Systems
ASTM F2145	Standard Specification for Polyamide 11 (PA11) and Polyamide 12 (PA12) Mechanical Fittings for Use on Outside Diameter Controlled Polyamide 11 and Polyamide 12 Pipe and Tubing
ASME SF2600	Specification for Electrofusion Type Polyamide-11 Fittings for Outside Diameter Controlled Polyamide-11 Pipe and Tubing
ASTM~~ASME SF-2634~~ F2634	Standard Test Method for Laboratory Testing of Polyethylene (PE) Butt Fusion Joints using Tensile-Impact Method
ASTM F2767	Standard Specification for Electrofusion Type Polyamide-12 Fittings for Outside Diameter Controlled Polyamide-12 Pipe and Tubing for Gas Distribution
ASTM F2785	Standard Specification for Polyamide 12 Gas Pressure Pipe, Tubing, and Fittings
ASME SF2945	Specification for Polyamide 11 Gas Pressure Pipe, Tubing, and Fittings

Others

ASTM D3159	Standard Specification for Modified ETFE-Fluoropolymer Molding and Extrusion Materials
ASME SD3307	Specification for Perfluoroalkoxy (PFA)-Fluorocarbon Resin Molding and Extrusion Materials
ASME SD4894	Specification for Polytetrafluoroethylene (PTFE) Granular Molding and Ram Extrusion Materials
ASME SD4895	Specification for Polytetrafluoroethylene (PTFE) Resin Produced From Dispersion

ASME SD6779	Classification System for and Basis of Specification for Polyamide Molding and Extrusion Materials(PA)
ASTM F1412	Standard Specification for Polyolefin Pipe and Fittings for Corrosive Waste Drainage Systems
ASME SF1498	Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings
Standards for Multilayered Reinforced Thermoplastic Piping Systems	
API Specification 15S Second Edition	Spoolable Reinforced Plastic Line Pipe
ASTM D323	Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)
NACE MR0175/ISO 15156-2	Petroleum and natural gas industries: Materials for use in H2S containing environments in oil and gas production.
Composites Standards	
ASTM F1281	Standard Specification for Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene (PEX-AL-PEX) Pressure Pipe
ASTM F1282	Standard Specification for Polyethylene/Aluminum/Polyethylene (PE-AL-PE) Composite Pressure Pipe
ASTM F1488	Standard Specification for Coextruded Composite Pipe
ASTM F1974	Standard Specification for Metal Insert Fittings for Polyethylene/Aluminum/Polyethylene and Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene Composite Pressure Pipe
ASTM F2262	Standard Specification for Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene Tubing OD Controlled SDR9
ASTM F2434	Standard Specification for Metal Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Cross-linked Polyethylene/Aluminum/Cross-linked Polyethylene (PEX-AL-PEX) Tubing
ASTM F2686	Standard Specification for Glass Fiber Reinforced Thermoplastic Pipe
ASTM F2720	Standard Specification for Glass Fiber Reinforced Polyethylene (PE-GF) Spiral Wound Large Diameter Pipe
ASTM F2805	Standard Specification for Multilayer Thermoplastic And Flexible Steel Pipe And Connections
ASTM F2855	Standard Specification for Chlorinated Poly(Vinyl Chloride)/Aluminum/Chlorinated Poly(Vinyl Chloride) (CPVC-AL-CPVC) Composite Pressure Tubing
ASTM F2896	Standard Specification for Reinforced Polyethylene Composite Pipe For The Transport Of Oil And Gas And Hazardous Liquids
CSA B137.9	Polyethylene/Aluminum/Polyethylene (PE-AL-PE) Composite Pressure Pipe systems
CSA B137.10	Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene (PEX-AL-PEX) Composite Pressure Pipe Systems
Piping Standards	
ASCE	Guidelines for the Design of Buried Steel Pipelines (2001)
ASCE	Manual of Practice No. 119, Buried Flexible Steel Pipe: Design and Structural Analysis
ASTM A53/A53M	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A105/A105M	Standard Specification for Carbon Steel Forgings for Piping Applications
ASTM A106/A106M	Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
ASTM A126	Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings
ASTM A135/A135M	Standard Specification for Electric-Resistance-Welded Steel Pipe
ASTM A182/A182M	Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASTM A216/A216M	Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

Table 4-2-2 Procurement Information

Organization	Contact Information
ASCE	The American Society of Civil Engineers 1801 Alexander Bell Drive Reston, VA 20191 (800) 548-2723 (www.asce.org)
ASME	The American Society of Mechanical Engineers 2 Park Avenue, New York, NY 10016-5990 (www.asme.org)
ASTM	~~American Society for Testing and Materials, Inc.~~ ~~100~~ ASTM International 100 Barr Harbor Drive P.O. Box C700 West Conshohocken, PA 19428-2959 (www.astm.org)
CSA	~~Canadian Standards Association~~ ~~178~~CSA Group178 Rexdale Boulevard Toronto, ON Canada M9W 1R3 (www.csagroup.org)
DIN	Deutsches Institut für Normung Am DIN-Platz Burggrafenstraße 6 10787 Berlin Germany (www.din.de)
ISO	International Organization for Standardization ISO Central Secretariat Chemin de Blandonnet 8 CP 401 - 1214 Vernier, Geneva, Switzerland
MSS	Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. 127 Park St. NE Vienna, VA 22180-4602 (www.msshq.org)
PPI	Plastics Pipe Institute 105 Decker Court, Suite 825 Irving TX 75062 (www.plasticpipe.org)
NACE	National Association of Corrosion Engineers 15835 Park Ten Place Houston, Texas 77084 (www.nace.org)

5-2 Joining Thermoplastic Piping Components by Heat Fusion or Solvent-Cement Welding

5-2.1 Processes and Procedures for Thermoplastic Joining

The components used in thermoplastic piping systems are composed of various polymeric compounds. Various methods may be used to join different polymeric compounds. Three common joining methods are heat fusion, solvent-cement welding, and mechanical joining. Heat fusion and solvent-cement welding are discussed in this Chapter; mechanical joining is discussed in the following sections:

(a) Chapter 8 discusses mechanical joining for multilayered reinforced thermoplastic piping systems. (Processes for joining thermoplastic liners by heat fusion are included in para. 5-2.2.1)

(b) Mandatory Appendix II discusses requirements for threaded thermoplastic connections.

(c) Mandatory Appendix V discusses requirements for one-piece thermoplastic flanges.

(d) Nonmandatory Appendix A provides guidance for mechanical joining using lap-joint thermoplastic flanges (LJTF).

NOTES:

(1) All joining processes do not work on all thermoplastics. The selection of compounds and joining techniques is based on the selected thermoplastic and the application requirements.
(2) Mechanical joining is a joining method in which a device or fitting, rather than heat fusion or solvent-cement welding, is used to connect the thermoplastic pipe sections. The term “mechanical fittings or devices” applies only to
(a) stab-type fittings
(b) nut-follower-type fittings
(c) bolted-type fittings
(d) other compression-type fittings

5-2.2 Thermoplastic Joining using Heat-Fusion Methods

In pressure piping systems, heat-fusion joining methods shall be used only to join like piping compounds.

NOTE: Many thermoplastic polymeric compounds cannot be joined to other, different thermoplastic compounds using standard heat fusion. There are exceptions to this general statement related to thermoplastic pipe liners.~~5-2.2.1 Butt Fusion~~

5-2.2.1 Butt Fusion

Joining thermoplastic liners using butt-fusion processes is defined in para. 5-2.2.1 (a) and 5-2.2.1 (b). The following limitations shall apply to the use of butt fusion joining for joining thermoplastic liners. When PTFE liners are joined as described in 5-2.2.1 (b), the procedure is different and is described in Mandatory Appendix I.

NOTE: The term “hot plate” or “heated tool butt welding” are used to describe butt fusion joining. Butt fusion is also called “heat fusion”.

(a) Thermoplastic liners of the following polymeric compounds shall be fused in accordance with JPSs specific to one polymer: PE, PP, PFA, PVDF homopolymer to PVDF homopolymer, and PVDF copolymer to PVDF copolymer.

(b) PTFE shall not be joined to itself, but two PTFE liner ends may be joined by fusing a PFA film insert between the two ends. A special JPS for fusion bonding PTFE is provided in Mandatory Appendix I.

(c) *PE Pipe and Fittings.* Butt fusion of PE pipe and fittings shall be conducted using an FPS qualified in accordance with ASME BPVC, Section IX, Articles XXI through XXIV, or AWS B2.4. For butt fusing of piping to be used in fuel-gas applications, a JPS shall be approved in accordance with the Code of Federal Regulations (49 CFR Part 192).

(d) *PA-11 Pipe and Fittings.* Butt-fusion joining of PA 11 nylon pipe and fittings shall be conducted using a JPS as described in PPI TR-45. The procedure specification for fuel-gas piping shall be qualified in accordance with the requirements in the Code of Federal Regulations (49 CFR Part 192).

(e) *PP Pipe and Fittings.* Butt fusion of PP pipe and fittings shall be conducted using a WPS qualified in accordance with AWS B2.4.

(f) *PVC Pipe and Fittings.* Butt fusion of PVC pipe and fittings shall be conducted using a WPS qualified in accordance with AWS B2.4.

(g) *PVDF Pipe and Fittings.* Butt-fusion joining of PVDF and PVDF copolymer pipe and fittings shall be conducted using a WPS qualified in accordance with AWS B2.4.

(h) *PFA Pipe and Fittings.* Butt-fusion joining of PFA pipe and fittings shall be conducted using a WPS qualified in accordance with AWS B2.4.

5-2.2.2 Socket Fusion

(a) PE Piping and Fittings. Socket fusion of PE pipe and fittings for fuel-gas applications shall be conducted using a JPS qualified in accordance with the requirements in the Code of Federal Regulations (49 CFR Part 192). For other applications, a WPS qualified in accordance with ASME SF2620 ~~(ASTM F2620)~~ or AWS B2.4 shall be used.

(b) PP Piping and Fittings. Socket fusion of PP pipe and fittings shall be conducted using a WPS qualified in accordance with AWS B2.4.

(c) PVDF Piping and Fittings .Socket fusion of PVDF and PVDF copolymer shall be conducted using a WPS qualified in accordance with AWS B2.4.

5-2.2.3 Electrofusion

(a) PE Piping and Fittings. Electrofusion of PE pipe and fittings shall be conducted using an FPS qualified in accordance with ASME BPVC, Section IX, Articles XXI through XXIV, or using a WPS qualified in accordance with AWS B2.4. For electrofusion of piping to be used in fuel-gas applications, the JPS shall be qualified in accordance with ASME BPVC, Section IX, AWS B2.4 or the Code of Federal Regulations (49 CFR Part 192) based on the requirements for the application.

(b) PA-11 Pipe and Fittings. Electrofusion of PA-11 pipe and fittings shall be conducted in accordance with a published qualified joining procedure. For electrofusion of piping to be used in fuel-gas applications, the JPS shall be qualified in accordance with the Code of Federal Regulations (49 CFR Part 192) based on the requirements for the application.

(c) PP Pipe and Fittings. Electrofusion of PP piping and fittings shall be conducted using a WPS qualified in accordance with AWS B2.4.

(d) PVDF Pipe and Fittings. Electrofusion of PVDF or PVDF copolymer pipe and fittings shall be conducted using a WPS qualified in accordance with AWS B2.4.

5-2.2.4 Same Physical Properties

Table 5-3-1 Qualification for Thermoplastic Joining Procedures

Thermoplastic	Joining Procedure/Method	Joining Procedure Qualification	Required Procedure Specification Type [Note (1)]
For Pipe and Fittings			
ABS	Solvent-cement welding	AWS B2.4	WPS
CPVC	Solvent-cement welding	AWS B2.4	WPS
PVC	Solvent-cement welding	AWS B2.4 or the manufacturer's procedure qualification	WPS
	Heat Fusion	AWS B2.4	JPS
PP	Contact or noncontact fusing Socket fusion Electrofusion	AWS B2.4	WPS
PVDF or PVDF copolymer	Heat fusion or noncontact fusing Socket fusion Electrofusion	AWS B2.4	WPS
PA-11	Contact fusing Electrofusion	ASME NM-.1, Mandatory Appendix I	JPS
PE	Contact fusion	ASME BPVC, Section IX, or AWS B2.4	FPS or WPS
	Saddle fusion	ASME NM-.1, Mandatory Appendix I	FPS
	Electrofusion	ASME BPVC, Section IX, or AWS B2.4	FPS or WPS
For Liners			
PP, PVDF (homo-polymer or copolymer), PFA, or PTFE	Butt fusion	ASME NM-.1, Chapter 7	JPS

NOTE:

(1) Environmental condition recommendations shall be included in all procedure specifications.

(2) Fusing is used in ASME BPVC Section IX, but Fusion is used in AWS B2.4. Both Fusing and Fusion is defined the same.

5-4 Operator Qualification

5-4.1 Requirements for Joining Listed Thermoplastics using Heat-Fusing and Solvent-Cement Welding. Below are lists of various thermoplastics and the Standard, Chapter or Appendix to qualify persons to join each thermoplastic.

5-4.1.1 When ABS pipe and fitting are joined using a solvent cement welding procedure, the welder shall be qualified using AWS B2.4

5-4.1.2 When CPVC pipe and fitting are joined using a solvent cement welding procedure, the welder shall be qualified using AWS B2.4.

5-4.1.3 When PVC pipe and fitting are joined using a solvent cement welding procedure, the welder shall be qualified using AWS B2.4.

5-4.1.3.1 When PVC pipe and fitting are joined using contact heat fusing, welder shall be qualified in accordance using AWS B2.4.

5-4.1.4 When PP pipe and fitting are joined using a contact or non-contact fusing methods, the welder shall be qualified using AWS B2.4.

5-4.1.5 When PP pipe and fitting are joined using socket fusion, the welder shall be qualified using AWS B2.4.

5-4.1.6 When PP pipe and fitting are joined using electrofusion, the welder shall be qualified using AWS B2.4.

5-4.1.7 When PVDF or PVDF copolymer pipe and fitting are joined using a contact or non-contact fusing methods, the welder shall be qualified using AWS B2.4.

5-4.1.8 When liners for thermoplastic lined metallic pipes are joined using heat fusing processes the joiner shall be qualified using the JPS and operator qualification requirements in ~~NM-1~~, Chapter 7. The thermoplastic liners covered by this section are PP, PVDF (homopolymer or copolymer) PFA and PTFE.

5-4.1.9 When PVDF or PVDF copolymer is joined using socket fusion, the welder shall be qualified using AWS B2.4.

5-4.1.10 When PVDF or PVDF copolymer is joined using electrofusion, the welder shall be qualified using AWS B2.4.

5-4.1.11 When PA 11 is joined using a contact fusing method, the fusing machine operator or joiner shall be qualified as required in the Mandatory Appendix I on Fusing in this Standard.

5-4.1.12 When PA 11 is joined using electrofusion, the fusing machine operator or joiner shall be qualified as required in the Mandatory Appendix I on Fusing in this Standard.

5-4.1.13 When PE is joined using a heat fusion method; the fusing operator or welder shall be qualified using ASME BPV Code Section IX, Article XXII; or AWS B2.4.

5-4.1.14 When PE is joined using saddle fusion, the fusing operator or welder shall be qualified using the Mandatory Appendix I on Fusing in this Standard or AWS B2.4.

5-4.1.15 When PE is joined using electrofusion, the fusing operator or welder shall be qualified using the using ASME BPV Code Section IX, or AWS B2.4.

Table 5-4-1 Qualification for Thermoplastic Fusion Equipment Operators, Welders, and Installers

Thermoplastic	Joining Procedure/Method	Personnel	Personnel Qualification Requirement
For Pipe and Fittings			
ABS	Solvent-cement welding	Welder	AWS B2.4
CPVC	Solvent-cement welding	Welder	AWS B2.4
PVC	Solvent-cement welding Contact heat fusing	Welder	AWS B2.4
PP	Contact or noncontact fusing Socket fusion Electrofusion	Welder	AWS B2.4
PVDF or PVDF copolymer	Contact or noncontact fusing Socket fusion Electrofusion	Welder	AWS B2.4
PA-11	Contact fusing Electrofusion	Fusing machine operator or joiner	ASME NM-.1, Mandatory Appendix I
PE	Heat fusion	Fusing machine operator or welder	ASME BPVC Section IX, Article XXII, or AWS B2.4
	Saddle fusion	Fusing machine operator or welder	ASME NM-.1, Mandatory Appendix I, or AWS B2.4
	Electrofusion	Fusing machine operator or welder	ASME BPVC Section IX, or AWS B2.4
For Liners			
PP, PVDF (homo-polymer or copolymer), PFA, or PTFE	Heat fusing	Joiner	JPS and ASME NM-.1, Chapter 7

Chapter 6

Inspection, Examination, and Testing

6-1 Inspection

6-1.1 General

This Chapter distinguishes between inspection and examination (see section 6-2). Inspection applies to functions performed for the owner by the owner's Inspector or the Inspector's delegates. References in this Standard to the "Inspector" are to the owner's Inspector or the Inspector's delegates.

NOTE: Requirements in this Chapter for inspection, examination, and testing of thermoplastic piping systems apply to all thermoplastic materials referenced in ASME NM-.1; additional requirements and exceptions for thermoplastic-lined metals and multilayered reinforced thermoplastic piping systems are found in Chapters 7 and 8, respectively.

6-1.2 Responsibility for Inspection

It is the owner's responsibility, exercised through the owner 's Inspector, to verify that all required examinations and testing have been completed and to inspect the thermoplastic piping system to the extent necessary to be satisfied that it conforms to all applicable examination requirements of this Standard and of the engineering design.

6-1.3 Rights of the Owner's Inspector

The owner's Inspector and the Inspector's delegates shall have access to any place where work concerned with the thermoplastic piping system installation is being performed. This includes manufacture, fabrication, assembly, erection, examination, and testing of the thermoplastic piping system. They shall have the right to audit any examination, to inspect the thermoplastic piping system using any examination method specified by the engineering design, and to review all certifications and records necessary to satisfy the owner's responsibility stated in para. 6-1.2.

6-1.4 Qualifications of the Owner's Inspector

(a) The owner's Inspector shall be designated by the owner and shall be the owner, an employee of the owner, an employee of an engineering or scientific organization, or of a recognized insurance or inspection company acting as the owner's agent. The owner's Inspector shall not represent nor be an employee of the thermoplastic piping component manufacturer, fabricator, or erector unless the owner is also the manufacturer, fabricator, or erector.

(b) The owner's Inspector shall be trained on the principles of the specific joining process to be inspected (minimum 24 h). This training shall be documented and shall cover, as a minimum, safety, fundamentals of the joining and installation process, and recognition of typical joint imperfections. In addition, the Inspector shall meet one of the following requirements:

(1) have at least 8 yr. of experience in the design, fabrication, or examination of industrial thermoplastic pressure piping systems. Completion of an engineering or technical degree accredited by the Accreditation Board for Engineering and Technology (ABET) shall be considered equivalent to 3 yr. of experience of the 8 yr. required.

(b) *Test Fluid Expansion.* If a pressure test is to be maintained for a period of time and the test fluid in the system is subject to thermal expansion, precautions shall be taken to avoid excessive pressure.

6-6.2.2 Other Test Requirements

(a) *Examination for Leakage.* A leakage test shall be maintained for at least 1 ~~h~~hr. All joints and connections shall be examined for leakage after the ~~1 h~~1hr. period.

(b) *Low Test Temperature.* The possibility of testing near the glass transition temperature or below the rapid crack growth prorogation critical temperature shall be considered when leakage tests are conducted on systems where the ductile–brittle transition temperature range is near the testing conditions.

(c) *Sectioning the System for Test.* The pipeline length tested shall be either the whole pipeline or a section of the entire pipeline capable of being isolated, dependent upon the length and diameter of the section of the pipe, the availability of water, the disposability of the water, and the spacing between sectioning valves or blind flanged ends. Based upon elevations and distance, the pipeline shall be divided into test sections such that

(1) the hydrostatic test pressure at any point in the test section shall be

(-a) not less than the design pressure

(-b) not more than 50% above the design pressure rating of any pipeline component

(2) Prior to testing execution, a pre-assessment should be made as to what the recorded pressure versus time curves should look like, and how to read or interpret the actual recorded pressure data, so that acceptance or corrective action may be taken by experienced, trained, and qualified operators.

