ASME NM.1-2018

Thermoplastic Piping Systems

ASME Standards for Nonmetallic Pressure Piping Systems

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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The American Society of Mechanical Engineers
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FOREWORD

In 2011, The American Society of Mechanical Engineers (ASME) established the Committee on Nonmetallic Pressure Piping Systems (NPPS) to develop standards for the construction of nonmetallic pressure piping systems. This Committee's goal was to specify construction[1] requirements for nonmetallic piping and piping products; such requirements were not adequately defined in existing standards.

Prior to the development of the ASME Standards for Nonmetallic Pressure Piping Systems, nonmetallic pressure piping requirements were contained within several existing standards. The nonmetallic piping requirements of the ASME B31 Code for Pressure Piping varied across Sections, with some Sections having no requirements for nonmetallic components at all. Other standards and codes, such as ASME RTP-1 and the ASME Boiler and Pressure Vessel Code (BPVC), Section X, included requirements for reinforced thermoset plastic (RTP) corrosion-resistant equipment but not for piping and piping components. ASME BPVC, Section III did have a few Code Cases that addressed requirements for some nonmetallic piping and piping components, including those made from glass-fiber-reinforced thermosetting resin (FRP) and a few thermoplastics, e.g., high density polyethylene (HDPE) and poly(vinyl chloride) (PVC). However, the scope of these Code Cases was very limited, and in some cases the methodology was nearly 30 years old. The ASME NPPS Standards now serve as a centralized location for NPPS requirements and are developed by committees whose members are experts in this field. The NPPS Committee's functions are to establish requirements related to pressure integrity for the construction of nonmetallic pressure piping systems, and to interpret these requirements when questions arise regarding their intent.

This first edition of ASME NM.1 provides requirements for the construction of thermoplastic pressure piping systems. This Standard addresses both pipe and piping components that are produced as standard products, and custom products that are designed for a specific application.

ASME NM.1-2018 was approved by the American National Standards Institute (ANSI) on July 27, 2018.

[1] *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, erection, examination, inspection, testing, and overpressure protection.

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Nonmetallic Pressure Piping Systems

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Secretary, NPPS Standards Committee
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990
http://go.asme.org/Inquiry

Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Proposing a Case. Cases may be issued to provide alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee web page.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Standard and the paragraph, figure, or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Standard to which the proposed Case applies.

Interpretations. Upon request, the NPPS Standards Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the NPPS Standards Committee.

Requests for interpretation should preferably be submitted through the online Interpretation Submittal Form. The form is accessible at http://go.asme.org/InterpretationRequest. Upon submittal of the form, the Inquirer will receive an automatic e-mail confirming receipt.

If the Inquirer is unable to use the online form, he/she may mail the request to the Secretary of the NPPS Standards Committee at the above address. The request for an interpretation should be clear and unambiguous. It is further recommended that the Inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry in one or two words.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. Please provide a condensed and precise question, composed in such a way that a "yes" or "no" reply is acceptable.
Proposed Reply(ies):	Provide a proposed reply(ies) in the form of "Yes" or "No," with explanation as needed. If entering replies to more than one question, please number the questions and replies.
Background Information:	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. The Inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in the format described above may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

Moreover, ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the Inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee or Subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

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INTRODUCTION

The ASME Standards for Nonmetallic Pressure Piping Systems (NPPS) are

NM.1 Thermoplastic Piping Systems: This Standard contains requirements for piping and piping components that are produced using thermoplastic resins or compounds. Thermoplastics are a specific group of nonmetallic materials that, for processing purposes, are capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.

NM.2 Glass-Fiber-Reinforced Thermosetting-Resin Piping Systems: This Standard contains requirements for piping and piping components that are produced using glass-fiber reinforcement embedded in or surrounded by cured thermosetting resin.

NM.3 Nonmetallic Materials: This Standard includes specifications for nonmetallic materials (except wood, nonfibrous glass, and concrete) and, in conformance with the requirements of the individual construction standards, methodologies, design values, limits, and cautions on the use of materials. This Standard is divided into three Parts:

– NM.3.1, Nonmetallic Materials, Part 1 — Thermoplastic Material Specifications: This Part contains thermoplastic material specifications identical to or similar to those published by the American Society for Testing and Materials (ASTM International) and other recognized national or international organizations.

– NM.3.2, Nonmetallic Materials, Part 2 — Reinforced Thermoset Plastic Material Specifications: This Part contains reinforced thermoset plastic material specifications identical to or similar to those published by ASTM and other recognized national or international organizations.

– NM.3.3, Nonmetallic Materials, Part 3 — Properties: This Part provides tables and data sheets for allowable stresses, mechanical properties (e.g., tensile and yield strength), and physical properties (e.g., coefficient of thermal expansion and modulus of elasticity) for nonmetallic materials.

It is the owner's responsibility to select the piping standard that best applies to the proposed piping installation. Factors to be considered by the owner include limitations of the standard, jurisdictional requirements, and the applicability of other standards. All applicable requirements of the selected standard shall be met. For some installations, more than one standard may apply to different parts of the installation. The owner is also responsible for imposing requirements supplementary to those of the standard if such requirements are necessary to ensure safe piping for the proposed installation.

Certain piping within a facility may be subject to other codes and standards, including but not limited to the following:

ASME B31.1, Power Piping: This code contains requirements for piping typically found in electric power generating stations, industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems.

ASME B31.3, Process Piping: This code contains requirements for piping typically found in petroleum refineries; onshore and offshore petroleum and natural gas production facilities; chemical, pharmaceutical, textile, paper, ore-processing, semiconductor, and cryogenic plants; food- and beverage-processing facilities; and related processing plants and terminals.