NOTES:
(1) Although written for polyethylene, PPI TN-46 and ASTM F2164 provide comprehensive guidelines for conducting pressure tests.
(2) ASME PCC-2, Part 5, Article 5.~~13~~1, provides comprehensive requirements for conducting pressure tests.

6-6.2.3 Special Provisions for Testing

(a) Piping Components and Subassemblies. Piping components and subassemblies may be tested either separately or as assembled piping.

(b) Flanged Joints. Flanged joints used to connect piping components and subassemblies that have previously been tested, and flanged joints at which a blank or blind is used to isolate equipment or other piping during a test, are not required to be leakage tested in accordance with para. 6-6.1.

(c) Closure Joints. The final joint connecting piping systems or components that have been successfully tested in accordance with para. 6-6.1 are not required to be leakage tested provided the joint is examined in-process in accordance with para. 6-5.4 and an initial service leakage test in accordance with para. 6-6.6.

6-6.2.4 Dual Containment Piping

(a) The internal or carrier pipe shall be leakage tested on the basis of the internal design pressure.

(1) In stagger welded systems, i.e., systems where the joining of the carrier pipe and the joining of the containment pipe are performed independently, any testing requiring visual access to welds or joints of the internal pipe shall be conducted before the containment pipe weld is performed.

Chapter 7

Use of Metallic Piping Lined With Thermoplastics

7-1 General

(a) This Chapter covers requirements for the design and use of piping systems comprising mechanically assembled metallic components, including a metallic pressure-containment host pipe and/or fittings, complemented or conjoined with a corrosion- or abrasion-resistant polymeric liner.

(b) These piping systems have special design and use requirements which are in addition to, or in some cases, in lieu of, the requirements in Chapters 1 through 6~~.”~~. They are detailed further in this Chapter.

(c) The requirements for pressure bearing components found in paras.7-4.2, 7-4.4.1 through 7-4.4.8, and Section 7-7 may be substituted with analogous requirements found in any section of ASME B31 pressure piping code. If another pressure piping code section is used, all relevant requirements from that code apply. All other requirements of this chapter shall apply.

(d) Columns, vessels, ~~nonpressure~~non-pressure piping, and other lined components (dip pipes, spargers, expansion joints, valves, sight glasses, hoses, and complex shape housings) are not addressed by this Chapter.

7-2 Standards

See Table 4-2-1 for a listing of the standards and specifications that apply to both the metallic and plastic components used to construct metallic piping lined with thermoplastics.

7-3 Materials

(a) Liner Polymers. The materials listed below are accepted for use in thermoplastic-lined metallic piping.

(1) polyethylene (PE) — PE 4710

(2) polypropylene (PP), both homopolymers and copolymers

(3) ~~poly(vinylidene~~polyvinylidene fluoride~~)~~ (PVDF), both homopolymers and copolymers

(4) ethylene–tetrafluoroethylene copolymer (ETFE)

(5) ethylene chloro-trifluoroethylene (ECTFE)

(6) polytetrafluoroethylene (PTFE)

(7) modified polytetrafluoroethylene (m-PTFE)

(8) ~~perfluoro(alkoxyalkane)(~~perfluoroalkoxyalkane (PFA)

(9) Perfluoro~~-(~~-ethylene–propylene~~)~~ copolymer (FEP)

(b) Recycled, Reprocessed, or Reground Resins. The acceptable use of qualified recycled, reprocessed, or reground resins for liners depends on the resin, as described below:

(a) Melt-processable resins containing nothing but the main identified polymer (neat resins) may be recycled provided the mechanical and thermal properties are maintained. Owners may disallow this at their discretion, and may also impose resin traceability or certification requirements that effectively disallow this practice.

(b) Melt-processable resins containing fillers, stabilizers, or pigments may be recycled at ratios of at least 6:1 virgin to regrind, provided the mechanical and thermal properties are maintained. Owners may disallow this at their discretion, and may also impose resin traceability or certification requirements that effectively disallow this practice.

(c) Only virgin PTFE or virgin modified PTFE may be used in making PTFE linings complying with this Standard.

7-4 Design Considerations

7-4.1 Qualifications of the Designer

(a) The designer is the person(s) in charge of the engineering design of a piping system and shall be ~~experienced in~~familiar with the ~~use~~requirements of ~~this~~the Standard.

(b) The qualifications and experience required of the designer will depend on the complexity and criticality of the system and the nature of the individual's experience.

(c) The designer should be licensed to practice engineering by local jurisdiction.

(d) If the designer is not licensed to practice engineering by the local jurisdiction, the owner's approval shall be required, and the individual shall meet at least one of the following criteria:

(1) completion of an Accreditation Board for Engineering & Technology (ABET) accredited or equivalent engineering degree requiring the equivalent of at least 4 years of study, plus a minimum of 5 years' experience in the design of related pressure piping

(2) completion of an accredited engineering technician or associate's degree requiring the equivalent of at least 2 years of study, plus a minimum of 10 years' experience in the design of related pressure piping

(3) fifteen years' experience in the design of related pressure piping (for an individual without a degree or no ABET accreditation)

(4) experience in the design of related pressure piping, which shall be satisfied by piping design experience that includes design calculations for pressure, sustained and occasional loads, and piping flexibility

7-4.2 Design Pressure

(a) The design pressure requirements of para. 2-1.2.2 shall be applied in their entirety.

(b) The design pressure of each component in a piping system shall be not less than the pressure at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service, except as provided in para. 7-4.4.4. The most severe condition is that which results in the greatest required component thickness and the highest component rating.

(c) When more than one set of pressure–temperature conditions exist for a piping system, the conditions governing the rating of components conforming to listed standards may differ from the conditions governing the rating of components designed in accordance with para. 7-4.4.6.

(d) When a pipe is separated into individualized pressure-containing chambers (jacketed piping, blanks, etc.), the partition wall shall be designed on the basis of the most severe coincident temperature (minimum or maximum) and differential pressure between the adjoining chambers expected during service, except as provided in para. 7-4.4.4.

P = internal design gauge pressure
S = stress value for material from ASME B31.1, Table A-1, or ASME B31.3, Table A-1

NOTE: Equations (7-4-5) and (7-4-6) differ from the thickness equations in Chapter 2.

7-4.4.6.3 Pressure Design of All Other Piping Configurations. ASME B31.3, para. 303 shall be used for requirements for pressure design of all other piping components.

7-4.4.7 Piping Support and Flexibility Analysis

The designer should perform piping support and flexibility analysis as specified in appropriate metallic piping codes and standards with the additional constraint that the flanged joint gasket's initial seating and residual sealing stress shall be sustained under all normal operating and loading conditions.

7-4.4.8 Permissible Flange Loading

(a) The flanges shall be uniformly loaded, as is practical.

(b) Beam-bending loads or lateral distortions imposing uneven pressure on opposite sides of the flange shall be minimized to below the compressive creep–stress limit of the plastic sealing surface at the operating and peak excursion temperatures.

(c) For above ground pipes and buried pipes with flanged joints in subterranean vaults, corrosion-resistant conical Belleville spring washers, used between the metal flange's back face and the nuts on the bolt studs, may be considered to enhance sealing by accommodating creep, and sustaining and balancing uniform sealing force, even when subjected to unanticipated pipe-run distortions.

(d) The designer should consider the potential detrimental metallurgical effects of process media on the Belleville springs.

7-4.4.9 Minimum Allowable Liner Thickness. The minimum liner wall thicknesses when metal piping lined with thermoplastics is subjected to positive internal pressure (only) and at ambient temperatures are listed for common liner materials in ~~ASTM F1545 (~~ASME SF-1545~~).~~.

(a) Guidelines for determination of minimum liner wall thickness when considering design variables such as temperature, thermal expansion to avoid buckling of the liner–pipe and the terminal flange joint, hydrocarbon saturation/chemical saturation (if present), and differential pressure across the liner wall (to avoid buckling), venting, and vacuum balancing should be obtained from manufacturer recommendations.

(b) Guidelines for determination of minimum liner wall thickness when considering chemical service should be obtained from the manufacturer or experiential data.

7-4.4.10 Pressure and Temperature Limits.

(a) The pressure and temperature limits are a function of chemical exposure and shall be determined by the manufacturer of the plastic-lined piping or experiential data.

(b) Where chemical service does not impact the pressure–temperature rating, pressure and temperature limits may be obtained from Table 7-4-3.

(c) Para. 7-4.4.6 shall also apply.

(c) Multiphase flow can cause ~~liner~~ damage to the liner if not appropriately understood. The designer should take extra precaution when designing systems that allow such flows. While multiphase flow is allowed, many of the design considerations may fall outside of this Standard .

(d) If abrasion resistance is a design requirement, the designer shall consider process parameters including, but not limited to, the following:

(1) liner material

(2) liner thickness

(3) process fluid composition, temperature, and flow velocity

(4) particle size, shape, and hardness

(5) fluid flow rate

(6) other factors as determined by designer

7-4.4.13 Electrostatic Charge Generation and Grounding. Grounding and electrical continuity shall be considered during the design of a system comprising thermoplastic-lined metallic components.

(a) The designer shall take into consideration that piping highly nonconductive flammable liquids or where multiphase flow is possible can generate a charge buildup on the plastic liner of sufficient magnitude to penetrate through the liner by an electrostatic discharge (ESD). The designer should consult the manufacturer for methods to minimize adverse effects of electrostatic charge generation on the integrity of plastic liners.

(b) Where flammable fluids can be present, the designer shall ensure that external electrical continuity is maintained between all flanged metallic piping components and that this piping is properly grounded as static sparking could cause ignition of flammable vapors.

(c) The owner shall develop and maintain a program to test grounded systems on a scheduled basis to ensure the grounding devices and flange continuity methods are still active.

7-4.4.14 Permeation Resistance of the Liners

The designer shall take into account the permeation resistance of the liner in the selection and design of the system. The manufacturer should provide guidance or test data, if available.

NOTE: Important factors that affect the rate of permeation include, but are not limited to:

(a) process temperature

(b) media vapor pressure

(c) media molecule size

(d) solubility coefficient

(e) polymer crystallinity

(b) For metallic piping lined with PE, the designer shall follow all guidelines from the manufacturer on the design and installation of a flangeless or reduced-flange, plastic-lined piping system.

(c) For metallic piping lined with PP, PVDF, and PTFE, the designer shall follow all guidelines from the manufacturer on the design and installation of a flangeless or reduced-flange, plastic-lined piping system (see Mandatory Appendix I).

7-4.4.19 Design Considerations for Metallic Piping Lined With Loose-Fitting Thermoplastics.

Loose-fitting liners perform differently than tightly restrained liners. They tend to shrink and grow with thermal cycles, concentrating stresses at the bore-to-sealing-surface transition. They will also exhibit reduced vacuum resistance compared to tight liners of the same thickness.

Loose-fitting thermoplastic liners should not be used in piping systems with thermal cycling or vacuum.

7-4.4.20 Designer Responsibility for Component Quality Assurance

(a) The designer shall exercise due diligence in ensuring that piping manufacturers supply components that meet acceptable quality standards. This shall include verification of a sound overall quality system, design control, qualification of new and revised component designs and ongoing workmanship, and final inspection requirements.

(b) Manufacturers of thermoplastic-lined metallic piping shall be able to provide evidence of compliance with ~~ASTM F1545 (~~ASME SF-1545~~)~~ qualification testing requirements and inspection requirements.

(c) Qualification testing records shall be available for every thermoplastic liner design in current use.

(d) If the piping manufacturer procures a liner from a subsupplier, each subsupplier's liner shall require distinct qualification testing.

7-4.4.21 Metal Welding

(a) Welding shall not be permitted on metals lined with thermoplastics.

(b) Metal piping lined with thermoplastics shall not be used as a ground for welding on other components. See para. 7-4.4.13.

(c) Installation of Grounding studs shall be permissible using stud welding techniques.

7-4.4.22 Category M Fluid Service

For thermoplastic-lined metallic piping to be used in Category M fluid service, the designer should follow design rules in ASME B31.3, Chapter VIII.

7-5 Fabrication and Installation

Fabrication and installation of thermoplastic-lined metallic piping components shall comply with the requirements of Sections 5-1 through 5-4. In addition, the requirements in paras. 7-5.1 through 7-5.10 shall apply.

7-5.1 Assembler Qualifications

Assemblers shall be trained and certified to meet the requirements of the owner.

7-5.2 Recommended Installation Practices

(b) Plastic liners may be pressure washed with nozzle tip pressures less than ~~13 790 kPa~~ 13.79 MPa (2,000 psi). Preferred flow should be forward or backward and not radially out to the liner wall.

NOTE: PP, PVDF, PFA, ETFE, E-CTFE, and PTFE plastic-lined pipe and fittings are not designed to be pigged.

7-5.9 External Paint Systems

(a) Plastic-lined pipe and fitting lines may be externally painted before entering service.

(b) The applied paint shall meet the specification requirements of the process as defined by the owner.

(c) External paint may be omitted for some materials, depending on the material of construction and the environment.

(d) If the piping is to be repainted in the field and the surface requires mechanical abrasive cleaning, care should be taken not to damage the plastic flare sealing surfaces.

NOTE: For buried pipelines, host steel pipes are typically sand-blasted, primed, epoxy or urethane coated or painted, followed by overwrapping with adhesively bonded polyethylene tapes.

(e) The openings of vents for all coated and painted pipes shall be kept open. See also para. 7-5.10.

7-5.10 Buried Piping

7-5.10.1 General Guidelines. Buried plastic-lined metallic pipe should be installed in accordance with one of the following:

(a) Guidelines for the Design of Buried Steel Pipelines (2001), issued by American Society of Civil Engineers (ASCE) / American Lifelines Alliance

(b) Manual of Practice No. 119, Buried Flexible Steel Pipe: Design and Structural Analysis by ASCE

7-5.10.2 Pertinent Forces and Access

(a) The installer of the coated and wrapped and cathodically protected steel pipe shall take into consideration all pertinent forces, including

(1) internal pressure

(2) start-up, operating, and shutdown conditions

(3) vertical earth loads

(4) live surface loads

(5) impact loads

(6) thermal strains

(7) additive strains at bends, elbows, and tees

(8) seismic considerations

(b) Annular venting pipes, when used, shall be corrosion proofed and shall rise to above the soil surface with a screened, valved, and U-bend outlet.

7-7.2 Examination

7-7.2.1 General. Examination applies to quality control functions performed by the manufacturer (for components only), fabricator, or erector. Reference in this Standard to an examiner is to a person who performs quality control examinations.

7-7.2.2 Responsibility for Examination. Inspection shall not relieve the manufacturer, the fabricator, or the erector of the responsibility for

(a) providing materials, components, and workmanship in accordance with the requirements of this Standard and of the engineering design

(b) performing all required examinations

(c) preparing suitable records of examinations and tests for the Inspector's use

7-7.2.3 Examination Requirements

7-7.2.3.1 General

(a) Prior to initial operation, each piping installation, including components and workmanship, shall be examined in accordance with the applicable requirements of para. 7-7.2.3.

(b) The type and extent of any additional examination required by the engineering design, and the acceptance criteria to be applied, shall be specified.

(c) Joints and vent openings not included in examinations required by para. 7-7.2.3 or by the engineering design shall be accepted, if they pass the ~~leakagetest~~leakage test required by para. 7-7.3.

7-7.2.3.2 Acceptance Criteria. Acceptance criteria shall be as stated in the engineering design and shall at least meet the applicable requirements for bonds stated below, and in Mandatory Appendix I and requirements elsewhere in the Standard.

(a) Metallic weld acceptance criteria shall be as stated in ASME B31.3, Chapter VI.

(b) Thermoplastic bond acceptance criteria shall be as stated in Mandatory Appendix I.

(c) Casting acceptance criteria shall be as stated in ASME B31.3, Chapter II.

7-7.2.3.3 Defective Components and Workmanship

(a) Defects (i.e., imperfections of a type or magnitude not acceptable by the criteria specified in para. 7-7.2.3.2) shall be repaired, or the defective item or work shall be replaced.

(b) Examination shall be as follows:

(1) When the defective item or work is repaired, the repaired portion of the item or work shall be examined. The examination shall use the same methods and acceptance criteria employed for the original examination.

(2) When the defective item or work is replaced, the new item or work used to replace the defective item or work shall be examined. The examination shall use any method and applicable acceptance criteria that meet the requirements for the original examination.

7-7.2.3.4 Progressive Sampling for Examination. When required spot or random examination reveals a defect, then the following steps shall be taken:

7-7.2.7 Types of Examination

7-7.2.7.1 General

(a) Methods Specified in This Standard. Except as provided in (b), any examination required by this Standard, by the engineering design, or by the Inspector shall be performed in accordance with one of the methods specified herein.

(b) Methods Not Specified in This Standard. If a method not specified herein is to be used, it and its acceptance criteria shall be specified in the engineering design in enough detail to permit qualification of the necessary procedures and examiners.

7-7.2.7.2 Visual Examination

(a) Visual examination of thermoplastic-lined metallic piping includes verification of standard and engineering design requirements for materials; components; dimensions; joint preparation; alignment; welding, bonding, brazing, bolting, threading, or other joining method; supports; assembly; and erection.

(b) Visual examination shall be performed in accordance with the ASME BPVC, Section V, Article 9.

(c) Records of individual visual examinations shall not be required, except for those of in-process examination as specified in para. 7-7.2.7.5.

7-7.2.7.3 Radiographic Examination. Radiographic examination may be used in accordance with ASME B31.3, para. 344.5.

7-7.2.7.4 Ultrasonic Examination. Ultrasonic examination may be used in accordance with ASME B31.3, para. 344.6.

7-7.2.7.5 In-Process Examination

(a) In-process examination comprises examination of the following, as applicable:

(1) joint preparation and cleanliness

(2) ~~preheating~~pre-heating

(3) fit-up, joint clearance, and internal alignment prior to joining

(4) variables specified by the joining procedure, including filler material and the following:

(-a) for welding — position and electrode

(-b) for brazing — position, flux, brazing temperature, proper wetting, and capillary action

(-c) for fusion bonding thermoplastics — bonding time, temperature pressure, and filler material

(5) for welding

(-a) condition of the root pass after cleaning — external and, where accessible, internal examination, aided by liquid-penetrant or magnetic-particle examination when specified in the engineering design

(-b) slag removal and weld condition between passes

(g) appearance of the finished joint

(b) In-process examination shall be visual, in accordance with para. 7-7.2.4, unless additional methods are specified in the engineering design.

7-7.3 Testing

7-7.3.1 Required Leakage Test

(a) Prior to initial operation, each piping system shall be tested to ensure tightness. The test shall be a hydrostatic leakage test in accordance with para. 7-7.3.4, except as provided herein.

(b) At the owner's option, a piping system in Category D fluid service may be subjected to an initial service leakage test in accordance with para. 7-7.3.8, in lieu of the hydrostatic leakage test.

(c) Where the owner considers a hydrostatic leakage test impracticable, either a pneumatic test in accordance with para. 7-7.3.7 or a combined hydrostatic–pneumatic test in accordance with para. 7-7.3.4 may be substituted.

NOTE: There can be a substantial hazard of stored energy in compressed gas. ASME PCC-2, Part 5, Article 5.1, provides extensive requirements for safely performing compressed gas testing.

7-7.3.2 General Requirements for Leakage Test. Requirements in para. 7-7.3.2.1 through 7-7.3.2.7 apply to more all the -types of leakage tests described in this chapter.

7-7.3.2.1 Limitations on Pressure

(a) *Test Fluid Expansion.* If a pressure test is to be maintained for a period of time and the test fluid in the system is subject to thermal expansion, precautions shall be taken to avoid excessive pressure.

(b) *Preliminary Pneumatic Test.* A preliminary test using air at no more than 170 kPag (25 psig) pressure may be made prior to hydrostatic testing to locate major leakage.

7-7.3.2.2 Other Test Requirements

(a) Examination for Leakage. The leakage test pressure shall be maintained for at least 10 min, and then all joints, vent openings, and connections shall be examined for leakage. The test pressure may be reduced to not less than the design pressure during this examination.

(b) The possibility of brittle fracture shall be considered when leakage tests are conducted on brittle materials or at low temperature.

(c) Liners that are not fully seated against the metallic housing can exhibit volume growth during pressurization, thus, pressure decay might not indicate leakage.

(1) Liner growth can result in pressure decay in systems where the pressure source is valved off.

(2) Higher than required test pressures (within the maximum allowable rating for the system) have been shown to accelerate liner seating and reduce pressure decay.

(3) The examiner should confirm leakage with visible indications at flanges or vent openings.

(d) Short-duration liquid drips from vent openings can be caused by aspirated moisture trapped between the liner and housing. This can also occur with sensitive or pneumatic leakage testing.

P_T = minimum test gauge pressure

S = allowable stress at component design temperature for the prevalent pipe material; see ASME B31.3, Table A-1

S_T = allowable stress at test temperature for the prevalent pipe material; see ASME B31.3, Table A-1 ~~in~~

(3) in those cases where the piping system does not include pipe itself, any other component in the piping system, other than pipe-supporting elements and bolting, may be used to determine the S_T/S ratio based on the applicable allowable stresses obtained from ASME B31.3, Table A-1. In those cases where the piping system is made up of equivalent lengths of more than one material, the S_T/S ratio shall be based on the minimum calculated ratio of the included materials.

(4) if the test pressure as defined in eqn. (7-7-1) would produce a circumferential pressure or longitudinal stress (based on minimum pipe wall thickness) in excess of the yield strength at test temperature or a pressure more than 1.5 times the component rating at test temperature, the test pressure may be reduced to the maximum pressure that will not exceed the lesser of the yield strength or 1.5 times the component ratings at test temperature.

7-7.3.5 Hydrostatic Test of Piping with Vessels as a System

(a) Where the test pressure of piping attached to a vessel is the same as or less than the test pressure for the vessel, the piping may be tested with the vessel at the piping test pressure.

(b) Where the test pressure of the piping exceeds the vessel test pressure, and it is not considered practicable to isolate the piping from the vessel, the piping and the vessel may be tested together at the vessel test pressure, provided the owner approves and the vessel test pressure is not less than 77% of the piping test pressure calculated in accordance with para. 7-7.3.4(b)(2).

7-7.3.6 Pneumatic Leakage Test

(a) Precautions. Pneumatic testing involves the hazard of released energy stored in compressed gas. Particular care shall be taken to minimize the chance of brittle failure during a pneumatic leakage test. Test temperature shall be considered when the designer chooses the material of construction. See para. 7-7.3.2.2(b).

(1) Pressure Relief Device. A pressure relief device shall be provided, having a set pressure not higher than the test pressure plus the lesser of 345 kPa (50 psi) or 10% of the test pressure.

(2) Test Fluid. The gas used as test fluid, if not air, shall be nonflammable and nontoxic.

(3) Test Pressure. The test pressure shall be not less than 1.1 times the design pressure and shall not exceed the lesser of

(-a) 1.33 times the design pressure

(-b) the pressure that would produce a circumferential pressure or longitudinal stress (based on minimum pipe wall thickness) in excess of 90% of the yield strength of any component at the test temperature

MANDATORY APPENDIX I

Fusing and ~~Electrofusion~~Electrofusing of Polyamide-11 Thermoplastic Piping; and Fusing of Polypropylene, ~~Poly(vinylidene fluoride),~~Polyvinylidene Fluoride, and Polytetrafluoroethylene Plastic Liners of Lined Steel Pipe

I-1 General Requirements

This Appendix contains requirements for design, fabrication, assembly and erection, examination, inspection, and testing of thermoplastic piping systems for polyamide-11 (PA-11) thermoplastic materials and polypropylene (PP), ~~poly(vinylidene~~polyvinylidene fluoride~~)~~ (PVDF). During the creation of ASME NM~~-~~.1, a review of existing standards revealed that neither ASME BPVC, Section IX, nor any of the American Welding Society standards include Joining Procedure Specifications for ~~(~~PVDF~~)~~,, and polytetrafluoroethylene (PTFE) liners of lined steel pipe. This Mandatory Appendix provides requirements for joining these material types.

NOTES:

(1) The fusion joining of PTFE liners is accomplished by the use of a perfluoro~~(~~ alkoxyalkane~~)~~ (PFA) film interface.

(2) PE liners that are to be fitted into a steel pipe housing are to be fusion welded by the procedures listed in ASME BPVC, Section IX, Part QF, Plastic Fusing, with the exception that the O.D. bead form is to be removed before the fusion-welded line is allowed to move back into the steel pipe bore.

I-2 Scope

The requirements in this Appendix apply to the preparation and qualification of the Joining Procedure Specification (JPS) for fusing and electrofusion joining of PA-11 thermoplastic materials, and PP, PVDF, and PTFE liners of lined steel pipe, and to the performance qualification of the fusing operator using those materials.

I-3 Joining Procedure

Each joining procedure shall be qualified by the employer or the employer's agent.

(a) Tests previously conducted by an employer, the employer's agent, or professional organization may be used to support a JPS in accordance with this Appendix. The Procedure Qualification Record(s) (PQR) shall address all essential variables applicable to the fusing process used, and the test results shall meet all requirements of this Appendix.

(b) The information to be included in the JPS for fusing and electrofusion joining of PA-11 and the fusion joining of PP, PVDF, and PTFE liners is provided in para. 5-2.2~~(~~.1, 5-2~~).~~.2.2 and 5-2.2.3. There are no required formats for JPSs or PQRs. Any format may be used providing all applicable information is recorded, including a certifying statement acknowledging the validity of the data and certifying that the specimens were made and tested in accordance with the requirements of this Appendix.

(c) PQRs shall not be revised except to correct errors or add new or omitted information. All such changes shall be identified, authorized, and dated on the PQR.

I-4 Joining Procedures Qualified by Employers or Agents
I-4.1 Qualification Variables
The qualification variables for the various processes used in making a procedure qualification test joint are listed in Tables I-8-1 (Essential Variables for Heat Fusing Joining Procedure Specification PA-11
), Table I-8-2 (Essential Variables for Electrofusion Joining Procedure Specification PA-11 Electrofusion Couplings) and Table I-8-3 (Essential Variables for Heat Fusion Joining Procedure Specification PP, PVDF, and PTFE/PFA liners).

I-4.2 Approval Tests
(a) The approved tests for qualifying a JPS are listed in section I-~~6~~7.

(b) The test results shall be recorded on or appended to a PQR containing the actual qualification variables.

I-4.3 Acceptance Criteria

(a) If the results meet the acceptance criteria specified, the employer or agent shall sign and date the PQR, indicating that the PQR is an accurate record of the joining and testing of the procedure qualification test specimen.

(b) The employer or agent may then prepare and issue an approved JPS.

(c) The employer or agent shall sign and date the JPS to signify acceptance of responsibility for use of the JPS in production.

I-4.4 JPS Range. Each JPS shall be supported by one or more PQRs, and shall specify a range or a single value for each essential variable applicable to the joining process.

I-4.5 Test for Procedure Qualification. Specified test specimens shall be used for procedure qualification. The specimens used shall be prepared as indicated in the specified test standard.

I-4.6 Control
During the fusing or electrofusion of procedure qualification specimens, fusing operators shall be under the full control and supervision of the employer or agent. The following steps shall be supervised:

(a) preparation of test specimens for fusing or electrofusion

(b) instruction of the fusing operator on use of the fusing or electrofusion joining procedure

(c) performance of fusing or electrofusion

(d) recording of the essential variables used in the fusing or electrofusion test

(e) operator performance examinations and tests

(f) documenting of test results

(g) certification of the final PQR

I-5 Evaluation of Test Specimens
(a) Test specimens shall be subjected to the applicable tests.

(b) Test methods are in Section I-7.

(c) The type, number, and location of tests, and evaluation criteria for tests shall be as indicated in the test standards and in this Standard.

I-6 Size Range for Specimens

I-6.1 Fusing Test Specimens. The limits of fusing test specimens shall be as provided below.

(a) The fusion of a DN 50~~ mm (~~ (NPS 2~~ in.)~~) PA-11 pipe qualifies a fusing operator to fuse DN 13~~ mm~~ to DN 100~~ mm (~~ (NPS $^1/_2$~~ in.~~ to NPS 4~~ in.)~~) PA-11 pipe.

(b) The fusion of a DN 150~~ mm (~~ (NPS 6~~ in.)~~) PA-11 pipe qualifies a fusing operator to fuse DN 100~~ mm~~ to DN 200~~ mm (~~ (NPS 3~~ in.~~ to NPS 8~~ in.)~~) PA-11 pipe.

(c) The fusion of a DN 50~~ mm (~~ (NPS 2~~ in.)~~) PP, PVDF, or PTFE/PFA liner qualifies a fusing operator to fuse DN 25~~ mm,~~, DN 38~~ mm~~, and DN 50~~ mm (~~ (NPS 1~~ in.,~~, NPS 1.5~~ in.,~~, and NPS 2~~ in.)~~) steel pipe lined with PP, PVDF, or PTFE/PFA liners.

(d) The fusion of a DN 100~~ mm (~~ (NPS 4~~ in.)~~) PP, PVDF, or PTFE/PFA liner qualifies a fusing operator to fuse DN 76~~ mm~~ and DN 100~~ mm (~~ (NPS 3~~ in.~~ and NPS 4~~ in.)~~) steel pipe lined with PP, PVDF, or PTFE/PFA liners.

I-6.2 Electrofusion Test Specimen. The limits of electrofusion test specimens are as provided below.

(a) The qualified joining of a DN 50~~ mm (~~ (NPS 2~~ in.)~~) PA-11 electrofusion coupling qualifies a fusing operator to join DN 13 ~~mm~~ to DN 100 ~~mm (~~(NPS $^1/_2$ ~~in.~~ to NPS 4~~ in.)~~) PA-11 couplings.

(b) The qualified joining of a DN 150~~ mm (~~ (NPS 6~~ in.)~~) PA-11 electrofusion coupling qualifies a fusing operator to join DN 100 ~~mm~~ to DN 200 ~~mm (~~(NPS 4 ~~in.~~ to NPS 8~~ in.)~~) PA-11 couplings.

I-7 Test Methods Required for Procedure Qualification

I-7.1 Visual Examination

(a) All fused joints or electrofusion joints shall receive a visual examination of all accessible surfaces of the fused joint.

(b) The visual examination shall be conducted as described in PPI TR-45 for fusing and as required in ~~ASTM F2600 (~~ASME SF-2600~~)~~ for electrofusion couplings.

(c) The visual examination for fused thermoplastic liners shall be conducted per the criteria listed in a published procedure.

(d) Visual examination results shall be recorded on the PQR.

I-7.2 Elevated-Temperature Sustained-Pressure Tests for PA-11 Fused Pipe or Electrofusion Coupling

(a) *Elevated-Temperature Sustained-Pressure Test for Fused PA-11 Pipe.* Elevated-temperature sustained-pressure tests shall not require test to failure. The test shall be performed in accordance with PPI TR-45, as follows:

(1) The test temperature shall be 80°C (176°F).

(2) The hoop stress shall be 12,755 kPa (1,850 psi) [14% above the hoop stress requirement in ~~ASTM D1733 (~~ASME SF-1733~~]~~.

(3) All pipe failures shall be ductile outside of the fusion joint (or ~~nonfailures~~non-failures).

This test shall be conducted using the requirements in ~~ASTM D1598 (~~ASME SD-1598~~)~~. The elevated-temperature sustained-pressure test does not require test to failure in this application. The duration of the test shall be not less than 170 hr. without failure.

(b) *Elevated-Temperature Sustained-Pressure Test for PA-11 Pipe Joined Using Electrofusion Couplings.* This test shall be conducted as described in ~~ASTM F2600 (~~ASME SF-2600~~),~~, using the requirements in ~~ASTM D1598 (~~ASME SD-1598~~)~~.

(1) The temperature shall be constant at 80°C (176°F).

(2) The sustained pressure shall be a pipe fiber stress of 1~~ 000 kPa~~.0 MPa (1,450 psi).

(3) The duration of the test shall not be less than 170 hr.

(4) All pipe failures shall be ductile outside of the fusion joint (or nonfailures).

(5) The elevated-temperature sustained-pressure test does not require test to failure in this application.

I-7.3 Quick-Burst Testing of PA-11 Fused and Electrofused Joints
Quick-burst testing of joints shall be conducted in accordance with ~~ASTM D1599 (~~ASME SD-1599~~)~~, using the requirements from ~~ASTM F2600 (~~ASME SF-2600~~)~~.

(a) Four samples shall be selected at random.

(b) The samples shall be conditioned for 16 hr. prior to testing.

(c) The minimum hydraulic burst pressure shall not be less than that required to produce 26~~,900 kPa~~.9 MPa (3 900-psig) fiber stress in the pipe.

(d) Failure of the fitting or joint shall constitute failure when the pressure is less than in (c).

(e) Failure of one of the four samples shall constitute failure.

I-7.4 Tensile Testing

I-7.4.1 Testing of PA-11 Fused Joints. Tensile testing of PA-11 fused joints shall be in accordance with ~~ASTM D638 (~~ASME SD-638~~)~~ at 5 mm/min (0.2 in./min), and the results shall be reported as required in that standard.

I-7.4.2 Testing of PA-11 Electrofusion Couplings. The testing of electrofusion couplings connected to pipe shall be done in accordance with ~~ASTM F2600 (~~ASME SF-2600~~)~~.
(a) Specimens shall be tested at a tensile stress that causes the pipe to yield or causes the pipe to break outside the joint area.

(b) The tensile test shall be made on the specimen as joined.

(c) Results shall be reported as required in ~~ASTM F2600 (~~ASME SF-2600~~)~~.

I-7.4.3 Testing of Fused PP, PVDF, and PTFE Liner Samples. Tensile testing of fused PP, PVDF, and PTFE liner samples shall be in accordance with ~~ASTM D638 (~~ASME SD-638~~)~~ but at a cross-head speed of 50 mm/min (2.0 in./min).

(a) Specimens shall be tested at a tensile stress that causes the pipe to yield or causes the pipe to break outside the joint area.

(b) Tensile test shall be made on specimen as joined

(c) Results shall be reported as required in ~~ASTM D638 (~~ASME SD-638~~)~~.

I-7.5 High-Speed Tensile Impact Testing (Fused PA-11 Pipe Only)

(a) The tensile impact test method develops adequate tensile impact energy at specific rates of strain to rupture standard tensile impact specimens of butt-fused plastic pipe.

(b) Testing shall be conducted in accordance with ~~ASTM F2634 (~~ASME SF-2634~~)~~.

(1) This test method shall be used to evaluate PA-11 butt joints.

(2) This is a pass–fail test.

(-a) Samples showing elongation are ductile and pass.

(-b) Samples failing in a brittle mode fail.

(3) A graphic representation showing stress–stain is created as the test is conducted. This graph of the test may be used to evaluate ductility.

I-7.6 Hydrostatic Testing of the Butt-Fusion-Welded PP, PVDF, and PTFE Liners for Lined Steel

I-7.6.1 Test Fluid. The fluid shall be water unless there is the possibility of damage due to freezing or adverse effects of water on the piping or process. If such a possibility exists, another suitable nontoxic liquid may be used. If the liquid is flammable, then its flash point shall be at least 49˚C (120˚F), and consideration shall be given to the test environment.

I-7.6.2 Fusion-Welded Samples. A minimum of three fusion welded samples shall be ~~hydrotested~~hydrostatically tested for each liner type for which the fusion operator is being qualified.

1-7.6.3 Mechanical Couplings. The mechanical couplings should not to be installed on the fusion-joined lined steel sample sections that are to be ~~hydrotested~~hydrostatically tested.

I-7.6.4 Fusion-Joined Lined Steel Pipe Samples

(a) The fusion-joined lined steel pipe samples shall be fixtured in a hydrostatic device capable of maintaining a sealing force on the open pipe ends and the welded samples.

(b) The test specimen shall be subjected to a test pressure of ~~3103 kPa~~3.103 MPa (450 psig) for a minimum of 10 minutes per the requirements of ASME B31.3, para. A345.4.

I-7.6.5 Alternate (Pneumatic) Sensitive Leak Test. An alternate (pneumatic) sensitive leak test may be performed with the owner’s approval. See ASME B31.3, para. A345.5.

I-7.6.6 Test Results. Test results shall be recorded in the Joining Procedure Qualification. A passing grade shall be given if there is no leakage of the test fluid or test gas through the fusion-welded joint.

I-7.7 Joint Integrity Tests for Electrofusion Couplings

(a) A joint integrity test shall be conducted on electrofusion joints.

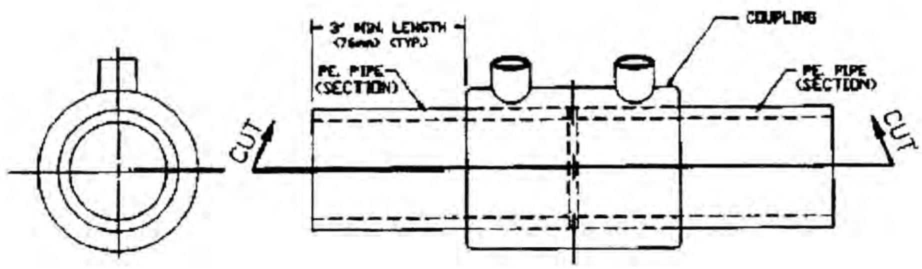
(b) The test shall be conducted using a vise to crush one-half of a split electrofusion coupling. Figure I-7-1 shows a half coupling.

(c) Instructions for specimen preparation are provided in ~~ASTM F2600 (~~ASME SF-2600~~).~~.

(1) This test provides an evaluation of the bonding strength between the pipe and fitting.

(2) Separation of the fitting from the pipe at the fusion interface shall constitute failure.

Figure 1-7-1 Instruction on Preparing and Cutting Electrofusion Coupling for Crush Test



I-7.8 Joint Crush Test

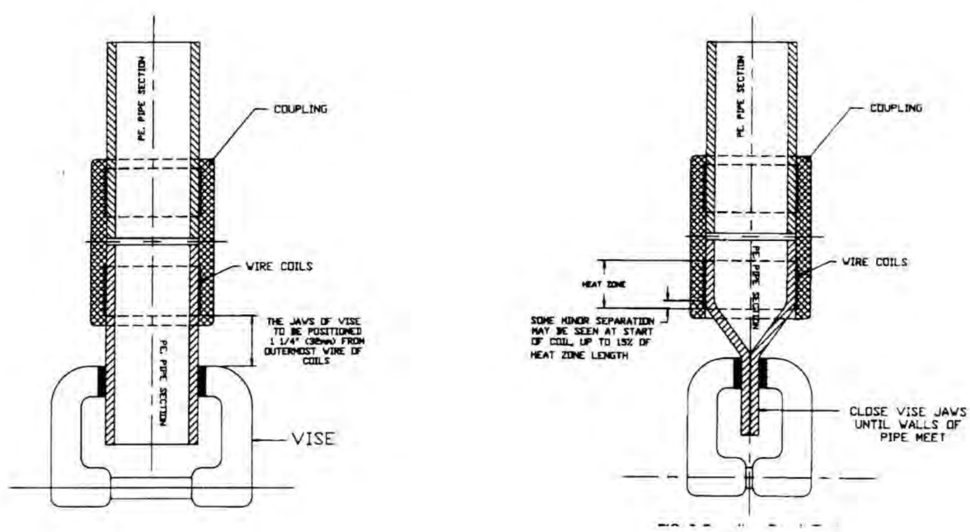
(a) A joint crush test shall be conducted on electrofusion joints.

(b) The test shall be conducted using a vise to crush the specimen (see Fig. I-7-2) as described in ~~ASTM F2600 (~~ASME SF-2600~~),~~, and the results reported as required in that standard.

(1) This test provides an evaluation of the bonding strength between the pipe and fitting.

(2) Minor separations shall be acceptable, but more than 15% separation of the heat-zone length shall constitute failure.

Figure I-7-2 Joint Crush Specimens in Vise



I-7.9 Saddle-Type Joint Crush Test

Electrofusion saddles shall be tested using a saddle-type joint crush test as described in ~~ASTM F2600 (~~ASME SF-2600~~),~~, and results reported per that standard.