ASME B31.4, Pipeline Transportation Systems for Liquids and Slurries: This code contains requirements for piping transporting products that are predominately liquid between plants and terminals, and within terminals and pumping, regulating, and metering stations.

ASME B31.5, Refrigeration Piping and Heat Transfer Components: This code contains requirements for piping for refrigerants and secondary coolants.

ASME B31.8, Gas Transmission and Distribution Piping Systems: This code contains requirements for piping transporting products that are predominately gas between sources and terminals, including compressor, regulating, and metering stations; and gas gathering pipelines.

ASME B31.9, Building Services Piping: This code contains requirements for piping typically found in industrial, institutional, commercial, and public buildings, and in multi-unit residences, which does not require the range of sizes, pressures, and temperatures covered in ASME B31.1.

ASME B31.12, Hydrogen Piping and Pipelines: This code contains requirements for piping in gaseous and liquid hydrogen service, and pipelines in gaseous hydrogen service.

National Fuel Gas Code: This code contains requirements for piping for fuel gas from the point of delivery to the connection of each fuel utilization device.

NFPA 99, Health Care Facilities: This standard contains requirements for medical and laboratory gas systems.

NFPA Fire Protection Standards: These standards contain requirements for fire protection systems using water, carbon dioxide, halon, foam, dry chemicals, and wet chemicals.

The ASME NPPS Standards specify engineering requirements deemed necessary for safe design and construction of nonmetallic pressure piping. These Standards contain mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities. These Standards do not address all aspects of these activities, and those aspects that are not specifically addressed should not be considered prohibited. While safety is the overriding consideration, this factor alone will not necessarily govern the final specifications for any piping installation. With few exceptions, the requirements do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. These Standards are not design handbooks. Many decisions that must be made to produce a safe piping installation are not specified in detail within these Standards. These Standards do not serve as substitutes for sound engineering judgment by the owner and the designer. The phrase *engineering judgment* refers to technical judgments made by knowledgeable designers experienced in the application of these Standards. Engineering judgments must be consistent with the philosophy of these Standards, and such judgments must never be used to overrule mandatory requirements or specific prohibitions of these Standards.

To the greatest possible extent, Standard requirements for design are stated in terms of basic design principles and formulas. These are supplemented as necessary with specific requirements to ensure uniform application of principles and to guide selection and application of piping elements. These Standards prohibit designs and practices known to be unsafe and contain warnings where caution, but not prohibition, is warranted.

These Standards generally specify a simplified approach for many of their requirements. A designer may choose to use a more rigorous analysis to develop design and construction requirements. When the designer decides to take this approach, he or she shall provide to the owner details and calculations demonstrating that design, fabrication, examination, inspection, testing, and overpressure protection are consistent with the criteria of these Standards. These details shall be adequate for the owner to verify the validity of the approach and shall be approved by the owner. The details shall be documented in the engineering design.

The designer is responsible for complying with requirements of these Standards and demonstrating compliance with the equations of these Standards when such equations are mandatory. These Standards neither require nor prohibit the use of computers for the design or analysis of components constructed to the requirements of these Standards. However, designers and engineers using computer programs for design or analysis are cautioned that they are responsible for all technical assumptions inherent in the programs they use and for the application of these programs to their design.

These Standards do not fully address tolerances. When dimensions, sizes, or other parameters are not specified with tolerances, the values of these parameters are considered nominal, and allowable tolerances or local variances may be considered acceptable when based on engineering judgment and standard practices as determined by the designer.

Suggested requirements of good practice are provided for the care and inspection of in-service nonmetallic pressure piping systems only as an aid to owners and their inspectors.

The requirements of these Standards are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the requirements of these Standards.

It is intended that editions of the ASME NPPS Standards not be retroactive. Unless agreement is specifically made between contracting parties to use another edition, or the regulatory body having jurisdiction imposes the use of another edition, the latest edition issued at least 6 months prior to the original contract date for the first phase of activity covering a piping installation shall be the governing document for all design, materials, fabrication, erection, examination, inspection, testing, and overpressure protection for the piping until the completion of the work and initial operation. Revisions to material specifications included in ASME NM.3.1 and ASME NM.3.2 are originated by ASTM and other recognized national or international organizations, and are usually adopted by ASME. However, those revisions do not necessarily indicate that materials produced to earlier editions of specifications are no longer suitable for ASME construction. Both ASME NM.3.1 and ASME NM.3.2 include a Mandatory Appendix, "Guideline on Acceptable ASTM Editions," that lists the latest edition of material specifications adopted by ASME as well as other editions considered by ASME to be identical for ASME construction.

Users of these Standards are cautioned against making use of revisions to these Standards without assurance that they are acceptable to the proper authorities in the jurisdiction where the piping is to be installed.

Chapter 1
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, and any additional requirements established by the owner, are met.

(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 4-2.1-1. 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 (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 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 Chapter 7, 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.

(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 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 through 100°C (−20°F through 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) 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.*

Category M: see *fluid service.*

component: as used in this Standard, an item within the piping system; components include, but are not limited to, pipe, piping subassemblies, parts, valves, strainers, relief devices, and fittings.

nonstandard component: a component not manufactured in accordance with any of the standards listed in Table 4-2.1-1.

specially designed component: a nonstandard component designed in accordance with section 2-1, section 2-2, section 2-3, section 7-4, or section 8-3 and complying with other requirements of this Standard.

standard component: a component manufactured in accordance with one or more of the standards listed in Table 4-2.1-1.

compression-type tube fitting: a flareless mechanical grip connection consisting of a body, a nut, and single or dual ferrules. See also para. 5-2.1.

connections for external piping: those integral parts of individual pieces of equipment that are designed for attachment of external piping.

convoluted backup ring: a unique geometric cross-sectional shape intended to increase the stiffness of a metallic or nonmetallic ring used within a thermoplastic lap-joint flange connection.

damaging to human tissues: for the purposes of this Standard, this phrase describes a fluid service in which exposure to the fluid, caused by leakage under expected operating conditions, can harm skin, eyes, or exposed mucous membranes so that irreversible damage may result unless prompt restorative measures are taken. (Restorative measures can include flushing with water or administering antidotes or medication.)

defect: a flaw (imperfection or unintentional discontinuity) of such size, shape, orientation, location, or properties as to give cause for rejection.

designer: the person or organization in responsible charge of the engineering design.

design life: duration of time used in design calculations, selected for the purpose of verifying that a replaceable or permanent component is suitable for the anticipated period of service. (Design life does not pertain to the life of a piping system because a properly maintained and protected piping system can provide service indefinitely.)

design pressure: see para. 2-1.2.2.

design temperature: see para. 2-1.2.3(e).

design temperature, minimum: see para. 2-1.2.3(b).

discontinuity: a lack of continuity or cohesion; an interruption in the normal physical structure of material or a product.

displacement stress range: see para. 2-2.3.3(b).

electrofusion welding (EFW): a joining process for thermoplastic materials in which heat for the welding is provided by energizing an electrically resistive coil in the weld zone.

elements: see *piping elements*.

employer: the owner, manufacturer, fabricator, contractor, assembler, or installer responsible for the welding, joining, and nondestructive examination (NDE) performed by their organization.

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 include the following:

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 gauge pressure does not exceed 1 035 kPa (150 psi).

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

Category M fluid service: a fluid service in which both of the following apply:

(a) The fluid is so highly toxic that a single exposure to a very small quantity of 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. Also known as fusion.

fusing machine operator: person who uses and controls the equipment (including manual, semiautomatic, and 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 operator for making sound and quality production fusion joints. See also *Joining Procedure Specification (JPS)* and *Procedure Qualification Record (PQR)*.

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 commingling 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 in which 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. Also called hydrotest.

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

inspection: the act of witnessing or verifying compliance to the specified requirements.

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

installer: person who performs the solvent weld, makes flange connections, or assembles other types of mechanical connections.

Joining Procedure Specification (JPS): general term for the documented procedure for all types of thermoplastic joining processes.

joint crush test: a method used to evaluate socket-fused or electrofused thermoplastic joints.

joint design: the joint geometry together with the required dimensions of the welded or heat-fused joint.

lap joint: a type of mechanical connection made between piping components using a flange adapter with a backup ring. Flared steel pipe with a thermoplastic liner can also be used.

listed: for the purposes of this Standard, a term describing a material that conforms to one or more specifications in ASME NM.3.1, or as defined in this Standard, or to the extent as referenced in the standards in Table 4-2.1-1.

long-term hydrostatic strength (LTHS): the estimated hoop stress, expressed in megapascals (pressure per square inch), in a plastic pipe wall that will cause failure of the pipe at an average of 100 000 h when subjected to a constant hydrostatic pressure.

material: a substance from which a component is made. Materials include, but are not limited to, thermoplastics, thermoset plastics, metal alloys, elastomers, reinforcing fibers, and thermoplastic fibers.

maximum allowable operating pressure (MAOP): the highest continuous internal pressure at which a piping system may be operated in accordance with the provisions of this Standard.

maximum allowable operating temperature (MAOT): the highest continuous operating temperature the piping system is able to resist while complying with the provisions of this Standard.

maximum allowable stress: the highest stress value that may be used in the design formulas for a given material and design temperature.

maximum allowable working pressure (MAWP): the pressure at the coincident temperature to which a component can be subjected without exceeding the maximum allowable stress of the material or pressure–temperature rating of the component.

maximum pressure rating: the highest internal pressure to which a piping component has been qualified.

maximum qualified temperature: the highest temperature at which the maximum pressure rating and minimum qualified pressure of a multilayered reinforced thermoplastic piping system have been established.

maximum sustained operating pressure (MSOP): the highest pressure at which a piping system is operated during a normal operating cycle; sometimes referred to as maximum actual operating pressure.

may: an expression of permission.

mechanical coupling: in a thermoplastic-lined metallic piping system, a metallic device that provides structural support to a butt-fusion-welded joint.

mechanical joining: the mating of piping components formed by a positive-holding mechanical assembly (e.g., flanged joint, threaded joint, or flared joint).

mechanical joint: a joint for the purpose of mechanical strength or leak resistance, or both, in which the mechanical strength is developed by threaded, grooved, rolled, flared, or flanged pipe ends, or by bolts, pins, toggles, or rings; and the leak resistance is developed by threads and compounds, gaskets, rolled ends, caulking, or machined and mated surfaces.

minimum allowable operating pressure: the lowest transient internal pressure the piping system is able to resist without damage.

minimum allowable operating temperature: the lowest continuous temperature that the piping system is able to resist while complying with the provisions of this Standard.

minimum operating bend radius (MOBR): the smallest bending radius that the multilayered reinforced thermoplastic piping system should be subjected to when the piping system is in operation.

minimum qualified pressure: the lowest internal pressure the component has been proven to resist.

minimum qualified temperature: the lowest temperature the component has been proven to resist.

miter: two or more straight sections of pipe matched and joined in a plane bisecting the angle of junction so as to produce a change in direction.

monolithic thermoplastic: piping or piping component that is formed from a homopolymer or copolymer resin or compound without joints or seams.

nominal: a numerical identification of dimension, capacity, rating, or other characteristic used as a designation, not as an exact measurement.

nominal thickness: the thickness given in the product material specification or standard to which manufacturing tolerances are applied.

noncontact fusion: a heat-joining process in which the heating element does not touch the ends of the thermoplastic piping components being joined.

nondestructive examination (NDE): the process of testing or evaluating materials, components, or assemblies without affecting the serviceability of the part or system, in order to detect, locate, measure, interpret, and evaluate flaws. Also known as nondestructive testing (NDT).

normal fluid service: see *fluid service*.

owner: the party or organization ultimately responsible for operation of a facility. The owner is usually the one who would be granted an operating license by the regulatory authority having jurisdiction or who has the administrative and operational responsibility for the facility. The owner can be either the operating organization (i.e., might not be the actual owner of the physical property of the facility) or the organization that owns and operates the plant.

packaged equipment: an assembly of individual pieces or stages of equipment, complete with interconnecting piping and connections for external piping. The assembly can be mounted on a skid or other structure prior to delivery.