(a) Pipe fused to the fitting is placed in the jaws of the vise.

(b) The jaws of the vise are closed.

(c) Separation of the pipe from the fitting at the fusion interface shall constitute failure.

I-7.10 Hydrotesting for Metallic Piping Lined With Fused PP, PVDF, or PTFE/PFA

(a) A representative section of lined steel pipe butt-fused at the midpoint, with a PP, PVDF, or PTFE/PFA liner and a combined length of approximately 203 mm (8 in.), shall be clamped in a pressure test unit such that the fusion-welded section can be subjected to a hydrostatic test pressurized to no less than 1.5 times the ASME Class 150 steel flanged-spool rating [2944 kPa (427 psig)] for a minimum of 10 min.

(1) The test section shall not have mechanical coupling installed.

(2) Any fluid leakage through the test section's fusion-welded joint shall constitute failure.

(b) Test Pressure

(1) The hydrostatic test pressure at every point in a metallic piping system shall be not less than 1.5 times the design pressure.

(2 When the design temperature is greater than the test temperature, the minimum test pressure, at the point under consideration, shall be calculated using eq. (I-7-1).

$$P_T = 1.5PS_T/S \qquad \text{(I-7-1)}$$

where

P = internal design gauge pressure
P_T = minimum test gauge pressure
S_T = allowable stress at test temperature for the prevalent pipe material; see ASME B31.3-2014, Table A-1
S = allowable stress at component design temperature for the prevalent pipe material; see ASME B31.3-2014, Table A-1

(c) In those cases where the piping system does not include pipe itself, any other component in the piping system, other than pipe-supporting elements and bolting, may be used to determine the S_T/S ratio based on the applicable allowable stresses obtained from ASME B31.3 Table A-~~1In~~1. In those cases where the piping system is made up of equivalent lengths of more than one material, the S_T/S ratio shall be based on the minimum calculated ratio of the included materials.

3. If the test pressure as defined above would produce a circumferential pressure or longitudinal stress (based on minimum pipe wall thickness) in excess of the yield strength at test temperature or a pressure more than 1.5 times the component rating at test temperature, the test pressure may be reduced to the maximum pressure that will not exceed the lesser of the yield strength or 1.5 times the component ratings at test temperature.

I-8 Essential Variables for Fusing PA-11

The essential variables for fusion joining of PA-11 are listed in Table I-8-1; those for electrofusion joining of PA-11 are listed in Table I-8-2; and those for heat-fusion joining of PP, PVDF, and PTFE/PFA liners are listed in Table I-8-3.

Table I-8-3 Essential Variables for Heat Fusion Joining Procedure Specification PP, PVDF, and PTFE/PFA Liners

Description of Variable	Essential	Nonessential
Joint type: Butt fusion	X	
Steel-pipe-to-liner cutback dimension		X
Appearance of liner at O.D. and I.D. of cutback		X
Installation of mechanical coupling onto one section of the to-be-joined piping [Note (1)]		X
Installation of wind bag around heater for PTFE/PFA liner weld	X	
Warming of steel pipe ends where installation is to be done at ambient temperatures below 45°F (7°C)	X	
Construction of onion-skin-type shelter around weld location to protect against inclement weather	X	
Fusing equipment manufacturer	X	
Correct distance fixturing of the steel pipe end within the fusing equipment		X
Alignment of pipe-liner surface and wall thickness	X	
Material (liner type)	X	
Trimming of liner ends with a facing tool to the proper dimension		X
Heater plate type	X	
Verification of heater plate surface temperature	X	
Weld position (only horizontal welds allowed)		X
PFA film thickness for fusing PTFE liners		X
Initial PP and PVDF bead size in contact with the heater plate	X	
Initial applied pressure against the heater plate to ensure intimate contact of the PTFE with the PFA film	X	
Removal of excess PFA film from heating plate after initial PTFE liner contact with heater plate	X	
Permissible open time between heater removal and welding	X	
Applied pressure for making weld	X	
Heater plate placed back in the metallic storage container to avoid damage		X
Cooldown time	X	
For PP and PVDF liners: Bead size and shape and/or appearance	X	
Joint appearance for PTFE fusion-welded liners	X	
PTFE fusion-welded connection wrapped with PTFE tape prior to mechanical coupling installation		X
~~Joint type: Butt fusion~~		~~X~~

NOTE:

(1) Make sure that coupling is a vented type for PTFE-lined piping.

I-8.1 Heater Removal Time

I-8.1.1 Butt-Fusion Welding of PA-11. The table below provides the maximum heater removal times that shall be used for butt-fusion welding PA-11.

Pipe Wall Thickness, mm (in.)	Maximum Heater Removal Time, s
1 to less than 9 (0.18 to 0.40)	8
9 to 15 (0.4 to 0.60)	10
15 to 31 (0.6 to 1.20)	15

Note: This is the maximum permitted time between the removal of the heater plate and the bringing together ~~of~~ the ~~liner~~ ends to form the weld.

I-8.1.2 Butt-Fusion Welding of PP, PVDF, and PTFE Liners. The table below provides the maximum heater removal times that shall be used for butt-fusion welding PP, PVDF, and PTFE liners.

Liner Type	Maximum Heater Removal Time, s [Notes (1) and (2)]
PP	5
PVDF	5
PTFE	3 to 5

NOTES:

(1) This is the maximum permitted time between the removal of the heater plate and the bringing together of the liner ends to form the weld.

(2) The differences between heater removal times for the PP, PVDF, and PTFE liners and those for PA-11 (see para. I-8.1.1) are due to differences in thickness — i.e., the liners are thinner than PA-11 pipe — and in the characteristics of the materials.

I-8.2 Beads

A bead is formed during the butt-fusion process. A typical bead is shown in Figure I-8-1. A typical manual fusion machine is shown in Figure I-8-2.

Figure I-8-1 Polyethylene Pipe Butt-Fusion Joint O.D. Bead (Cross Section View)

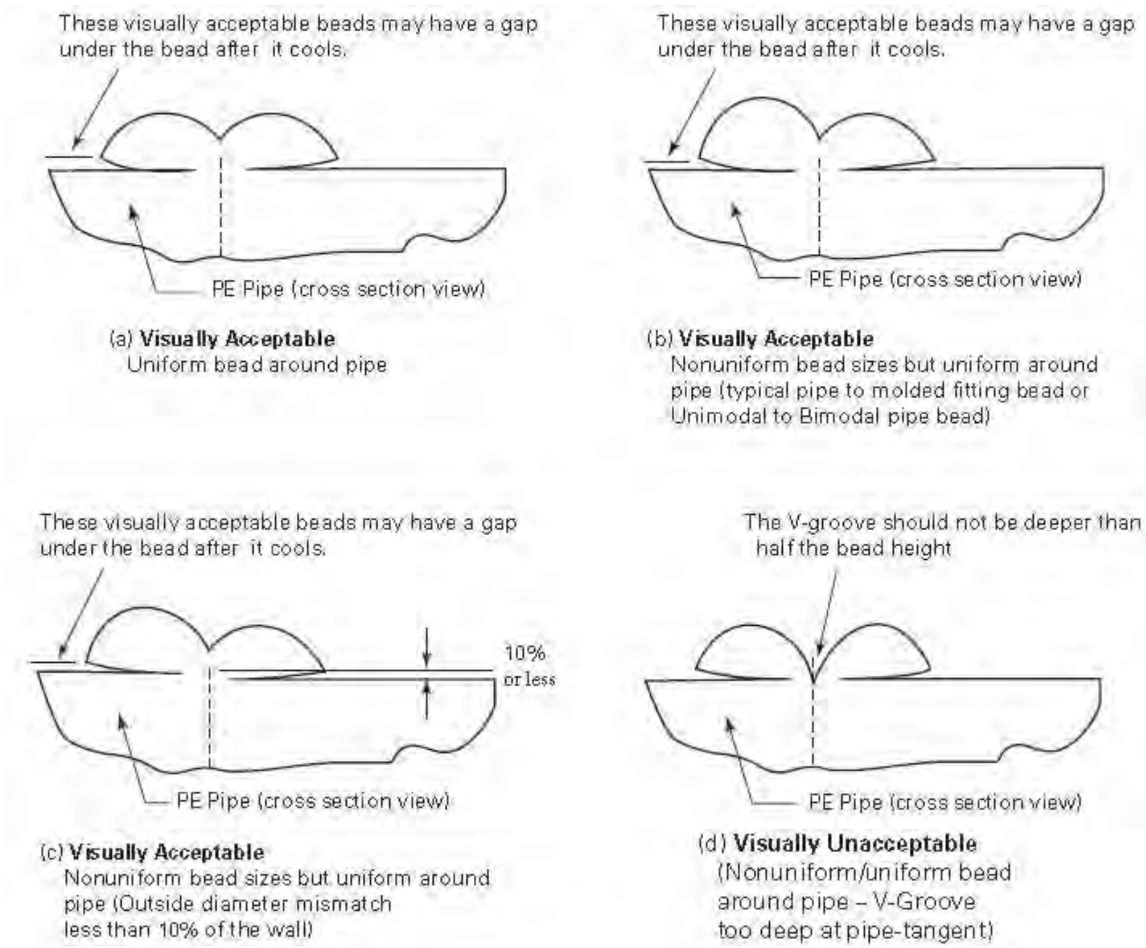
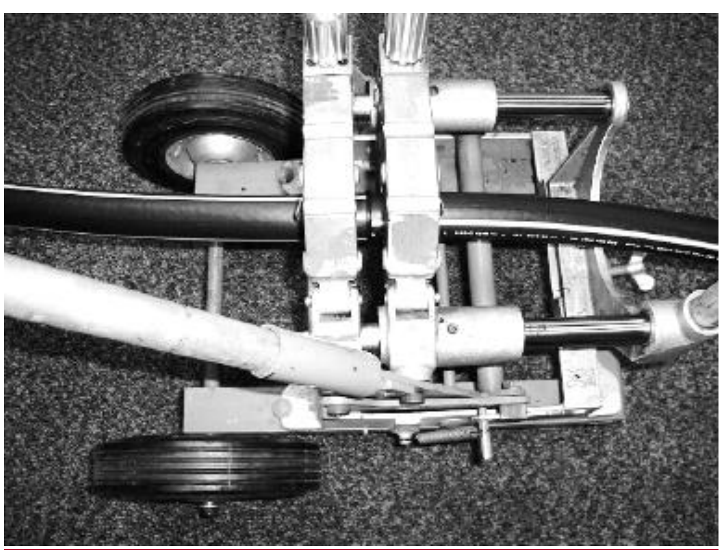


Figure I-8-2 Butt Fusion of PA-11 Using Manual Fusion Machine



I-8.2.1 Bead Size for Butt Fusion. The tables below provide maximum bead sizes that shall be formed during butt fusion of defined materials.

(a) *Typical Butt-Fusing Bead Sizes for PA-11*

Pipe Size, mm (in.)	Typical Fusing Bead Size, mm (in.)
40 and smaller (1.25 and smaller)	1 to 2 ($^1/_{32}$ to $^1/_{16}$)
Greater than 40 to less than 90 (1.25 to 3)	3 to less than 5 ($^1/_{32}$ to $^1/_{16}$)
90 to 225 (3 to 8)	3 to 5 ($^1/_8$ to $^5/_{16}$)

GENERAL NOTE: When the proper bead size is formed against the heater surfaces all around the pipe or fitting ends, remove the heater. Melt bead size is dependent on pipe size.

(b) Typical Butt-Fusing Bead Sizes for PP and PVDF Liners

Pipe Size, mm (in.)	Typical Fusing Bead Size, mm (in.)
25 to 50 (1 to 2)	4.8 to 6.4 ($^3/_{16}$ to $^1/_4$)
75 to 100 (3 to 4)	6.4 to 7.9 ($^1/_4$ to $^5/_{32}$)

GENERAL NOTE(S):

(a) There is no bead formed when PTFE liners are butt fused together with a PFA film interface.

(b) The dimensions in this table refer to bead size on the liner after fusion.

I-8.2.2 Bead Appearance

(a) PA-11 Fusion Beads. The presence of bubbles on the (PA-11 fusion bead shall not be reason for rejection.

NOTE: The PA-11 material absorbs moisture from air. This moisture creates bubbles in the beads. The bubbles are limited to the beads and do not affect the strength of butt-fusion joints. See PPI TR-45 for pictures of typical beads with bubbles.

(b) Fusion Beads for PP and PVDF Liners. Fusion beads for PP and PVDF liners joints shall meet the size criteria shown in the para. I-8.2.1(b) and shall be uniform in size around the entire liner joint.

NOTES:

(1) The outward edge of the bead shall be completely rolled over and touching back with the liner O.D. surface.

(2) Beads shall not be wavy as this indicates that the heater plate was too hot.

(3) There shall be a minimum 2-mm ($^1/_{16}$-in.) gap between the outward edge of the bead and the steel pipe end. Beads cannot touch the steel pipe end.

(4) Air bubbles shall not appear in the bead or fusion joints. This applies to PP, PVDF, and PTFE/PFA liners.

(c) PTFE/PFA Liner Joints. The PTFE/PFA liner joint shall appear as a straight liner joint with the location raised slightly outward to less than 1 mm ($^1/_{32}$ in.).

(1) The PFA film shall be uniformly visible over the entire 360-deg surface of fusion weld and protruding slightly out past the weld O.D. surface.

(2) There shall be no obvious gaps where there is no PFA film between the two PTFE liner ends.

I-9 Verification of Essential Variables

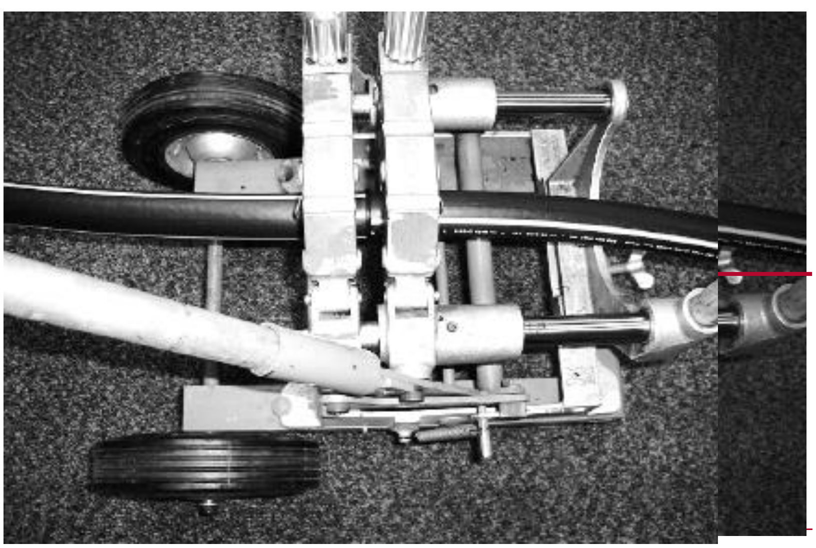
The essential variables for butt fusion of PA-11 plastic piping are discussed in para. I-9.1; those for electrofusion of PA-11, in para. I-9.2; and those for butt fusion of PP, PVDF, and PTFE/PFA pipe and fitting liners, in para. I-9.3.

I-9.1 Essential Variables for Butt Fusion of PA-11

Figure I-~~9-1~~8-2 shows a manual fusing machine used to make PA-11 fusion joints. The joint shall be made by heating the ends of PA-11 pipe as describe in the JPS.

The essential variables for butt-fusion of PA-11 are as follows:

~~Figure I-9-1 Butt Fusion of PA-11 Using Manual Fusion Machine~~



(a) Pipe Surface Alignment. The maximum misalignment of the PA-11 pipes shall be 10% of the wall thickness.

(b) Material

(1) The requirements for procedure qualifications are limited to PA-11 pipe or fittings butt fused or electrofused.

(2) The PA-11 shall meet the requirements of Group 2, Class 2, and Grade 3 (PA 32312) as described in ASTM D6779.

(c) Wall Thickness and Cross-Sectional Area. The cross-sectional area is used to determine the force needed to make a PA-11 butt-fusion joint.

(d) Interfacial Pressure. When the owner has selected ~~ASTM F2600 (~~ASME SF-2600~~)~~ for the parameters to fuse PA-11, the interfacial pressure required shall be 414 kPa to 621 kPa (60 psi to 90 psi).

NOTE: This interfacial pressure was determined by testing published in PPI TR-45.

(e) Heater Surface Temperature. The heater temperature required to join PA-11 shall be 257°C to 263°C (495 to 505°F).

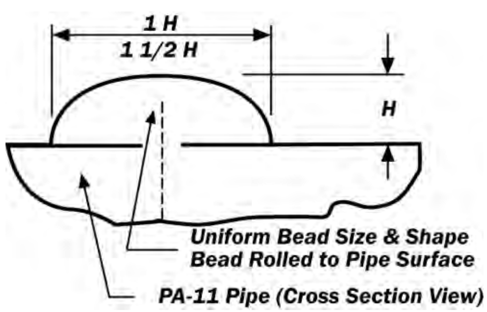
(f) *Heater Removal Time.* Heater removal times shall be as provided in para. I-8.1.1.

(g) Bead Size, Shape, and Appearance. The bead size shall be as provided in para. I-9.2.1(a). See also Figure I-9-~~2~~1.

NOTES:
(1) This bead-size data is provided in PPI TR-45.
(2) The shape of the bead is different from that for polyethylene pipe.

(b) See Figure I-9-~~2~~1 for a drawing from PPI TR-45.

Figure I-9-~~2~~1 Cross-Sectional View of PA-11 Butt-Fusion Bead



GENERAL NOTES:

(a) Figure is adapted with permission from PPI TR-45 (TR-45/2016; Butt Fusion Joining Procedure for Field Joining of Polyamide-11 (PA-11) Pipe, page 13, Figure C.1. Illustration of a Properly Made PA-11 Butt Fusion Joint).

(b) H= bead height

(c) The presence of bubbles in the bead is normal, and varies with the amount of absorbed water in the pipe and/or fitting. When PA-11 pipe is butt fused to molded fittings, the fitting-side bead can have an irregular appearance.

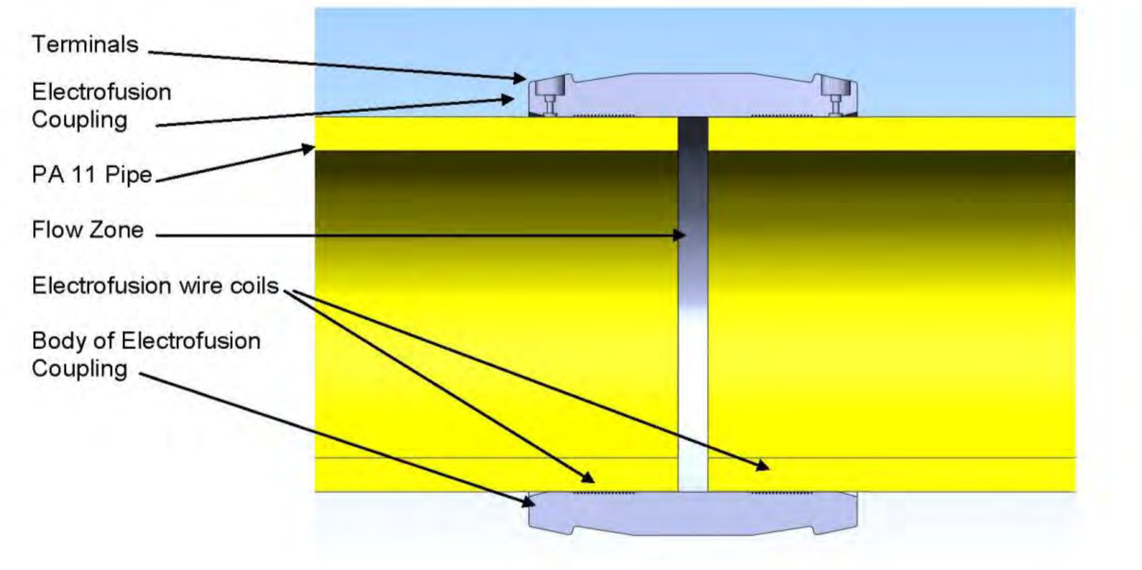
(h) Cooldown Time. Cooldown time for a PA-11 butt fusion shall be at 12 min/25 mm (12 min/in.) of pipe wall thickness.