Performance Qualification Test Record (PQTR): a written record of a test administered to a welder or a welding operator to determine the individual's capacity to perform a specific welding application. Welding performance qualification tests are specific to a Welding Procedure Specification (WPS). See also *Fusion Performance Qualification (FPQ)*.

permeation: the three-step physical process of absorption, diffusion, and desorption by which a fluid passes through a barrier.

pipe: a pressure-tight cylinder used to convey a fluid or to transmit a fluid pressure, which is ordinarily designated "pipe" in applicable material specifications. Materials designated "tube" or "tubing" in the specifications are treated as pipe when intended for pressure service.

pipe 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, 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 support elements but does not include support structures, such as building frames, bents, foundations, or any equipment excluded from this Standard [see para. 1-2.1(d)].

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 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 length of time for which a nonmetallic, reinforced, multilayered thermoplastic piping system has been qualified for use. [See para. 8-3.2.1(c).]

reinforcing ring: a metallic or nonmetallic ring used to distribute the load from the 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 chloride) (CPVC), poly(vinyl 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-gauge tests.[1]

hydrostatic design basis (HDB): selected properties of plastic piping materials to be used in accordance with ASTM D2837 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-gauge tests.

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 to 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).

unlisted: see para. 3-2.2.

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 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 BPVC 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 4-2.1-1.

1-5 STATUS OF APPENDICES

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

[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.

Table 1-4-1 Abbreviations

Abbreviation	Definition
ABS [Notes (1) and (2)]	Acrylonitrile-butadiene-styrene
CPVC [Note (1)]	Chlorinated poly(vinyl chloride)
DR [Note (2)]	Dimension ratio
E-CTFE [Note (1)]	Ethylene-chlorotrifluoroethylene
EFW	Electrofusion welding
ETFE [Note (1)]	Ethylene-tetrafluoroethylene copolymer
FEP [Note (1)]	Perfluoro(ethylene propylene) 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 [Notes (1) and (2)]	High-density polyethylene
HDS [Note (2)]	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 [Notes (1) and (2)]	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
NPS	Nominal pipe size
O.D.	Outside diameter
PA	Polyamide
PB [Note (1)]	Polybutylene
PE [Note (1)]	Polyethylene
PE-RT	Polyethylene of raised temperature
PEX	Cross-linked polyethylene
PFA [Note (1)]	Perfluoroalkoxy alkane
PP [Note (1)]	Polypropylene
PQR	Procedure Qualification Record
PQTR	Performance Qualification Test Record
PR [Note (2)]	Pressure rating
PTFE [Note (1)]	Poly(tetrafluoroethylene)
PTFE-M	Modified PTFE
PVC [Note (1)]	Poly(vinyl chloride)
PVC-O	Oriented poly(vinyl chloride)
PVDF [Note (1)]	Poly(vinylidene fluoride)
PVDF-C	Poly(vinylidene fluoride) copolymer
PVVE	Perfluoroalkyl vinyl ether
RPM	Reinforced plastic mortar
RTP	Reinforced thermosetting plastic
RTR	Reinforced thermosetting resin

Table 1-4-1 Abbreviations (Cont'd)

Abbreviation	Definition
SDR [Note (2)]	Standard dimension ratios
SIDR [Note (2)]	Standard inside diameter dimension ratio
SPIG	Spigot end
WPS	Welding Procedure Specification

NOTES:
(1) Abbreviation is in accordance with ASTM D1600.
(2) Abbreviation is in accordance with ASTM F412.

Table 1-5-1 Status of Appendices

Appendix	Title	Status
Mandatory		
I	Fusing and Electrofusing of Polyamide-11 Plastic Piping; and Fusing of Polypropylene, Poly(Vinylidene Fluoride), and Poly(Tetrafluoroethylene) 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 Flanges	Requirements
Nonmandatory		
A	Components for Thermoplastic Lap-Joint Flange Connections	Guidance
B	Design 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 material properties for a given loading.

NOTE: The physical properties for thermoplastic materials are provided in ASME NM.3.3.

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 megapascals (MPa) above atmospheric pressure [MPa (gauge)] [pounds per square inch gauge (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. This 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 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 hammer 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 sustained loads on the pipe are evaluated, 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 fact that further settlement of 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 Table 4-2.1-1. 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 4-2.1-1.

(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 manufacture 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 ratings 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 do not exceed the maximum pressure and temperature allowed by this Standard for that particular 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 4-2.1-1.