I-9.2 Essential Variables for Electrofusion Joints

Electrofusion coupling joints shall be made using two pieces of pipe and one electrofusion coupling. See Fig. I-9-~~3~~2. Saddle electrofusion joints shall be made using an electrofusion saddle and a piece of PA-11 pipe.

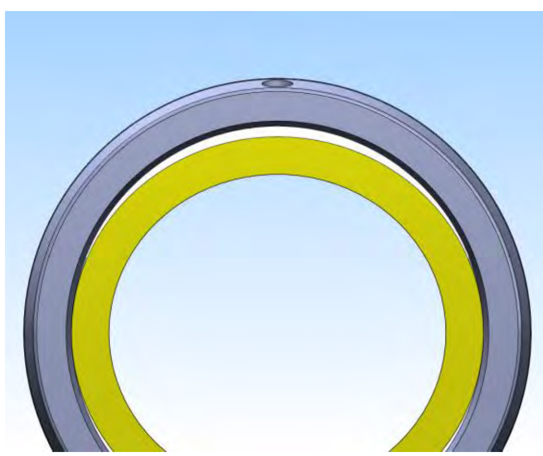
The essential variables for electrofusion joints are as follows:

Figure I-9-~~3~~2 Cross-Sectional View of an Electrofusion Coupling



(a) Fit-Up Gap. The fit-up gap shall be the space between the pipe and the electrofusion coupling or saddle that is not in contact with the coupling and the pipe or the saddle and the pipe. See Figure I-9-~~4~~3.

Figure I-9-~~4~~3 Fit-Up Gap



(b) Material

(1) The requirements for procedure qualifications shall be limited to PA-11 pipe or fittings butt fused or electrofused.

(2) The PA-11 shall meet the requirements of Group 2, Class 2, and Grade 3 (PA 32312) as described in ASTM D6779.

(c) Coupling or Saddle Manufacturer. Each manufacturer uses its own distinct processes to make its electrofusion couplings or saddles.

(-a) PP homopolymer per ~~ASTM D4101 (~~ASME SD-4101~~)~~, Type II

(-b) PVDF copolymer per ~~ASTM D5575 (~~ASME SD-5575~~)~~

(-c) PTFE (ram-extruded pipe liner) per ~~ASTM D4894 (~~ASME SD-4894~~)~~, Type V; and PTFE fittings (isostatically molded liner) per ~~ASTM D4894 (~~ASME SD-4894~~)~~, Type IV, Grade 1 or Grade 2.

(-d) PFA film used as the weld interface to make the PTFE fusion weld per ~~ASTM D3307 (~~ASME SD-3307~~)~~, Type II

(f) Heater Plate Type

(1) The designated heater plate for fusing PP and PVDF liners shall have a nonstick PTFE coating that accommodates the 232˚C (450°F) fusion joining temperature.

(2) The designated heater plate for fusing the PTFE liners with the PFA film interface shall be coated with a special nonstick (metallic-colored) alloy coating that can accommodate the 418°C (785˚F) fusion weld temperature.

NOTE: The metallized heater plate shall not be used for welding PP or PVDF liners. The PP and PVDF liner ends may be charred at the PTFE weld temperatures, resulting in transfer of charred debris to other fusion welds that will result in a joint leak.

(3) The heater plate type used shall be recorded on the Fusion Weld Log.

(g) Heater Plate Surface Temperature

(1) *PP and PVDF Liners.* For fusing of PP and PVDF pipe and fitting liners, the heater plate temperature shall be 232˚C ± 6˚C (450°F ± 10°F). The fusing temperature shall be as recommended by the supplier of the plastic-lined steel pipe. The heater plate temperature shall be verified with a digital pyrometer and recorded on the Fusion Weld Log and/or by a data logger.

(2) *PTFE Liners*

(-a) For fusing of PTFE pipe and fitting liners, the heater plate temperature shall be 418˚C ± 2˚C (785°F ± 5°F). The heater plate temperature shall be verified with the output reading on the built-in temperature gauge and recorded on the Fusion Weld Log.

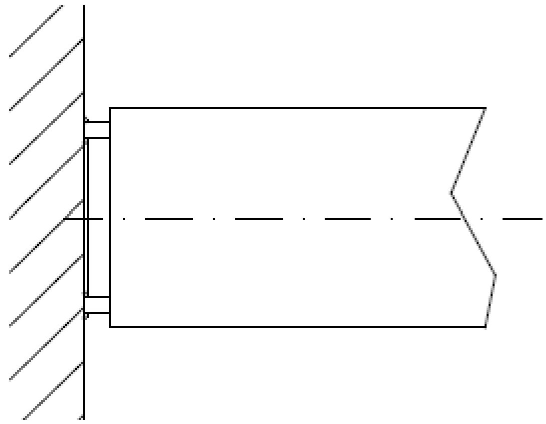
(-b) A wind bag is a device (heat-resistant cloth) that is positioned directly underneath and around the PTFE-lined pipe ends that are to be butt-fusion joined. Its purpose is to prevent a chimney effect of cooler air moving up past these heated pipe ends and reducing the liner temperature. The use of the wind bag shall be recorded on the Fusion Weld Log.

(h) Initial PP and PVDF Bead Size in Contact With the Heater Plate. A small, uniform 2-mm ($^{1}/_{16}$–in.) diameter bead shall be formed all the way around each PP or PVDF liner end. A uniform bead indicates that there is a positive contact with the heater plate. (See Fig. I-9-~~5~~4.)

(1) The fusion operator shall apply a force of 18 N to 27 N (4 lbf to 6 lbf) to make this initial bead.

(2) When fusing is performed aboveground up in the pipe rack, care shall be exercised such that the electrical cord does not become restrained, causing the heater plate to tilt to one side and resulting in uneven bead formation and heating.

Figure I-9-~~5~~4 Cross-Sectional View of a PP and PVDF Butt-Fusion Liner Bead Formed Against the Heater Plate



GENERAL NOTES:
(a) The bead shall be uniform around the liner.
(b) Beads form only with PP and PVDF liners. No bead is present when PFA film is sandwiched between the PTFE liner and the heater plate.

(i) Initial Interfacial Pressure of the PTFE Liner Against the PFA Film Next to the Heater Plate. For the first 30 sec when heating the PTFE liner ends for making the PTFE fusion weld, the fusing operator shall apply 111 N to 133 N (25 lbf to 30 lbf) to the liner ends so that there is intimate contact with the PFA film that is now sandwiched between the PTFE liner end and the heater plate. This initial pressure ensures that the melted PFA film is able to migrate into the microstructure of the PTFE liner, further anchoring the PFA interfacial layer in place.

NOTE:

(1) Failure to apply initial interfacial pressure can result in a weld with poor tensile strength.

(j) Removal of the Excess PFA Film. After the PTFE liner ends have sandwiched the PFA film against the heater plate, the excess film material shall be removed prior to removal of the heater plate.

NOTES:

(1) When the heater plate is removed, any excess PFA film adhering to the heater plate can be dragged across the PTFE liner end, thereby pulling off some of the desired film material and resulting in poor weld strength.

(2) Removal of the excess PFA film is accomplished by use of a PTFE spatula.

(k) Permissible Liner-End Open Time after Heater Plate Removal. Paragraph I-8.1.2 provides the maximum permissible open time between the removal of the heater plate and the bringing together of the PTFE liner ends to form the weld.

(l) Application of Liner Contact Pressure

(1) For making PP or PVDF fusion welds, the fusion operator shall apply enough even liner contact pressure to create a uniform bead rollover on both sides of the weld, such that the leading bead outside edge touches the liner surface O.D. The bead-size requirements are listed in para. I-9.2.1(b).

NOTES:
(1) The amount of contact pressure will be a function of the pipe diameter and the wall thickness of the thermoplastic liner.
(2) Applying too much pressure will drive the liner ends through the melted plastic zone, resulting in a weld with poor

(3) In place of the elevated temperature sustained pressure test, the manufacturer of the pipe or of the resin can provide times and temperatures as are shown for other thermoplastics in EN 12814-3 and prior testing.

NOTES:
(1) Since PA-11 is not listed in EN 13067, for operator qualification, testing as described in para. I-9.2 shall be conducted for international use.
(2) The standards listed for International Joining Procedure Qualifications may be used in countries other than the United States provided they are acceptable in the country of use.

I-10.3 Standard Joining Procedure Specifications for Plastic-Lined Steel Pipe

(a) For joining plastic-lined steel pipe liners, refer to the published SJPS that addresses the fusing variables listed in Table I-8-3.

(b) Organizations may use a SJPS for production fusing without further qualification.

I-10.4 Contents of the SJPS

(a) The SJPS shall address all of the essential and nonessential variables listed in Tables 1-8-1, I-8-2, and I-8-3.

(b) The organization may include any additional information in the SJPS that can be helpful in making a fused joint.

I-10.5 Changes in Documented Parameters

Changes in the documented parameters of a SJPS beyond the limits specified in Tables I-8-1, I-8-2 or I-8-3 shall require the qualification of a new JPS.

I-11 Qualification of a Fusing Joining Procedure Specification

I-11.1 PA-11 Butt-Fusing Joining Coupons

(a) The PA-11 butt-fusing joint coupons shall be prepared in accordance with the JPS using the following combinations of heater temperature ranges and interfacial pressure ranges:

(1) high heater surface temperature and high interfacial pressure, five joints

(2) high heater surface temperature and low interfacial pressure, five joints

(3) low heater surface temperature and high interfacial pressure, five joints

(4) low heater surface temperature and low interfacial pressure, five joints

(b) Each fused joint shall be subject to visual examination per PPI TR-45 or EN 13100-1.

(c) Two fused joints of each combination described in (a)(1) through (a)(4) shall be evaluated using the elevated-temperature sustained pressure tests for pipe specified in PPI TR-45 or as defined for PA-11 for tensile creep test (EN 12418-3) by prior testing [see I-9.2 (b)(3)].

(d) Three joints of each combination described in (a)(1) through (a)(4) shall be evaluated using the high-speed tensile impact test specified in para. I-6.5 or as required in EN-12418-7 or ISO 13953. The specimen shall be ductile and have a welding factor of 0.8 or higher ISO/EN applications.

I-11.2 Coupons for Acceptance of the JPS

If the coupons described in I-10.1 pass the specified test, the JPS using the range of temperature, interfacial pressure, and cooling times shall pass and be allowed as a new JPS.

I-11.3 Procedure Qualification~~-~~ for Joining PP, PVDF and PTFE/PFA Steel Pipe Liners

The JPS or SJPS shall be used to qualify procedures for joining PP, PVDF, and PTFE/PFA steel pipe liners.

I-12 Qualification of an Electrofusion Joining Procedure Specification

The PA-11 electrofusion coupling shall be prepared in accordance with the JPS using the following test methods:

(a) Four electrofusion couplings selected at random shall be quick-burst tested as required in ~~ASTM F2600 (~~ASME SF-2600~~)~~ and fail in a ductile manner.

(b) Four electrofusion couplings selected at random shall be tested using the elevated-temperature sustained-pressure test described in ~~ASTM F2600 (~~ASME SF-2600~~)~~. There shall be no failures in a 170-hr test period.

(c) Four electrofusion couplings selected at random shall be tested using the tensile test described in ~~ASTM F2600 (~~ASME SF-2600~~)~~.

(1) The tensile test shall be conducted as required in this Standard and the results reported as pass or fail.

(2) If all samples pass, no additional testing shall be required. If samples fail, then additional samples shall be selected and tested again.

(3) If all samples pass the second test, then the test shall be considered acceptable.

(d) Joint integrity test shall be conducted on four electrofusion couplings and four electrofusion saddles as described in ~~ASTM F2600 (~~ASME SF-2600~~)~~.

(1) The results shall be reported as pass or fail.

(2) If all samples pass, no additional testing shall be required. If samples fail, then additional samples shall be selected and tested again.

(3) If all samples pass the second test, then the test shall be considered acceptable.

I-13 Fusing Operator Qualification

I-13.1 General

(a) Qualification of a PA-11 fusing operator requires that the operator make a specimen in accordance with ASTM F2600 or the requirements in this Standard.

NOTE: The operator may be qualified to fuse all sizes and wall thicknesses that are within the range of the fusing machine by being trained on fusing the smallest size in DR 11 or lower and the largest size in DR 17 or lower that the machine is capable of fusing.

(b) Qualification of a fusing operator for joining liners requires that the operator make specimens in accordance with the requirements for the specific liner types.

(c) The fusing equipment used to qualify butt-fusion operators shall be of the same type and manufacturer as that used in the field.

NOTE: An automated data logger or manual record of the fusing parameters may be used make the test specimen shall be provide for documentation.

(d) Currently Qualified Personnel. Personnel currently qualified by the employer or agent to the requirements in this Appendix shall be considered qualified under this Appendix, provided the basis for their qualification meets all the requirements of this Appendix. In such cases, a certification form shall be initiated and signed by the employer to verify in compliance with this Appendix.

I-13.2 Fusing Operator Test

The fusing operator test shall comprise a written examination and a performance test.

I-13.2.1 Written Examination

(a) The supervisor shall be trained to the requirements of I-13.2.1 (a~~-~~) through (d). The trained supervisor shall supervise the testing.

(b) The written test shall consist of a minimum of 20 questions.

(c) The operator shall answer 80% of the questions correctly.

(d) The written test shall cover

(1) safety

(2) fundamentals of the fusing process

(3) identification of typical fusing errors

(4) fusion equipment operation and maintenance

(5) Fusing Procedure Specification to be used by operator for butt fusion or electrofusion

(6) Data logger operation (for hydraulic fusing machines or electrofusion universal controllers)

(7) visual inspection of the finished joint

(8) destructive test methods or performance tests

I-13.2.2 Performance Qualification Testing

(a) Performance qualification testing shall be in accordance with the testing requirements of the referenced standards or this Appendix.

(b) The fusing operator taking performance qualification tests shall be under the full supervision and control of a qualified supervisor during the fusing of test specimens.

I-13.2.3 Performance Qualification Records (PQR). For each fusing operator seeking qualification, a qualified supervisor shall compile a Performance Qualification Record (PQR) that documents both acceptable and unacceptable test results.

(a) There is no required format for PQR. Any PQR format may be used.

(b) The documentation shall identify, at a minimum

(1) the JPS used

(2) the essential variables required for the JPS

(3) the written test, and the examination methods used to evaluate the test specimens

(4) the limits of qualification for the fusing operator, i.e., whether the fusing operator is qualified only for certain sizes or liner types

(5) The supervisor shall be trained to the requirements of para. I-13.2.1 (a-) through (d). The trained supervisor shall supervise the testing

I-13.2.4 Acceptance of Test Results

(a) Acceptance of test results shall be responsibility of the qualified supervisor or agent.

(b) Qualification records shall be signed and dated by the qualified supervisor or agent after satisfactory completion of the written examination and performance test.

(c) Qualification records shall reference and may include mechanical test and nondestructive examination test reports that are signed by others.

(d) An Operator Identification number is assigned to the fusing operator when the fusing written test and test specimens are approved by the qualified supervisor or agent. The fusing Operator identification number is recorded in Fusing Operator Identification log or other list of Operator identification numbers.

I-13.2.5 Test Failure. A fusing operator who fails the written test or the performance test may be retested at the option of the qualified supervisor.

(a) If the fusing operator fails the written examination, he/she shall first pass the written examination before taking the performance test.

(b) If the fusing operator passes the written examination but fails the performance test, the qualified supervisor shall determine the training needed and then retrain as required before allowing the fusing operator to take the performance test.

I-13.3 Expiration and Revocation of Performance Qualification, and Requalification

(a) The performance qualification of a fusing operator shall be affected when one of the following conditions occurs:

(1) When the fusing operator has not fused PA-11, PP, PVDF, or PTFE/PFA during a period of six months, his or her qualifications for this process shall be considered expired.

(2) A fusing operator whose qualification expires as a result of (a)(1) shall be permitted to requalify by making one test fusion. If the test fusion meets the requirements of the JPS, then all of the fusing operator's previous qualifications for fusing PA-11, PP, PVDF, and PTFE/PFA shall be reinstated.

(3) When there is a specific reason (e.g., one or more failed butt-fusion joints) to question a fusing operator's ability to make fusion joints that meet the specification, the operator's qualifications for that type of fusing shall be revoked.

(4) A fusing operator whose qualification is revoked as a result of(a)(3) shall be permitted to requalify by first passing the written examination and then successfully completing the performance qualification test(s) that support the qualification(s) questioned.

(b) Maximum duration of fusing operator's qualification shall be 1 yr.

NOTE: Requalification within a time frame shorter than 1 yr can place an undue economic burden on the owner or operator.

(-c) Butt-fusing pressure applied during the fusing/cool cycle should be calculated to include the drag pressure. The drag pressure shall be within the JPS or SJPS range for the applicable size (e.g., pipe diameter). The calculated drag pressure plus the fusion pressure should agree with the recorded hydraulic fusing pressure.

NOTE: No drag pressure is used when calculating fusion pressure for PP, PVDF, and PTFE liners when a manual fusing machine is used. Butt-fusing pressure shall be reduced to a value less than or equal to the drag pressure at the beginning of the heat soak cycle,

(2) When a manual butt-fusion machine is used, instructions shall provide

(-a) visual indications of the size

(-b) shape of the butt-fusion bead when heat and pressure are applied

(3) The fusing machine shall be opened at the end of the heat soak cycle, the heater removed, and the pipe joint ends brought together at the fusing pressure within the time frame specified by the JPS or SJPS.

(4) Cooling time at butt-fusing pressure shall be the minimum time specified by the JPS or SFPS. If the recorded data is outside the limits of the JPS or SJPS, the joint shall be declared unacceptable.

(5) In addition to the data listed above, for PA-11, documentation of the essential variables listed in Table I-8-1 shall be noted. The additional data listed above and the essential variables for fusion welding of PP, PVDF and PTFE steel pipe liners are provided in Table I-8-3.

(b) *Electrofusion Joint for Evaluation*

(1) All essential variables listed in Table I-8-2 shall be recorded.

(2) Each element listed in Table I-8-1 and Table I-8-2 shall be considered during operator evaluation.

(3) There shall be no electrical fault during fusing operation.

I-13.4.6 Visual Examination of Test Specimens

(a) For pipe and electrofusion coupons, all surfaces shall be examined visually before cutting specimens.

(b) Pipe test coupons shall be visually examined as outlined in paras. I-13.4.6.1 and I-13.4.6.2.

I-13.4.6.1 Visual Examination

I-13.4.6.1.1 Butt Fusion PA-11

There shall be no visible evidence of cracks or incomplete fusing. Bubbles are allowed in the fusion beads shall exhibit proper fused bead configuration. See Figure I-9-~~2~~1 for proper configuration.

(a) Fused joints shall not display visible angular misalignment, and outside diameter mismatch shall be less than 10% of the nominal wall thickness.

(b) The data record for the fusing operator performance qualification test shall be reviewed and compared to the JPS or SJPS to verify observance of the specified variables applied when completing the fused test joint.

I-13.4.6.1.2 Visual Examination—Butt Fusion PP, PVDF, and PFA/PTFE

(a) There shall be no visible evidence of cracks or incomplete fusing.

(b) Joints shall exhibit proper fused bead configuration.

(c) See Figure I-~~9~~8-1. GENERAL NOTES and NOTES provide a description of the proper fused bead configuration. No bead forms when the PFA/PTFE joint is created.

(d) Fused joints shall not display visible angular misalignment, and outside diameter mismatch shall be less than 10% of the nominal wall thickness.

(e) The data record for the fusing operator performance qualification test shall be reviewed and compared to the JPS or SJPS to verify observance of the specified variables applied when completing the fused test joint.

I-13.4.6.2 Visual Examination Electrofusion

(a) There shall be no visible evidence on external and accessible internal surfaces of cracks, excess internal (I.D.) melt caused by overheating, fitting malfunction, or incomplete fusion.

(1) Burn-through, pipe wall collapse, and melt extrusion between the pipe ends shall not be acceptable.

(2) Maximum fit-up gap, or maximum misalignment and out-of-roundness, shall be within JPS limits.