2-2.2.4 Ratings: Allowance for Variation 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/yr

(2) 20% if the event duration occurs for not more than 1 h at any one time and not more than 80 h/yr

(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 duration 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 listed in ASME NM.3.3 for each material are 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:

$$S_{\text{specific}} = S_{\text{NM.3.3}} \frac{\text{service factor}_{\text{specific}}}{\text{design factor}_{\text{NM.3.3}}} \quad (2\text{-}2\text{-}1)$$

where

design factor$_{\text{NM.3.3}}$ = the service factor used in development of the ASME NM.3.3 S values

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

S_{specific} = S value to be used in design, MPa (psi)

service factor$_{\text{specific}}$ = the service factor to be used in design

This requirement applies only to the S values, not to the S_A values, where S_A is the secondary stress allowable range as found in NM.3.3, Table 1-1-3:

$$S = S_{\text{specific}}(\text{EF}) \quad (2\text{-}2\text{-}2)$$

where

EF = environmental derating factor based on fluid–material interaction effects; EF ≤ 1.0

2-2.3.3 Limits for Sustained and Displacement Stresses

(a) *Sustained Stresses*

(1) *Internal Pressure Stress.* The calculated stress due to internal pressure shall not exceed the allowable stress values given in the Allowable Stress Tables in ASME NM.3.3 at the maximum operating temperature. This criterion is satisfied when the wall thickness of the piping component, including any reinforcement, meets the requirements of paras. 2-3.2.1 through 2-3.2.7, excluding para. 2-3.2.1.2 but including the consideration of allowances permitted by paras. 2-2.2.4 and 2-2.4.

(2) External Pressure Stress. Piping subject to external pressure shall be considered safe when the wall thickness and means of stiffening meet the requirements of para. 2-3.2.1.2.

(3) Longitudinal Pressure Stress. For straight pipe, the sum of the longitudinal stresses, S_L, due to pressure, weight, and other sustained loads shall not exceed the basic material allowable stress, S, in the hot condition. Where the material has different properties in the axial and hoop directions, the allowable stress, S, shall be that applicable to the axial direction. The longitudinal pressure stress, S_{lp}, for pipe joined to transmit axial pressure thrust loads may be determined by eq. (2-2-3) or eq. (2-2-4):

$$S_{lp} = \frac{PD}{4t_n} \tag{2-2-3}$$

$$S_{lp} = \frac{Pd^2}{D^2 - d^2} \tag{2-2-4}$$

where

D = outside diameter, mm (in.)
d = inside diameter, mm (in.)
P = internal pressure, MPa (psig)
t_n = nominal thickness, mm (in.)

(4) Combined Longitudinal Stress. The sum of the longitudinal stresses produced by external pressure, live loads, dead loads, and other sustained loads shall meet the requirements of para. 2-3.3.1.1.

(b) Displacement Limited Stress Range. The calculated reference displacement stress range, per para. 2-3.3.1.3, shall not exceed the allowable stress range, S_A, as given in ASME NM.3.3 based on the fatigue properties for the given material at the given temperature. S_A shall be selected based on the total number of temperature cycles or the number of equivalent reference displacement stress range cycles, N, as determined below:

(1) HDPE

$$N = N_E + N_1\left(\frac{\Delta T_1}{\Delta T_E}\right)^{5.0} + N_2\left(\frac{\Delta T_2}{\Delta T_E}\right)^{5.0} + \dots + N_n\left(\frac{\Delta T_n}{\Delta T_E}\right)^{5.0} \tag{2-2-5}$$

where

$N_1, N_2, \dots, N_n$ = number of cycles at letter temperatures changes, $\Delta T_1, \Delta T_2, \dots, \Delta T_n$
N_E = number of cycles at maximum temperature change ΔT_E
$\Delta T_1, \Delta T_2, \dots, \Delta T_n$ = the lower temperature changes experienced by the pipe, °C (°F)
ΔT_E = maximum temperature change experienced 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, $\Delta T_E, \Delta T_1, \Delta T_2, \dots, \Delta T_n$:

$$N = N_E + N_1 + N_2 + \dots + N_n \tag{2-2-6}$$

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 6-3, the circumferential (hoop) stress shall not exceed 150% of the 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 the allowable stress value given in ASME NM.3.3 at test temperature.

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

2-2.4.4 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 2-3.2.7, 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, t_{min}, of straight pipe sections for pressure design shall be determined by the following:

(1) For O.D.-controlled pipe

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

(2) For I.D.-controlled pipe

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

where

A = an allowance to be determined by the designer for threading, grooving, erosion, or other wall loss mechanisms, mm (in.)
D = specified or actual outside diameter, mm (in.)
d = specified or actual inside diameter, mm (in.)
P = internal pressure, MPa (psig)
P_D = design pressure, MPa (psig)
S = maximum allowable stress from ASME NM.3.3, Table 1-1-1, MPa (psi)

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

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

(2) For I.D.-controlled pipe

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

where

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.)

2-3.2.1.2 Straight Pipe Under External Pressure. 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. For straight pipe made of HDPE, the sum of the maximum anticipated operating pressure plus the maximum anticipated occasional pressure spikes shall be not greater than $1.5P_D$. 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.

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 electrofusion 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:

$$\mathrm{PR} = \mathrm{GSR}\left(\frac{2S}{\mathrm{DR} - 1}\right) \geq P_D \qquad (2\text{-}3\text{-}5a)$$

where GSR is the geometric shape rating factor per Table 2-3.2.2-1 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 2-3.2.2-1, illustration (a) or illustration (b), as applicable. This requirement shall be identified on the design and fabrication drawings.

(c) Materials Other Than HDPE. Tables 2-3.2.2-2 and 2-3.2.2-3 list the design factors (DF) and pressure ratings (PR), respectively, for non-HDPE thermoplastic

Table 2-3.2.2-1 Geometric Shape Rating (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 tee equal outlet (two DR less than pipe) DR 5 to DR 9	0.65
Mitered elbows [Note (3)] (one to five segments) DR 5.6 to DR 9	0.80
Mitered elbows [Notes (1) and (3)] (one to five segments) DR 9.5 to DR 13.5 (segments ≤22.5-deg directional changes per fusion)	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. (2-3-5a) 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.