(b) The data record for the fusing operator performance qualification test shall be reviewed and compared to the JPS to verify observance of the specified variables applied when completing the fused test joint.

(c) Evidence of scraping at the end of the electrofusion coupling shall be present.

(d) *Sectioned Electrofusion Joints.* Voids due to trapped air or shrinkage during the cooling process shall be acceptable only if round or elliptical in shape with no sharp corners, and provided they meet the following requirements (see ASTM F2600):

(1) Individual voids shall not exceed 10% of the fusion zone length.

(2) Multiple voids shall not exceed a combined total of 20% of the fusion zone length.

(3) When voids are detected, additional sections or examinations shall be made to verify that the void does not follow a diametric path connecting with the pressure-containing area of the joint (see ASTM F2600).

NOTE: NDE can be used as an alternative to using sectioned electrofusion joints, with the owner's approval.

I-13.4.7 Evaluation of Operator Performance Tests

I-13.4.7.1 Performance Test for Fusing PA-11

(a) A specimen joint shall be cut into at least three longitudinal bend test pieces, each of which is deformed by torque or impact.

(1) If a failure occurs, the fracture shall not initiate in the joint area.

(2) The test shall be conducted using a bend test.

(b) Upon passing the performance test and the written test, the operator shall be qualified for 1 yr.

I-13.4.7.2 Performance Test for Fusing Liners

(a) Each of the three to five butt-fused lined steel pipe samples from each pipe size shall be hydrostatically tested at 3 103 kPa (450 psig).

Mandatory Appendix II
Threaded Thermoplastic Connections

II-1 Scope

This Mandatory Appendix provides information for threaded thermoplastic components manufactured in accordance with existing ~~ASTM (~~ASME~~)~~ standards.

Manufactured threaded thermoplastic components for which no ~~ASTM (~~ASME~~)~~ standards exist shall be qualified by testing and by providing data as required by this Standard.

The limitations listed in paras. II-1.1 through II-1.4 apply to thermoplastics manufactured in accordance with ~~ASTM (~~ASME~~)~~ standards and those not manufactured to ~~ASTM (~~ASME~~)~~ standards.

II-1.1 General Limitations

(a) Threaded thermoplastic connections shall not be used in fuel gas applications.

(b) Threaded connections that are not specially designed for compressed-air service shall not be used in compressed-air or other compressed-gas applications. Only manufactured threaded products designed to be used in compressed-air or other compressed-gas applications may be used for such applications.

(c) Threaded thermoplastic connections shall not be used in ASME B31.3 Category M Service (toxic fluids or gases). This includes threaded thermoplastic flange connections.

II-1.2 Size Limitations

(a) Only threaded connections less than 25 mm (1 in.) may be used for instrument connections in process piping systems.

(b) The threading of pipe shall be limited to Schedule 80 wall thickness or thicker for all pressure applications of PVC and CPVC pipe. For other thermoplastic, Schedule 80 or equivalent shall be as specified by the design engineer.

(c) Testing to verify thread strength shall be performed in addition to the standard acceptance test for the pipeline. See requirements in Nonmandatory Appendix A, Table A-3-1.

(d) The maximum size molded adapter shall be 168 mm (6.625 in.).

II-1.3 Pressure Limitations. The maximum pressure allowed in molded threaded adapters shall be as shown in Table II-2.5.1.1-1.

II-1.4 Temperature Limitations. Review the temperature range of the application with the manufacturer before design.

II-2 Threaded Joint Design

II-2.1 Threaded Joint Design for Listed Thermoplastics

The following requirements shall apply to threaded joint design for PVC and CPVC components:

(a) The thermoplastic pipe threads shall conform to ~~ASTM F1498 (~~ASME SF-1498~~)~~ or those specified by the design engineer. Thermoplastic piping components with metal threads shall conform to ASME B1.20.1.

(b) Components threaded into the thermoplastic threaded connections shall be tapered.

(1) Metal threads shall be made with a taper described in ASME B1.20.1.

(2) Thermoplastic threads shall be made with a taper described in ~~ASTM F1498 (~~ASME SF-1498~~)~~.

(3) The taper shall be compatible for each male and female size components.

(c) Thread shapes other than those described in (a) and (b) may be used if testing shows that the shapes are designed to provide for strength in axial loads and leak-tight sealing.

(d) Threaded thermoplastic CPVC and PVC connections shall be field tested for acceptance following the design test requirements for the pipeline.

II-2.2 Threaded Joint Design for ~~Nonlisted~~Non-listed Thermoplastics

(a) The threaded joint design requirements in para. II-2.1 shall apply to components made of nonlisted- thermoplastics.

(b) The design engineer shall specify testing and test conditions for acceptance of nonlisted- thermoplastic threaded connections in the piping system.

II-2.3 Mechanical Load Design

In addition to pressure loading, the following mechanical loads can have detrimental effects and shall be considered based on the risk of failure of the threaded joint:

(a) deadweight

(b) thermal expansion and contraction

(c) environmental loads such as wind, seismic, snow, and ice

(d) vibration

(e) thermal shock

(f) pressure surge (including changes in velocity)

(1) For threaded pipe, the maximum pressure rating shall not be greater than 50% of the wall thickness of the pipe.

(2) A pipe rated at 1379 kPa (200 psi) may have a threaded joint with a pressure rating of 689 kPa (100 psi). This requirement shall apply to PVC, CPVC, and other thermoplastics.

II-2.4 Threaded Joint Assembly

Threaded connections shall be assembled according to the requirements provided the manufacturer for the application or published recommendations for the application. The following requirements also apply:

(a) The maximum and minimum torque limits shall be identified and respected.

(b) Backing off threaded joints to allow for alignment shall not be performed.

(c) Threaded PVC and CPVC connections require thread sealant. The design engineer shall determine which other thermoplastic threaded connections require sealant.

(1) Sealant shall be compatible with the thermoplastic materials used at the joint.

(2) Sealant shall be compatible with the fluids to be used in the pipe once the system is in service.

(3) Sealant is not required if the joint is to be subsequently sealed with overlay materials.

(4) Tape-type thread sealants shall not be mixed with paste sealants.

(d) Any compound or lubricant used in threaded joints shall be suitable for the service conditions, and shall be compatible with the piping material.

(e) Primers or solvent cement

(1) shall not be applied to threads on pipe or threads on fittings

(2) shall not be allowed to run or drip into the threaded portion of the fitting

(f) Metallic threads shall not be screwed into plastic internal threads except those that have metal reinforcement.

II-2.5 Molded Threaded Adapters and Threaded Pipe Ends

II-2.5.1 Molded Threaded Adapters. Molded threaded adapters are those made by injection molding of thermoplastics. They shall comply with the following requirements:

(a) PVC and CPVC Adapters

(1) Molded threaded adapters are external and internal. Solvent-cement joining shall be used to attach the nonthreaded end of a molded PVC or CPVC adapter to a pipe or component.

(2) CPVC and PVC materials used to make threaded adapters shall meet the requirements of ASME NM.3.1.

(3) Molded PVC fittings shall comply with either ~~ASTM D2464 (~~ASME SD-2464~~)~~ or ~~ASTM D2467 (~~ASME SD-2467~~)~~.

(4) Molded CPVC threaded adapters shall meet the requirements of ~~ASTM F437 (~~ASME SF-437~~)~~.

(5) Molded threaded adapters shall be tested as required in the applicable specification [see (2) and (3) above]. A manufacturer of molded threaded adapters shall show compliance to the specification to which the threaded adapters were molded.

(6) The maximum pressure rating for molded PVC and CPVC threaded adapters shall be as listed in Table II-2.5.1-1.

Table II-2.5.1-1 Pressure Ratings for Molded PVC and CPVC Threaded Adapters

Nominal Pipe Size (NPS)	Actual Pipe Size, mm (in.)	Type of Adapter	Pressure- Temperature Rating, kPa (psi) at 23˚C (73˚F) [Note (1)]
13 (0.50)	21.336 (0.840)	PVC Sch. 40	2 068.4 (300)
13 (0.50)	21.336 (0.840)	PVC Sch. 80/CPVC Sch. 80	2 930.27 (425)
19 (0.75)	26.670 (1.050)	PVC Sch. 40	1 654.74 (240)
19 (0.75)	26.670 (1.050)	PVC Sch. 80/CPVC Sch. 80	2 378.69 (345)
25 (1.00)	33.401 (1.315)	PVC Sch. 40	1 551.32 (225)
25 (1.00)	33.401 (1.315)	PVC Sch. 80/CPVC Sch. 80	2 171.85 (315)
32 (1.25)	42.164 (1.660)	PVC Sch. 40	1 275.53 (185)
32 (1.25)	42.164 (1.660)	PVC Sch. 80/CPVC Sch. 80	1 792.64 (260)
38 (1.50)	48.260 (1.900)	PVC Sch. 40	1 137.63 (165)
38 (1.50)	48.260 (1.900)	PVC Sch. 80/CPVC Sch. 80	1 620.27 (235)

51 (2.00)	60.325 (2.375)	PVC Sch. 40	925.27 (140)
51 (2.00)	60.325 (2.375)	PVC Sch. 80/CPVC Sch. 80	1 378.95 (200)
76 (3.00)	88.900 (3.500)	PVC Sch. 40	896.32 (130)
76 (3.00)	88.900 (3.500)	PVC Sch. 80/CPVC Sch. 80	1 275.53 (185)
102 (4.00)	114.300 (4.500)	PVC Sch. 40	758.42 (110)
102 (4.00)	114.300 (4.500)	PVC Sch. 80/CPVC Sch. 80	1 103.16 (160)
152 (6.00)	168.275 (6.625)	PVC Sch. 40	620.53 (90)

NOTE:

(1) When higher temperatures are used, the manufacturer's temperature–pressure rating for the temperature shall be used. In no case shall threaded connections be used at pressures or temperatures higher than the manufacturer's ratings.

(b) *Adapters Made of Other Thermoplastics***.** The following requirements apply to threaded adapters made of ABS, PP, or PVDF:

(1) Molded threaded adapters are male and female. The method of attaching the adapter to a pipe or component shall be a specified manufacturer. The design engineer shall follow the requirements of this Standard for listed thermoplastics.

(2) The thermoplastics shall meet the requirements of ASME NM.3.1 or shall be approved by the design engineer using test data as approved by the design engineer (and shall be identified as not conforming to ASME NM.3.1).

(3) The design engineer shall specify the requirements for molded thread adapters made from ABS, PP, or PVDF. This shall include minimum wall thickness and dimensions of the molded fittings. The pressure rating shall be verified by testing approved by the design engineer.

II-2.5.2 Threaded Pipe Ends

Threaded pipe ends are created by cutting or machining threads into the ends of extruded thermoplastic pipes. Pressure limitations of threaded pipe ends shall be as listed in the Mandatory Appendix II for materials with an ~~ASTM (~~ASME~~)~~ standard or if the pipe material complies with an ~~ASTM (~~ASME~~)~~ specification, the pressure limitations of the threaded pipe end shall be as listed in the Mandatory Appendix II; if there is no ~~ASTM (~~ASME~~)~~ specification for the pipe material, the pressure limitation shall be determined by testing.

(a) PVC and CPVC Pipe

(1) Only Schedule 80 or thicker PVC or CPVC pipe may be threaded.

(2) CPVC and PVC pipe used for threading shall meet the requirements of ASME NM.3.1.

(3) The maximum allowed pipe size to be threaded shall be DN 100 (NPS 4).

(4) When pipe is threaded by a contractor or supplier, samples of all sizes to be used in an ASME-stamped thermoplastic piping system shall be fitted together and the resulting assembly tested for joint tightness using ~~ASTM F1970 (~~ASME SF-1970~~),~~, and Section 8.3.

(-a) The test requirements of this section are above the system test pressure.

(-b) The tested components shall not be used in the piping system.

Table II-2-2 Pressure Ratings for Molded PVC and CPVC Field-Threaded Pipe Ends

Nominal Pipe Size (NPS)	Actual Pipe Size, mm (in.)	Type of Threaded Pipe Ends	Pressure – Temperature Rating Before Threading, kPa (psi) at 23˚C (73˚F) [Note (1)]	Pressure – Temperature Rating of Threaded Pipe End Threaded, kPa (psi) at 23˚C (73˚F) [Note (1)]
13 (0.50)	21.336 (0.840)	PVC Sch. 80/CPVC Sch. 80	5 860.5 (850)	2 930 (425)
19 (0.75)	26.670 (1.050)	PVC Sch. 80/CPVC Sch. 80	4 757 (690)	2 378 (345)
25 (1.00)	33.401 (1.315)	PVC Sch. 80/CPVC Sch. 80	4 344 (630)	2 172 (315)
32 (1.25)	42.164 (1.660)	PVC Sch. 80/CPVC Sch. 80	3 585 (520)	1 793 (260)
38 (1.50)	48.260 (1.900)	PVC Sch. 80/CPVC Sch. 80	3 241 (470)	1 621 (235)
50 (2.00)	60.325 (2.375)	PVC Sch. 80/CPVC Sch. 80	2 758 (400)	1 379 (200)
76 (3.00)	88.900 (3.500)	PVC Sch. 80/CPVC Sch. 80	2 551 (370)	1 276 (185)
101 (4.00)	114.300 (4.500)	PVC Sch. 80/CPVC Sch. 80	2 206 (320)	1 103 (160)

NOTE:

(1) When higher temperatures are used, the manufacturer's temperature–pressure rating shall be used. In no case shall threaded connections be used at pressures or temperature higher than ratings.

(b) Pipe Made of Other Thermoplastics. The following requirements apply to threaded pipe ends on pipes made of thermoplastics other than PVC or CPVC:

(1) The minimum wall thickness of the pipe shall be Schedule 80 or equivalent as specified by the design engineer.

NOTE: A greater wall thickness may be used.

(2) Thermoplastic pipe shall be selected from listings in ASME NM.3.1.

(3) The maximum allowed thermoplastic pipe size to be threaded shall be DN 100 (NPS 4).

(4) When pipe end is threaded by a contractor or supplier, samples of all sizes to be used in the thermoplastic piping system shall be tested using the test and inspection requirements of the design engineer.

II-2.6 Test Report

(a) The design engineer shall provide a test report that documents the results of the tests in (a) (4) and (b) (4) above and that verifies the following:

(1) The threaded connections are being used only in approved applications.

(2) Thermoplastic threads conform to ~~ASTM F1498 (~~ASME SF-1498~~)~~.. Metallic threads to be used with thermoplastic components conform to ASME B1.20.1. Threads other than those conforming to (2) may be used. When these threads are used the design engineer shall provide the test requirements for these threads.

(3) The assembly of threaded connections conforms to section II-2.

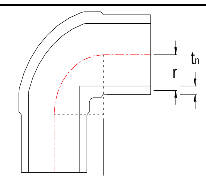
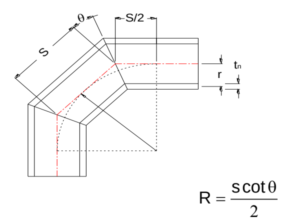
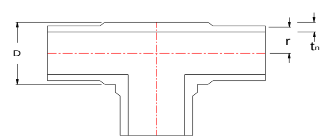
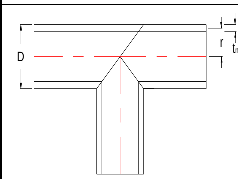
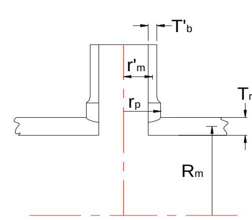
(4) The manufacturer of molded thermoplastic threaded adapter has provided a certificate of conformance for each lot of molded components.

(5) Threaded pipe ends meet the requirements of para. II-2.5.2.

Mandatory Appendix IV

Stress Intensification Factors and Flexibility Factors

Table IV-1 Stress Intensification Factors, *i*, and Flexibility Factors, *k*, for High-Density Polyethylene

Description	Flexibility Characteristic, *h*	Flexibility Factor, *k* [Note (1)]	Stress Intensification Factors, *i* [Note (1)]	Sketch
Straight pipe	N/A	1.0	1.0	
Butt Fusion Joint	N/A	1.0	1.0	
Molded Elbow	$\frac{t_n R}{r^2}$	~~TBD~~--	$\frac{1.25}{h^{2/3}}$	
Miter Elbow $s \geq r(1+\tan\theta)$ [Note (2)]	$\frac{(1+\cot\theta)}{DR-1}$ or $\frac{t_n(1+\cot\theta)}{2r}$			
Equal outlet molded tee [Note (4)]	$\frac{4.4t_n}{r}$	1.0	$i_b = \frac{1.73}{h^{2/3}}$ $i_r = \frac{1.17}{h^{2/3}}$	
Equal outlet mitered tee	$\frac{4.4t_n}{r}$ or $\frac{8.8}{DR-1}$	1.0	$i_b = \frac{4.45}{h^{2/3}}$ $i_r = \frac{2.21}{h^{2/3}}$	
Sidewall Fusion Branch Connection [Note (5)]	N/A	1.0	$i_b = 1.74\left(\frac{R_m}{T_r}\right)^{\frac{2}{3}}\left(\frac{T'_b}{T_r}\right)\left(\frac{r'_m}{r_p}\right) \geq 1.5$ $i_r = 1.54\left(\frac{R_m}{T_r}\right)^{\frac{2}{3}}\left(\frac{r_p}{R_m}\right) \geq 1.5$	

V-2.2 Bolt Circle

(a) *Standard.* The dimensions for standard bolt circles shall be those used in ASME B16.5 for sizes from DN 15 to DN 600 (NPS $^{1}/_{2}$ to NPS 24).

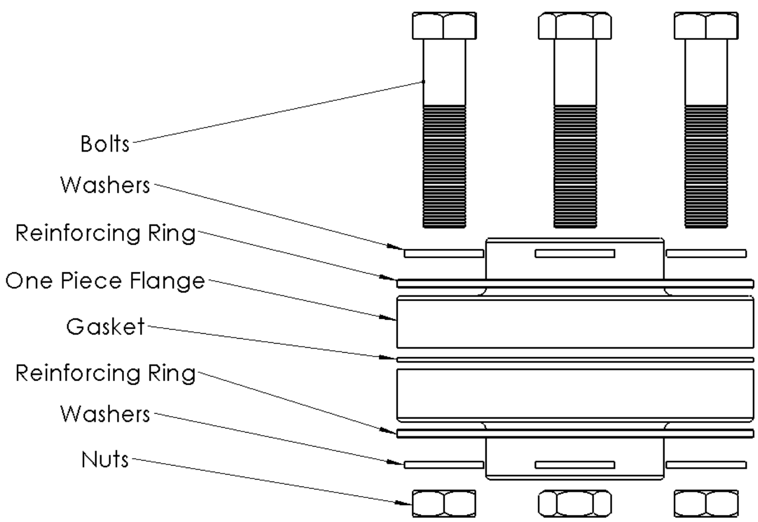
(b) *Metric.* Metric bolt circles may be used. Dimensions are provided in Nonmandatory Appendix A, Table A-2-2.

V-2.3 Reinforcing Rings

(a) Metallic or nonmetallic reinforcing rings may be used with one-piece thermoplastic flanges. See Figure V-2-1.

(b) The pressure rating of the one-piece flange shall not be increased when reinforcing rings are used.

Figure V-2-1 One-Piece Thermoplastic Flange with Reinforcing Rings



GENERAL NOTE: Hex head bolts are shown above. Studs or hex head bolts may be used.

V-2.4 Washers

Washers shall be used between the nut or bolt head and the one-piece thermoplastic flange or reinforcing ring.

V-2.5 Stress Relaxation of Thermoplastics

Additional wall thickness may be needed to compensate for stress relaxation. Each thermoplastic has a unique set of stress relaxation curves.

V-2.6 Temperature

As ~~temperaure~~temperature increases, modulus and tensile strength decrease. Temperature-related changes in the physical properties of thermoplastics vary depending on the type of thermoplastic See values for each thermoplastic engineering property in ASME NM.3.3.

V-3 Proof-Testing Requirements for One-Piece Thermoplastic Flanges

V-3.1 Materials

(a) *Listed Materials.* The following materials are currently listed for one-piece thermoplastic flanges:

(1) heat fusion

(2) solvent-cement welding

(3) threaded connections

V-3.2.6 Bolt Torque

(a) *General.* The bolt torque required shall be determined by one of the following:

(1) The bolt torque recommended by the manufacturer of the flange adapter or the manufacturer of the backup ring shall be used with the specified full-face gasket type and thickness.

(2) Torque calculations shall be based on sealing forces plus expected stress relaxation or based on gasket sealing stress plus expected stress relaxation.

(b) Bolt Lubrication and Friction-Reducing Coated Bolts

(1) When methods (a) or (b) are used to determine bolt torque, only bolts, nuts, and washers recommended by the flange adapter manufacturer or the backup ring manufacturer shall be used.
(-a) Lubricate only if required by the manufacturer.
(-b) Use friction-reducing components only if specified by the manufacturer.
(2) When torque calculations are used, only the bolts and nuts with the coefficient of friction used in calculations shall be used.
(3) During installation, bolts and nuts may be lubricated only if such lubrication is specified in accordance with (b)(1) or (b)(2).

NOTE: Refer to ASME PCC-1 for more information on fit-up of flanges. If using HDPE flanges and calculations from PPI TN-38, use information on lubrication and *k* factors from this Standard.

V-3.2.7 Test Specimens. Specimens shall be tested after the heat-fused or solvent-weld joint has had adequate time to cool or cure.

V-3.2.8 Proof Testing Results. Proof testing results shall be part of the submittal information for one-piece thermoplastic flanges (See Section V-4).

V-4 Submittal Information for One-Piece Thermoplastic Flanges

V-4.1 PVC

Submittal information for PVC one-piece flanges shall be include dimensions as indicated below.

(a) If the one-piece flange is for socket joining, dimensions shall conform to ~~ASTM D2467 (~~ASME SD-2467~~)~~.

(b) If the one-piece flange is for spigot joining, dimensions shall conform to Schedule 40 or Schedule 80 pipe dimensions.

(c) If the one-piece flange is for threaded joining, the threads shall meet the requirements of Nonmandatory Appendix B.

(d) The bolt circle shall conform to ASME B16.5 or the flange standard used for other metal components in the system as required in the owner's design specifications.

(e) The O.D. and the I.D. of the flange face shall be provided.

V-4.2 CPVC

Submittal information of CPVC one-piece flanges shall include dimensions as indicated below.

(a) If the one-piece flange is for socket joining, dimensions shall conform to ~~ASTM F439 (~~ASME SF-439~~)~~.

(b) If the one-piece flange is for spigot joining, dimensions shall conform to Schedule 40 or Schedule 80 pipe dimensions.

(c) Pipe used to make socket connections shall meet required dimensions for Schedule 40 or Schedule 80 pipe dimensions.

(d) If the one-piece flange is for threaded joining, the threads shall meet the requirements of Nonmandatory Appendix B.

(e) The O.D. and the I.D. of the flange face shall be provided.

(f) The bolt circle shall conform to ASME B16.5 or the flange standard used for other metal components in the system as required in the owners design specifications.

V-4.3 PVDF and PVDF Copolymer

Submittal information for PVDF or PVDF copolymer one-piece flanges shall be provided with dimensions as indicated below.

(a) If the one-piece flange is for socket joining, female socket dimensions shall conform to published socket dimensions; pipe dimensions shall comply with published dimensions for socket connections.

(b) If the one-piece flange is for spigot joining, dimensions shall conform to PVDF or copolymer PVDF pipe dimensions.

(c) If the one-piece flange is for threaded joining, the threads shall meet the requirements of Nonmandatory Appendix B. For materials not listed in the Nonmandatory Appendix B, the manufacturer may provide equivalent test data and descriptive information.

(d) The bolt circle shall conform to ASME B16.5 or for metric dimensions flange standard, ISO 7005 or EN 1092-1 shall be used. Other bolt circles dimensions may be used if required in the owner's design specifications.

(e) The O.D. and the I.D. of the flange face shall be provided.

V-4.4 PP

Submittal information for PP one-piece flanges shall be provided with dimensions, as indicated below.

(a) If the one-piece flange is for socket fusion joining, dimensions shall conform to published socket dimensions.

(b) If the one-piece flange is for threaded joining, the threads shall meet the requirements of Nonmandatory Appendix B. For materials not listed in the Nonmandatory Appendix B, the manufacturer may provide equivalent test data and descriptive information.

(c) If the one-piece flange is for socket-fusion joining, dimensions shall conform to PP pipe dimensions.

(d) The bolt circle shall conform to ASME B16.5 or for metric dimensions flange standard, ISO 7005 or EN 1092 shall be used. Other bolt circle dimensions may be used if required in the owners design specifications;

(e) The O.D. and the I.D. of the flange face dimensions shall be provided.

V-4.5 ABS

Nonmandatory Appendix A

Components for Thermoplastic Lap-Joint Flange Connections

A-1 Scope

(a) This Nonmandatory Appendix is limited to component for thermoplastic lap-joint flange connections (TLJF) (Van Stone flanges). Components used in TLJF connections include backup rings and flange adapters, and may also include fasteners, washers, and gaskets. Proof test requirements are in Table A-3-1

(b) Metallic backup rings, thermoplastic backup rings, reinforced thermoplastic backup rings, and thermoplastic flange adapters used in thermoplastic-lined metal piping systems and reinforced thermoplastic piping systems are included in this Nonmandatory Appendix when requirements are the same as or similar to those for thermoplastic piping systems.

A-2 General Requirements for Backup Rings for TLJF Connections

A-2.1 Flange Adapters and Backup Rings for Butt Fusion Applications

Backup rings for heat-fusion joining methods shall conform to the dimensions in Table A-2.1-1 for NPS sizes or Table A-2.1-2 for metric sizes and the following general requirements:

(a) Nonmetallic or metallic backup rings, or metallic backup rings with nonmetallic encapsulation or coating may be used.

(b) Backup rings made of metallic or nonmetallic material, or combinations of metallic and nonmetallic materials, when used with thermoplastic flange adapters, gaskets, washers, bolts, and nuts, shall pass the test requirements for the thermoplastic as described in Table A-3-1

NOTE: Gaskets are optional for PE and other thermoplastics and liners used in thermoplastic-lined metallic pipe TLJF connections.

(c) Additional design requirements, when needed for the backup rings, shall be provided in the owner's specification.

(d) Backup rings made to the requirements of ASME B16.5 or ASME B16.47 may be used if they are made with proper dimensions and I.D. corner radius for thermoplastic backup rings and flange adapters.

NOTE: ASME lapped flanges made with standard ASME I.D. and corner radii dimensions are for use in welded metallic piping systems and those dimensions do not meet the dimensional requirements of this Standard for plastic piping systems.

(e) The backup ring O.D., bolt-hole diameter, and bolt-circle dimensions shall conform to:

1) ASME B16.5 Class 150 dimensions for nominal pipe sizes DN 15 to DN 600 (NPS $^1/_2$ to NPS 24)

(2) one of the following for DN 650 to DN 1350 (NPS 26 to NPS 54~~:~~):

(-a) ASME B16.47 Class 150, Series A dimensions

(-b) ASME B16.1 Class 125 dimensions

(-c) AWWA C207-CL dimensions for Series B, D, and E flanges

D_o = specified or actual outside diameter

P_D = design pressure

S = allowable stress at the design temperature for the long-term duration of load, including service factors, environmental factors, and joint-derating factors.

t_{min} = wall thickness of the flange adapter barrel

The flange adapter shall be made from materials meeting the requirements of ASME NM.3.3 for the materials required.

NOTE: Equation (A-4-1) cannot easily be used to analyze the wall thickness of socket-fusion-joined flange adapters. It may be used to evaluate the ability of pipe wall thickness for flange adapters to handle the design pressure.

(b) The dimensions of heat-fusion flange adapters are determined by material type and IPS or metric sizing. Figure A-4.2.1 shows typical configuration for a butt fusion PE Flange adapter. Para. A-4.3.3 (a) provides references for flange adapter dimensions.

A-4.3.2 PE Flange Adapters

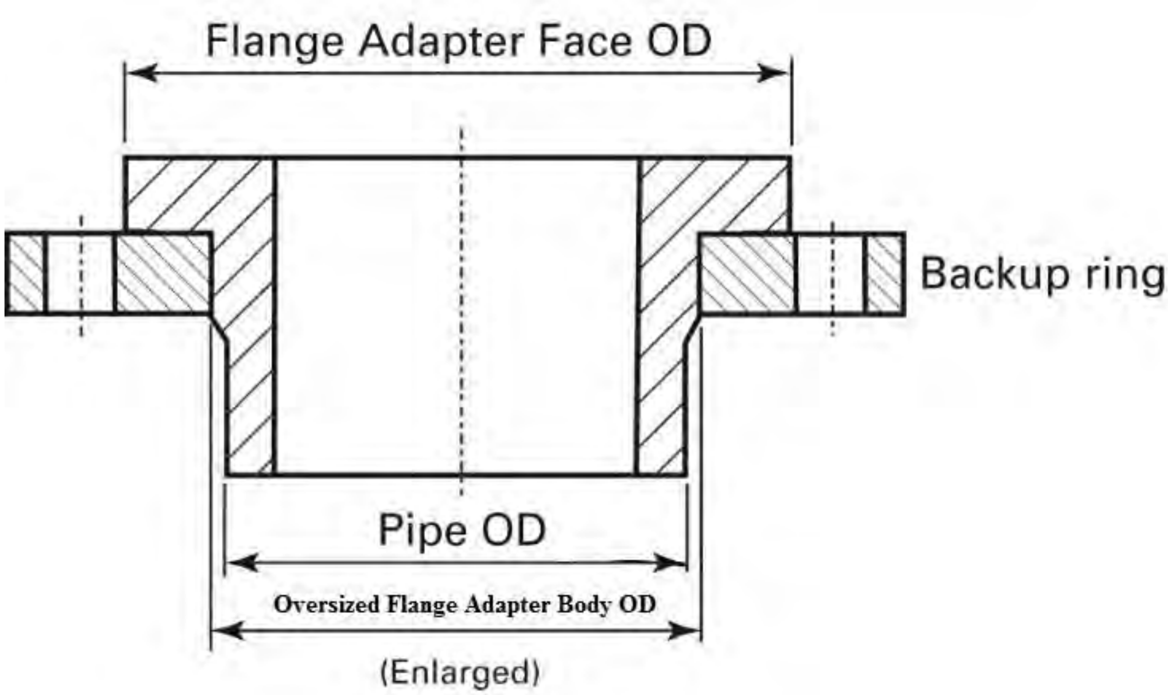
(a) IPS PE flange adapters shall meet the requirements of ~~ASTM F2880 (~~ASME SF-2880~~).~~. Figure A-4.2-1 shows a typical configuration of an ~~ASTM F2880 (~~ASME SF-2880~~)~~ flange adapter.

(1) The design pressure shall be used to determine the wall thickness of the flange adapter using stress tables in ASME NM.3.3, equation A-4-1, and the design rules in A-4.3.1.

(2) The flange adapter shall be made from materials meeting the requirements of ASME NM.3.3 for PE. The ASTM D3350 cell classification for PE 3608 shall be PE 345464C or PE 4710 with a cell classification of PE 445574C or PE 445474C shall be provided.

(b) PE metric flange adapters (also called welding necks or neck bushes) made to the requirements of DVS 2210-1 shall have radii as required for socket fusion or for butt fusion. Figures A-4.3.2-1, A-4.3.2-2, and A-4.3.2-3 show typical configurations for metric flange adapters.

Figure A-4.3.2-3 Special ISO or DVS Metric Butt-Fusion Flange Adapter for Higher Pressure Connections



A-4.3.3 PP and PVDF Flange Adapters

(a) *Requirements for Metric Adapters.* Metric PP and metric PVDF flange adapters (also called welding necks or neck bushes) shall meet the requirements of DVS 2110-1 and/or dimensions of EN 15484~~ (see para. <<reference gen'l para. suggested in earlier query>>. ~~.

(b*) Materials for PP Flange Adapters*

(1) PP flange adapters shall be made from materials meeting the requirements of ~~ASTM D4101 (~~ASME SD-4101~~),~~, Group 1, Class 2, ß nucleated homopolymer. The cell classification by ASTM D5857 shall be PP0510866851.

(2) When PP flange adapters are natural material, ~~ASTM D4101 (~~ASME SD-4101~~)~~ Group 2, Class 2, nucleated copolymer material shall be used.

(c) Materials for PVDF Flange Adapters. PVDF flange adapters shall meet the requirements of ~~ASTM D3222 (~~ASME SD-3222~~)~~ as Type 1, Grade 2 for fittings up to 160 mm (6.3 in.). For fittings 160 mm (6.3 in.) and larger, a Type 2 shall be used.

(d) PP and PVDF NPS or DN Flange Adapters. A drawing with flange adapter dimensions shall be provided. The drawing shall provide flange adapter sizes in NPS or DN for the following:

(1) minimum neck length

(2) flange adapter face width (O.D.)

(3 flange face thickness

(4) radius between the barrel and the flange face

A-4.4 Design Requirements for Thermoplastic Flange Adapters Attached by Solvent-Cement Welding

(a) The minimum wall thickness of the flange adapter for solvent-cement welding (see Figure A-4.4-1) shall be determined using eq. (A-4-1).

NOTE: Equation (A-4-1) cannot easily be used to analyze the wall thickness of solvent-cement-welded socket-joined flange adapters. It may be used to evaluate the ability of pipe wall thickness on spigot-type flange adapters to handle the design pressure.

(b) The dimensions of the flange adapters may be provided by ranges in drawing or by requirements in ASTM or EN standards.

(c) PVC flanges adapters shall meet the following requirements:

(1) The dimensions of the socket solvent-cement-weld connection shall conform to the dimensions in ~~ASTM D2467 (~~ASME SD-2467~~)~~ for Schedule 80 flange adapters or ~~ASTM D2466 (~~ASME SD-2466~~)~~ for Schedule 40. Because of pressure ratings, Schedule 40 flange adapters shall be limited to 203.2 mm (8 in.) and smaller.

(2) The PVC materials shall meet the requirements of ASME NM.3.3. The material shall be PVC as defined by ~~ASTM D1784 (~~ASME SD-1784~~)~~ Table 1 and meet a cell classification of 12454 (Type 1, Grade 1).

(3) The dimensions of the flange adapter and backup rings shall be within the range provided in Table A-2.4-1 ,or A-2.4-2

(4) The flange adapter face width shall match the backup ring inside dimension.

(5) The pressure rating of the flange adapter, the backup ring, and the gasket shall not be less than 10.34 bar (150 psi) when tested as required in ~~ASTM F1970 (~~ASME SF-1970~~).~~.

(d) CPVC flange adapters shall meet the following requirements:

(1) The dimensions of the socket solvent-cement-weld connection shall conform to the dimensions for Schedule 80 CPVC shall meet the dimension provided in Specification ~~ASTM F439 (~~ASME SF-439~~)~~ and Schedule 40 shall meet the dimensions provided in Specification ~~ASTM F438 (~~ASME SF-438~~).~~. Because of pressure ratings, Schedule 40 flange adapters shall be limited to 203.2 mm (8 in.) and smaller.

(2) The materials shall meet the requirements of ASME NM.3.3. The material shall be CPVC as defined by ~~ASTM D1784 (~~ASME SD-1784~~)~~ and shall meet a cell classification 23447 (Type IV, Grade 1).

(3) The dimensions of the flange adapter and backup rings shall conform to the range in Table A-2.4-1 or A-2.4-3.

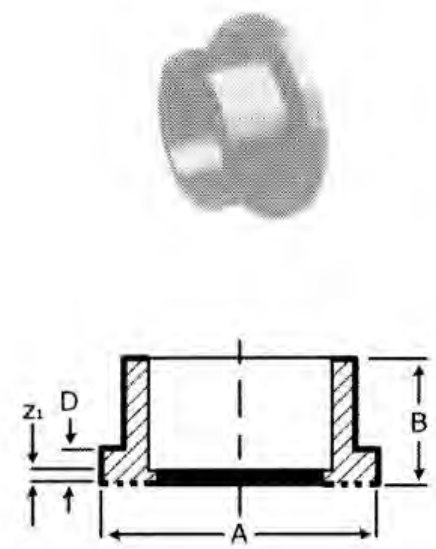
(4) The pressure rating of the flange adapter, the backup ring, and the gasket shall not be less than 10.34 bar (150 psi). The flange adapter, backup ring and gasket shall be test as required in ~~ASTM F1970 (~~ASME SF-1970~~).~~.

(d) ABS flange adapters shall meet the following requirements:

(1) The dimensions of the socket solvent-weld connection shall conform to the dimensions for ABS and shall meet the dimensions as provided in this standard or DVS 2210-1.

(2) The flange adapters shall be compatible with the backup rings. ABS flange adapters made to be used with metric ABS piping systems shall be used only with metric systems. ABS flange adapters made to be used with other dimensional systems shall be used only with matching systems.

Table A-4.4-2 ABS Socket Flange Adapter



Nominal Pipe Size, mm (in.)	Actual Pipe Size, mm (in.)	Length of Socket (Socket to Face), Z_1, mm (in.)	Length From Flange Face to End of Socket, *B*, mm (in.)	O.D. of Flange Adapter, *A*, mm (in.)	Thickness of Flange Adapter Face, *D*, mm (in.)
50.80 (2)	60.33 (2.375)	3.05 (0.12)	39.88 (1.57)	96.01 (3.78)	13.97 (0.55)
76.20 (3)	88.90 (3.50)	6.10 (0.24)	56.90 (2.24)	127.00 (5.00)	18.03 (0.71)
101.60 (4)	114.30 (4.50)	6.10 (0.24)	69.09 (2.72)	159.00 (6.26)	20.07 (0.79)
152.40 (6)	168.28 (6.625)	10.92 (0.43)	103.89 (4.09)	213.11 (8.39)	23.88 (0.94)
203.20 (8)	219.08 (8.625)	13.97 (0.55)	132.08 (5.20)	268.99 (10.59)	25.91 (1.02)
254.00 (10)	273.05 (10.75)	8.13 (0.32)	157.99 (6.22)	305.56 (12.03)	28.96 (1.14)
304.80 (12)	323.85 (12.75)	9.91 (0.39)	180.09 (7.09)	362.46 (14.27)	34.04 (1.34)

GENERAL NOTES:

(a) This Table provides dimensions for ABS lap-joint flanges made to BPS Standards.

(b) There are no published requirements for radii on flange adapters or backup rings.

(c) The pressure rating for ABS lap-joint flange connections is greater than 10.34 bar (150 psi).

A-4.5 Thermoplastic Threaded Lap-Joint Flange Adapters

(a) Typical dimensions for PVC and CPVC threaded lap-joint flange connections are shown in Table A-2.4-3.

(b) Threaded PVC flanges adapters shall meet the following requirements:

(1) Threaded PVC flange adapters shall be made to the requirements of ~~ASTM D2464 (~~ASME SD-2464~~).~~.

(2) The threads shall meet the requirements of ASTM F1498.

(3) The PVC materials shall meet the requirements of ASME NM.3.3. The material shall be PVC as defined by ~~ASTM D1784 (~~ASME SD-1784~~)~~ Table 1 and shall meet a cell classification of 12454 (Type I, Grade 1).

(4) The dimensions of the flange adapter and backup rings shall be within the range provided in Table A-2.4-3.

(5) The flange adapter face width shall match the backup ring inside dimension.

(6) The pressure rating of the flange adapter, the backup ring, and the gasket shall not be less than 10.34 bar (150 psi) when tested as required in Specification ~~ASTM F1970 (~~ASME SF-1970~~).~~.

(7) The threaded flange adapter, backup ring, and gasket shall be proof tested as described in para. A-3.2.

(c) Threaded CPVC flange adapters shall meet the following requirements:

(1) Threaded CPVC flange adapters shall be made to the requirements of ~~ASTM F437 (~~ASME SF-437~~).~~.

(2) The threads shall meet the requirements of ~~ASTM F1498 (~~ASME SF-1498~~).~~.

(3) The materials shall meet the requirements of ASME NM.3.3. The material shall be CPVC as defined by ~~ASTM D1784 (~~ASME SD-1784~~)~~ and shall meet a cell classification 23447 (Type IV ,Grade 1).