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 for other thermoplastic piping components shall be determined by testing or by the following calculation:

$$PR = DF\left(\frac{2S}{D/t - 1}\right) \geq P_D \tag{2-3-5b}$$

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 $O.D._{branch}/O.D._{run}$ 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. For mitered elbows made of HDPE, the following requirements apply:

(a) The design pressure rating of the mitered elbow, P_m, shall be calculated as the lesser of eqs. (2-3-6) and (2-3-7) (see Figure 2-3.2.2-1) or as determined by testing per para. 2-3.2.2(b)(1):

$$P_m = \frac{St_{elbow}}{r_2}\left(\frac{t_{elbow}}{t_{elbow} + 0.622 \tan\theta\sqrt{t_{elbow}r_2}}\right) \tag{2-3-6}$$

or

$$P_m = \frac{St_{elbow}}{r_2}\left(\frac{R_1 - r_2}{R_1 + 0.5r_2}\right) \tag{2-3-7}$$

where P_m shall be greater than or equal to P_D and

R_1 = centerline radius of mitered elbow, mm (in.); see Figure 2-3.2.2-1, 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.)

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

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

(d) The minimum fabricated wall thickness of the monolithic reinforced sections of the mitered elbow shall be >$1.25t_{min}$ 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 ASME SF-2206, a wall thickness >$1.25t_{min}$ may not be required, provided the owner approves the thickness and it has been verified by test data.

(e) The fabricated tolerance of the fitting angular direction shall be +3 deg. Mitered joints of 3 deg or less (angle α_{elb} in Figure 2-3.2.4-1) shall not require redesign consideration as mitered elbows.

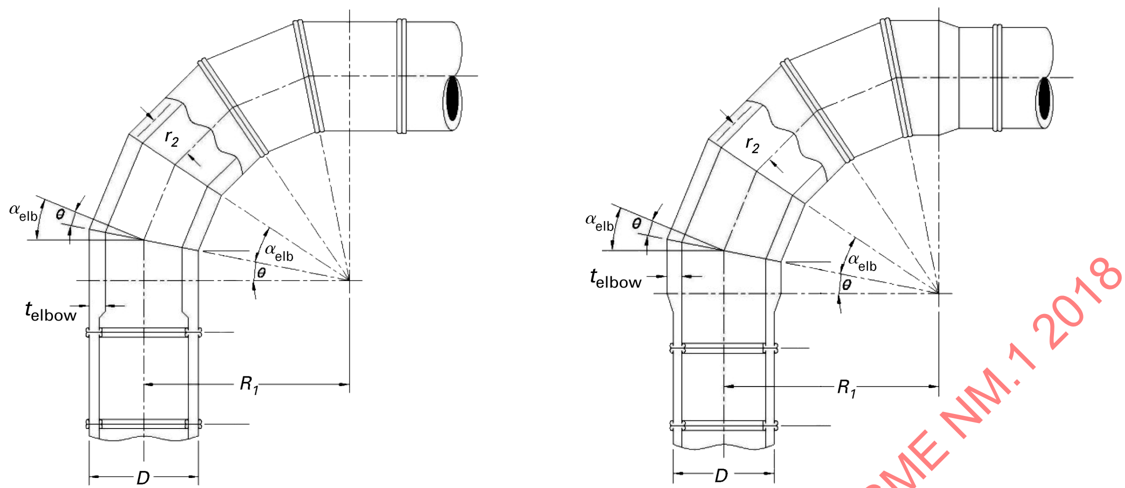
(f) HDPE mitered elbows shall comply with the following requirements, except the wall thickness shall be determined as outlined in (c):

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

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

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

Figure 2-3.2.2-1 Nomenclature for 90-deg Mitered Elbows



(a) Constant O.D., Five-Segment, Reinforced Mitered Elbow [Note (1)]

(b) Constant I.D., Five-Segment, Reinforced Mitered Elbow [Note (2)]

GENERAL NOTE: α_{elb} = 22.5 deg max.; θ = angle of miter cut, deg. See para. 2-3.2.4 for definitions of other terms.

NOTES:
(1) This design has a reduced I.D. A thicker wall pipe shall be used for reinforcement.
(2) This design has approximately the same I.D. as the pipe connecting to this fitting. An oversize pipe shall be used for the fabricated segments.

Table 2-3.2.2-2 Design Factor (DF)

Fitting Description	DF	Reference Specification
PVC Schedule 40		
Straight pipe	1.0	ASME SD-1785
Molded fittings, solvent weld	0.6	ASME SD-2466
Molded fittings, threaded (threads are actually Sch. 80)	0.5	ASME SD-2464, ASME SD-2467
PVC Schedule 80		
Straight pipe	1.0	ASME SD-1785
Molded fittings, solvent weld	0.6	ASME SD-2467
Molded fittings, threaded	0.5	ASME SD-2464, ASME SD-2467
CPVC Schedule 40		
Straight pipe	1.0	ASME SF-441
Molded fittings, solvent weld	0.6	ASME SF-438
CPVC Schedule 80		
Straight pipe	1.0	ASME SF-441
Molded fittings, solvent weld	0.6	ASME SF-439
Molded fittings, threaded	0.5	ASME SF-437
ABS Pressure Piping Components		
Straight pipe	1.0	ASTM D2661, ASTM F2806, ASTM F2969
Molded fittings, solvent weld	0.6	ASTM D2235, ASTM F2135
Molded fittings, threaded	0.5	ASTM D3311, ASTM F1498

Table 2-3.2.2-3 Pressure Rating (PR) at 23°C (73°F)

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

GENERAL NOTE: An appropriate derating factor shall be applied for higher-temperature applications or services.

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 to either pressure or thermal effects, is relatively high 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 4-2.1-1, and used within the specified pressure–temperature ratings.

(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.

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 (2-3-8) and (2-3-9) 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, S_L, in the pipe caused by applied pressure and bending loads in thermoplastic pipe shall satisfy eq. (2-3-8):

$$S_L = S_{lp} + 0.75i\frac{M_A}{Z} \leq 1.0S \tag{2-3-8}$$

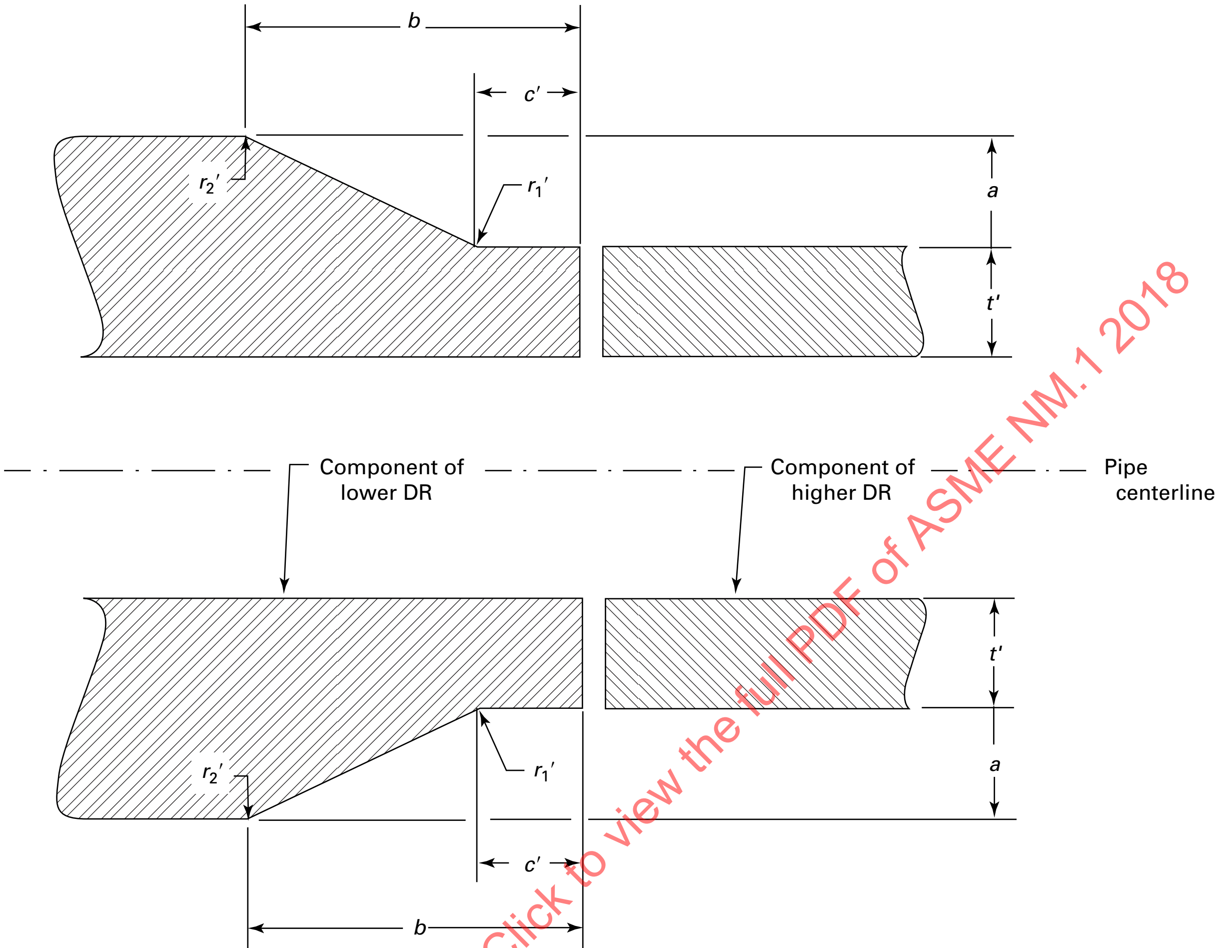
where

i = stress intensification factor (see Mandatory Appendix IV)