(4) The dimensions of the flange adapter and backup rings shall conform to the range in Table A-2.4-3.

(5) The pressure rating of the flange adapter, the backup ring, and the gasket shall not be less than 10.34 bar (150 psi). The flange adapter, backup ring, and gasket shall be tested as required in ~~ASTM F1970 (~~ASME SF-1970~~).~~.

(6) The threaded flange adapter, backup ring, and gasket shall be proof tested as described in para. A-3.2.

(d) Threaded PVDF flange adapters shall meet the following requirements:

(1) The threads shall meet the requirements of ~~ASTM F1498 (~~ASME SF-1498~~).~~.

(2) The materials shall meet the requirements of ASME NM.3.3. The material shall be PVDF as defined by ~~ASTM D3222 (~~ASME SD-3222~~)~~ as Type 1, Grade 2 for fittings up to 160 mm. For fittings 160 mm (6.3 in.) and larger, a Type 2 shall be used.

(3) The dimensions of the threaded flange adapter and backup rings shall be provided.

(4) The pressure rating of the threaded flange adapter, the backup ring, and the gasket shall not be less than the pressure rating of the pipe.

(5) The threaded flange adapter, backup ring, and gasket shall be proof tested as described in para. A-3.

A-4.6 Proof Test Requirements for Thermoplastic Flange Adapters Used as Part of a Lap-Joint Flange Connection

The thermoplastic flange adapter (heat fused, solvent cement welded, or threaded) is a component in the lap-joint flange connection, and is proof-tested as part of that connection, as outlined in section A-3.

A-5 Methods of Installing Flange Adapters Onto Thermoplastic Pipes and Fittings

A-5.1 General

The requirements for installing flange adapters using heat fusion and solvent -cement welding are provided in Chapter 5. Requirements for threaded connections are provided in Chapter 5 and Nonmandatory Appendix B.

because of either the gasket's lack of stiffness or the size of the gasket, the installer of the gasket and the owner or the owner's representative shall determine acceptable limits of projections for gaskets for the application.

(4) Hydrocarbons shall not be applied on thermoplastic surfaces for lubrication or as adhesives during installation or operation.

(5) Hydrocarbons may be used for cleaning the surface of thermoplastics when allowed by the manufacturer of the flange or flange adapter.

(6) When full-face gaskets are used, bolts shall be installed to hold the gasket in place.

A-7.2 Thermoplastic Flanges Requiring Gaskets

Table A-7.2-1 lists gasket requirements for thermoplastic flanges.

Table A-7.2-1 Gasket Requirements for Thermoplastic Flanges

Material of Flange and Pipe	**Gasket Required**	**Gasket Optional**
ABS	X	. . .
CPVC	X	. . .
PVC	X	. . .
PE	. . .	X
PP	X	. . .
PVDF and PVDF copolymer	X	. . .
Thermoplastic-lined metallic pipe	. . .	X

A-8 Tightening of Bolts

Bolts for one-piece flanges and thermoplastic lap-joint flanges shall be tightened using the traditional cross-pattern approach.

(a) Tighten bolts in increments. Follow the bolt-tightening sequence shown in ASME PCC-1, Table 2 or Table 3. Use ASME PCC-1, Table 4 for proper sequence based on number of bolts. ASME PCC-1, Table 4.1 may also be used.

(b) Nonmetallic backup rings or one-piece thermoplastic flanges may require special procedures for bolt tightening. When using nonmetallic backup rings or one-piece thermoplastic flanges, follow procedures specific to the components or application.

(c) When gaskets are used, use the torque recommended by the manufacturer for the gasket and thermoplastic flange or flange adapter combination.

NOTE: When the torque is above the compressive strength of the gasket and/or the thermoplastic flange or flange adapter, the flange connection can be damaged or lose its sealing ability.

A-9 ~~Bolt Torque Requirements~~ ~~This section will be balloted separately under a new record.~~

~~A-10~~ Washers, Bolts, Nuts, and Studs

A-~~10~~9.1 Washers

(a) Washers shall be used between the head of the bolt or nuts and the backing ring or device to which the flange connection is being made.

NOTE: The washer prevents galling or surface damage that can increase the rate of corrosion (of metallic components) or damage to components in some applications.

(b) The owner or user may use washers with metallic backup rings.

(c) Washers shall be used when using nonmetallic backup rings.

(1) Washers and nuts shall be made of like materials (e.g., steel to steel or bonze to bronze).

(2) Washers shall be marked with the manufacturer's name and the washer type. All markings shall be depressed and located on the same face of the washer.

(3) If metric washers are used with metric bolts, the dimensional requirements provided in ASME PCC-1, Nonmandatory Appendix M shall be used.

(4) If U.S. customary washers are used, dimensional requirements in ASME PCC-1, Nonmandatory Appendix M shall be used.

A-~~10~~9.2 Bolts

Bolts are used for the assembly to two unthreaded components. The bolt has male threads. For flange connections, bolts and nuts are used to provide force to seal a flange connection.

(a) The size of bolts shall conform to the requirements in ASME PCC-1, Nonmandatory Appendix L and Table L-1.

(b) The class of bolt (see ASME PCC-1, Table L-1) shall be determined by the pressure requirements for design pressure and test pressure.

(c) Bolts shall conform to the requirements in ASME B16.5, Table 1B, and ASME B18.2.1.

A-~~10~~9.3 Nuts

A nut is a fastener with a threaded hole. A nut is used with a washer and bolt to create force and create a seal on a flange connection.

(a) The size of the nut shall conform to the size of the bolt.

(b) The nuts shall conform to the requirements of ASME B16.5.

(c) The nut dimensions shall meet the requirements of ASME B18.2.2 and ASME B18.2.4.6M.

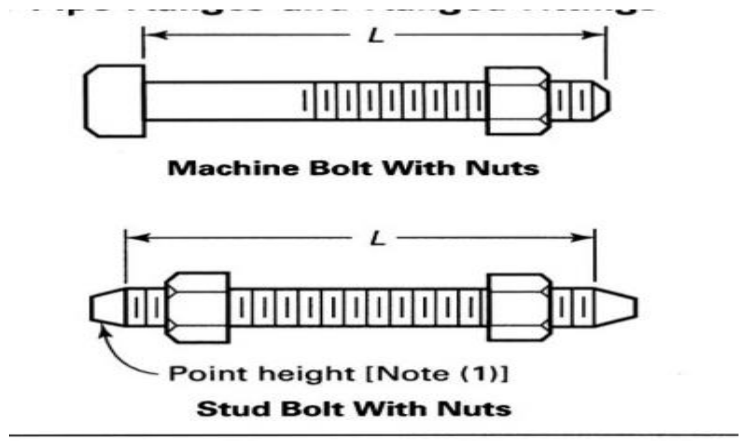
A-~~10~~9.4 Studs Bolts

Stud bolts are used in the same applications as a bolt. A stud bolt has male threads and nuts are used on both ends. A head is not on one end of a stud. See Figure A-10.4-1, illustration shows (a) and (b) respectively. .

(a) The stud bolt shall be made from materials listed in ASME B15.5, Table 1B.

(b) Threads shall conform to ASME B1.1 Class 2A for external threads.

Figure A-~~10~~9.4-1 Drawings for Bolts With Nuts and Stud Bolts With Nuts



A-~~11~~10 Bolted Joint Assembly Records

When joint assembly records are required, they shall include the following information:

(a) joint location or identification

(b) joint pressure rating and size

(c) specifications and conditions of flanges, fasteners, bolts, washers (including nut- or washer-bearing surfaces), and gaskets

(d) date of activity (assembly, disassembly, pressure test, etc.)

(e) names of assemblers/workers

(f) name of inspector or responsible person

(g) flatness measurements, when made

(h) assembly procedure and tightening method used, including applicable target ~~prestress~~pre-stress values as per the indicated tightening method

(i) date when a ~~retorque~~re-torque was performed

(j) tool data such as type, model, pressure setting, and calibration identification

Nonmandatory Appendix B
Design ~~Rules~~Requirements for Buried Piping

B-1 Introduction

B-1.1 Purpose

~~ASME NM.1~~This Standard contains requirements governing the materials, design, fabrication, erection, examination, and testing of thermoplastic piping systems. These requirements were written for thermoplastic piping suspended in open space, with the supports located at local points on the pipe (unrestrained condition). Buried thermoplastic piping, on the other hand, is supported, confined, and restrained by the passive effects of the backfill and the trench bedding. Thus, the following general considerations apply to the design of buried piping:

(1) Pipe-to-soil interactions shall be evaluated to ensure that the soil provides adequate restraint to limit the movement of the buried pipeline as is required to prevent unacceptable levels of stress and/or strain in the piping and to prevent failure of the soil support.

(2) All components in the buried piping system shall be given consideration, including the building penetrations, branches, bends, elbows, flanges, valves, grade penetrations, and tank attachments.

(3) The effects of restraint cannot be easily evaluated by the usual methods applied to the exposed or aboveground thermoplastic piping, since these methods cannot easily accommodate the effects of bearing and friction at the pipe–soil interface.

This Appendix sets forth additional design considerations deemed necessary for safe design of restrained buried thermoplastic piping.

B-1.2 Scope

(a) The scope of this Appendix is limited to the design of buried piping as defined in para. 2-3.3.2.

(b) This Appendix deals only with the buried portions of the system, and not the complete system.

(c) The design requirements for pressure and other loads not specifically addressed in this Appendix shall meet the requirements of ASME NM.1, Chapters 2, 3, 4, and 5, as applicable.

(d) Unless altered by this Appendix, the allowable stress values are per ASME NM.3.3.

B-1.3 Nomenclature

A_p = cross-sectional area of pipe at the pipe section where the evaluation is conducted, mm^2 (in.^{2})
D = average outside diameter of thermoplastic pipe in accordance with ASME NM.1, Chapter 4, mm (in.)
DR = ratio of the outside diameter to the wall thickness of the pipe
= D/t
E' = modulus of soil reaction, MPa (psi) (data is site specific)
E_{pipe} = modulus of elasticity of pipe per ASME NM.3.3, MPa (psi)
g_c = acceleration due to gravity, m/s^2 (ft/sec^2)
H = height of ground cover, m (ft)
H_{gw} = height of groundwater above top of the pipe, m (ft)

i = stress intensification factor, per ASME NM.1 Appendix IV
P = internal design ~~gage~~gauge pressure, plus pressure spikes due to transient events, MPa (psi)
P_E = vertical soil pressure due to earth loads, MPa (psf)
P_{gw} = pressure due to groundwater above the top of the pipe, MPa (psf)
P_{hydro} = external hydrostatic pressure, equal to earth plus groundwater pressure plus surcharge load, MPa (psi)
P_L = vertical soil pressure due to surcharge loads, MPa (psf)
M_C = resultant moment range due to thermal expansion and/or contraction and/or the restraint of free end displacement, N·mm (in.-lb)
R = buoyancy reduction factor
S = allowable stress, per ASME NM.3.3, in the form of hydrostatic design stress (HDS), design stress (DS), and hydrostatic design basis (HDB), MPa (psi)
S_A = allowable secondary or fatigue stress value per ASME NM.3.3
S_{comp} = allowable side wall compression stress per ASME NM.3.3, MPa (psi)
S_L = longitudinal stresses, MPa (psi)
t = minimum wall thickness from the standard to which the pipe was made, accounting for manufacturing tolerances, or the minimum measured wall thickness, , mm (in)
T_{ground} = temperature of the soil in which the pipe is buried °C (°F)
T_{water} = temperature of the water or other fluid in the pipe °C (°F)
W_p = weight of empty pipe, per unit length, kg/m (lb/ft)
W_w = buoyant force, kg/m (lb/ft)
Z = section modulus of pipe cross section at the pipe section where the moment is calculated, mm^3 (in.^{3})
α = coefficient of thermal expansion of pipe, 1/°C (1/°F)
$\Delta T = T_{water} - T_{ground}$, °C (°F)
ν = Poisson's ratio (see ASME NM.3.3)
ρ_{dry} = unit weight (density) of dry soil (data is site specific), kg/m^3(lb/ft^3)
$\rho_{saturated}$ = unit weight (density) of saturated soil (data is site specific), kg/m^3(lb/ft^3)
ρ_W = density of fluid, kg/m^3 (lb/ft^3)
σ_{SW} = circumferential compressive stress in the sidewalls of pipe, MPa (psi)
σ_τ = tensile stress in the pipe, MPa (psi)
Ω = change in diameter as a percentage of the original diameter, commonly called the change in ring diameter

B-2 Loads

B-2.1 Sustained Loads

(a) For buried piping applications, the sustained loads are pressure, pipe weight, fluid weight, backfill, soil cover, groundwater effects, and surcharge loads.

(b) Buried pipe design requires consideration of burial depth, soil type, and compaction to determine the external loads on the pipe.

B-2.2 Soil and Surcharge Loads

It is critical for buried thermoplastic piping systems to consider the external dead loads due to soil weight, backfill, and surcharge (structure foundation, footing) in the design. ~~Paragraphs~~Paras. B-2.2.1 and B-2.2.2 provide recommended methods for determining the soil pressure from earth and surface loads acting on the crown of the pipe. Other methods may be used.

B-2.4 Construction Loads

Loads that occur during hydrostatic testing shall be considered. These loads include weight of contents, thermal, and pressured end effect.

B-2.5 Transient Loads

Transient loads are those that can occur during operation of the pipeline. An example of a transient load is surge pressure in a liquid pipeline produced by a change in the velocity of the moving fluid as defined in the Nonmandatory Appendix C. Surge pressure can result from shutting down or starting up a pump station or pumping unit, closing a valve, or blockage of the moving fluid (e.g., water hammer),

B-2.6 Combining of Loads

When calculating equivalent stresses or strains, the most critical combination of sustained, occasional, construction, and transient loads that can be expected to occur shall be considered.

B-3 Piping Analysis

B-3.1 External Soil Loads

The requirements for external soil loads are provided in paras. B-3.1.1 through B-3.1.5.

B-3.1.1 Compression of Sidewalls. The circumferential compressive stress in the sidewalls, σ_{SW}, due to soil and surcharge loads shall not exceed S_{comp}.

$$\sigma_{SW} = \frac{(P_E + P_L) \times DR}{2} \leq S_{comp}\ (SI\ Units) \qquad \text{(B-3-1a)}$$

$$\sigma_{SW} = \frac{(P_E + P_L) \times DR}{2 \times 144} \leq S_{comp}\ (US\ Customary\ Units) \qquad \text{(B-3-1b)}$$

Values of S_{comp} may be found in ASME NM.3.3

B-3.1.2 ~~Through-Wall Bending~~

~~IN DEVELOPMENT~~

~~B-3.1.3~~ Buckling

External pressure from groundwater, earth loads, and surcharge loads on a buried thermoplastic piping system shall not cause the pipe to buckle.

B-3.1.~~4~~3 **Ring Deflection.** The soil and surcharge loads on a buried thermoplastic pipe shall not result in a pipe diameter ring deflection, Ω, beyond allowable defection for the pipe inside the diameter of the thermoplastic pipe.

$$\Omega = \frac{100}{144} \times \frac{K \times L \times P_E \; + K \times P_L}{\frac{2E_{pipe}}{3} \times (\frac{1}{DR-1})^3 + 0.061 \times F_S \times E'} \leq \Omega_{\max} \qquad \text{(B-3-6)}$$

where

K = bedding factor (0.1)

L = deflection lag factor (1.0 to 1.5); see para. B-4.2.3

Ω_{max} = maximum allowable change in diameter as a percentage of the original diameter

F_s = soil support factor (given in Table B-4.2.2-4)

B-3.1.~~5~~4 Flotation. Buried thermoplastic piping system shall have sufficient cover or be anchored to the ground to prevent flotation by groundwater (upward resultant force due to buoyancy on a buried pipe in saturated soil). Flotation of a buried pipeline is prevented when the weight of the pipe, its contents, and the soil above the pipe exceed the buoyant force acting on the pipe. To ensure this effect occurs, the following relationship shall be satisfied:

$$W_W < W_P + P_E \times D/12 \;\; (US\ Customary\ Units) \qquad \text{(B-3-7)}$$

$$W_W < W_P + (1000 \times P_E \times D/g) \;\; (SI\ Units) \qquad \text{(B-3-8)}$$

$$W_W < \frac{W_P + W_C + W_S}{FS_f} \qquad \text{(B-3-9)}$$

where
FS_f = safety factor against flotation (engineering judgment or 1)
W_C = pipe content weight, kg/m (lb/ft)
W_P = pipe weight, kg/m (lb/ft); may be obtained from manufacturer or estimated from the following equation

$$W_P = \frac{\pi \rho_W G_{SP} D^2}{144} \left[\frac{(1.06DR - 1.12)}{DR^2} \right]$$

G_{SP} = specific gravity of pipe material (W_S = soil weight, kg/m (lb/ft)

$$W_S = \rho_{dry} \frac{D}{12}(H - H_{gw}) + \frac{(\rho_{Saturated} - \rho_W)}{12} \left[\frac{(4-\pi)D^2}{96} + DH_{gw} \right]$$

W_W = buoyant force, kg/m (lb/ft) $\qquad W_W = \dfrac{\pi \rho_W D^2}{48}$

where
B_w = bulk modulus of the fluid, MPa (lbf/ft^2)
c_p = pressure wave velocity mm/s; (in./sec)
d = pipe inside diameter, mm (in.)
E_{pipe} = modulus of elasticity of pipe per ASME NM-.3.3, MPa (psi)
t = pipe nominal wall thickness, mm (in.)
ψ_c = pipe wall flexibility reduction factor (see Table C-2-1)

The fluid transient pressure, P_{wh}, can be either a positive (compressive) or negative (tensile) pressure depending on the direction of flow. A tensile pressure can cause local cavitation, and, thus, reduce the positive traveling wave.

The effect of the thermoplastic pipe wall flexibility is to slow the wave velocity, c_p. This is accounted for by the reduction factor, ψ_C. Table C-2-1 provides ψ_C for various thermoplastic materials.

Table C-2-1 Pipe Wall Flexibility Reduction Factors, ψ_C

Material	Factor [Note]
HDPE	1.0
PVC	1.0
CPVC	1.0
PVDF	1.0

NOTE:

(1) Pipe wall flexibility reduction factors higher than 1.0 may be used if they can be technically justified.

C-3 Pressure Surge

Pressure surge from fluid transient shall develop both circumferential stresses and longitudinal stresses in the pipe wall as well as dynamic loads on fitting and closed valves in the piping system.

(a) The circumferential pressure stresses in the pipe wall shall be determined using the following equations for O.D. and I.D. controlled pipe, respectively.

(1) O.D. controlled pipe

$$S_{CP} = \frac{P_{wh}(DR-1)}{2}$$

(2) I.D. controlled pipe

$$S_{CP} = \frac{P_{wh}(IDR+1)}{2}$$

where

DR = ratio of the average outside diameter to the minimum fabricated wall thickness of the pipe
IDR = ratio of the average inside diameter to the minimum fabricated wall thickness of the pipe
S_{CP} = changes circumferential pressure stresses, MPa (psi)

(b) Changes in the longitudinal stresses due to the transient pressure pulse in axially constrained piping systems shall be determined as follows:

$$S_{ax} = vS_{\mathrm{CP}}$$

where
S_{ax} = Changes in axial pressure stress, MPa (psi)
v = Poisson's ratio (see ASME NM~~-~~.3.3)

(c) Changes in the longitudinal stresses due to the transient pressure pulse in unconstrained or aboveground piping systems shall be determined as follows:

$$S_{ax} = \frac{P_{wh} d}{4t}$$

(d) Structural loads are imparted to the piping system at changes in flow direction due to the momentary unbalanced pressure thrusts due to the pressure surge and shall be determined as follows:

$$F_{wh} = DLF \frac{P_{wh} \pi d^2}{4}$$

This F_{wh} is then applied to each straight run of pipe to determine the pipe movement and resulting stresses. The dynamic load factor (DLF), depends on the piping system response to the pressure surge of the fluid transient and shall be calculated. In the absence of any detailed system response data, a DLF of 2 may be used. Alternately, more detailed analysis of the event may be conducted to determine less conservative loads.