M_A = resultant bending moment due to the applicable applied sustained load

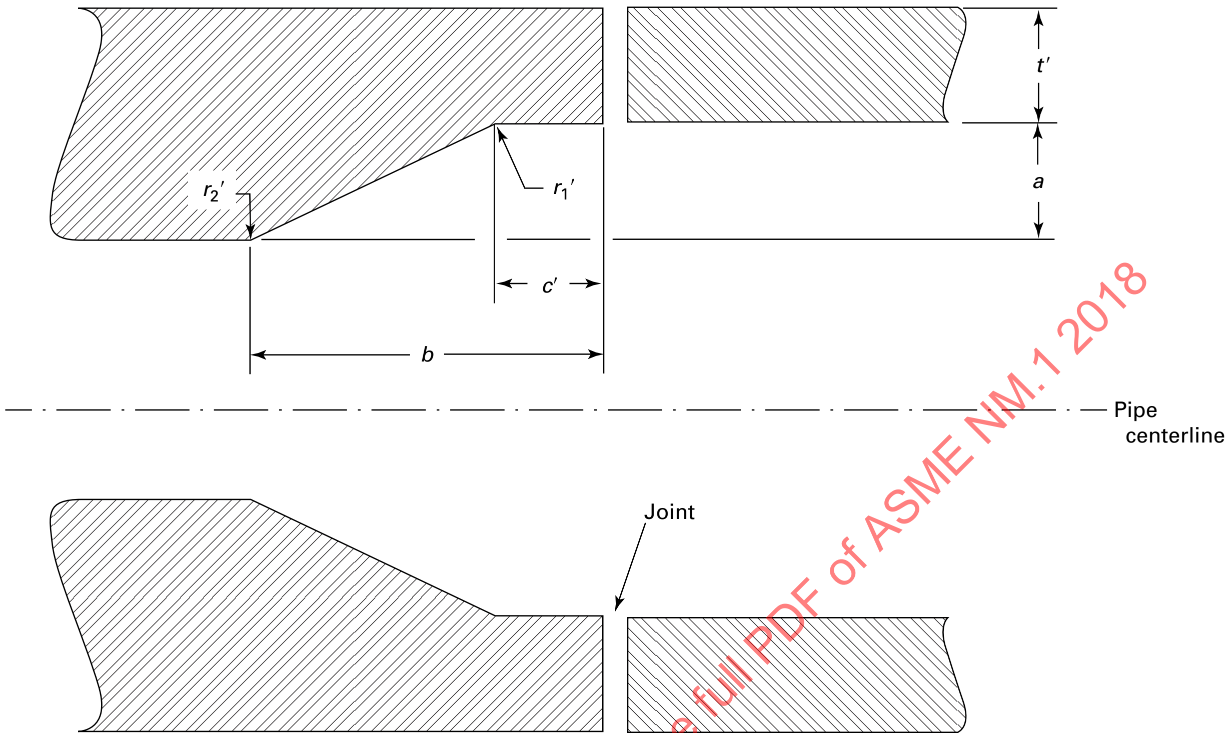
S = basic allowable stress, MPa (psi), given in ASME NM.3.3 for long-term load duration at the design temperature

Figure 2-3.2.4-1 Tapered Transition Joint



(a) Constant I.D. With Reinforcement on O.D.

Figure 2-3.2.4-1 Tapered Transition Joint (Cont'd)



(b) Constant O.D. With Reinforcement on I.D.

GENERAL NOTE:

c'_{min} = $2.5t'$; c' values are after facing

$$0.35 < \frac{a}{b - c'} < 0.6$$

$r_1'{}_{min}$ = $0.05t'$

$r_2'{}_{min}$ = $0.05t'$

t' = thickness of thinner component

S_{lp} = longitudinal pressure stress, MPa (psi), for the axially coupled pipe [see para. 2-2.3.3(a)(3)]

Z = section modulus (see para. 2-3.3.3)

2-3.3.1.2 Stress Due to Occasional Loads

(a) Longitudinal stresses, S_L, in the pipe caused by applied pressure and occasional bending loads in thermoplastic pipe shall satisfy eq. (2-3-9):

$$S_L = S_{lp} + 0.75i\frac{M_A}{Z} + 0.75i\frac{M_B}{Z} \leq kS \tag{2-3-9}$$

where

k = 1.0 for design loads and any loads occurring more than 8 h at any one time and more than 800 h/yr

= 1.1 if the event duration occurs for no more than 8 h at any one time and not more than 800 h/yr

= 1.2 if the event duration occurs for not more than 1 h at any one time and not more than 80 h/yr. In the case of multiple possible k values, the limiting k value shall apply.

M_B = resultant bending moment due to occasional loads

(b) If the load duration basis for the sustained loads differs from that for the occasional loads, then the Miner's rule summation shall be used:

$$\left[\frac{\left(S_{lp} + 0.75i\frac{M_A}{Z}\right)}{S_{(LT)}}\right] + \ldots + \left[\frac{\left(0.75i\frac{M_B}{Z}\right)}{S_{(B)}}\right] + \ldots \leq k \tag{2-3-10}$$

where

$S_{(B)}$ = S value, MPa (psi), from ASME NM.3.3 at the duration of the occasional load, M_B

$S_{(LT)}$ = S value, MPa (psi), from ASME NM.3.3 at the duration of the sustained load, M_A

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 eq. (2-3-9)], and vibrations.

(b) The bending stresses in the thermoplastic pipe caused by applied cyclic secondary loads shall satisfy eq. (2-3-11):

$$\frac{iM_c}{Z} \leq S_A \tag{2-3-11}$$

where

M_c = range of resultant cyclic secondary moment load on 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 Secondary Loads

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

(b) The bending stresses in the thermoplastic pipe caused by applied noncyclic secondary axial and longitudinal loads shall meet eq. (2-3-12):

$$\frac{iM_D}{Z} \leq 2S_h \tag{2-3-12}$$

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

$$Z = \frac{\pi(D_{oh}^4 - d_h^4)}{32D_{oh}} \tag{2-3-13}$$

where

d_h = inside diameter of header, mm (in.)

D_{oh} = outside diameter of header, mm (in.)

(2) For the branch pipe

$$Z = \frac{\pi(D_{ob}^4 - d_b^4)}{32D_{ob}} \tag{2-3-14}$$

where

d_b = inside diameter of the branch pipe, mm (in.)

D_{ob} = outside diameter of the branch pipe, mm (in.)

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

$$Z = \frac{2I}{D} \tag{2-3-15}$$

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

(f) Where pipe support elements contact the pipe, the load shall be distributed over the pipe using sleeves, wraps, etc. U-bolts should not be used.

(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 may be used to direct the pipe to expand and contract into portions of the system that 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 that 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) When determining pipe support requirements, consider the following:

(1) the effects of decreases in the modulus of elasticity with increasing temperature

(2) creep effects of the pipe material with time

(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 eq. (2-4-1):

$$\tau_i = \frac{F_i}{A_S} < 0.8S_h \tag{2-4-1}$$

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) For HDPE piping, the modulus used for thermal expansion analysis shall be selected to be consistent with the duration of the application of the thermal expansion load.

(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
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

Materials 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 III 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 materials for linings

(1) polyolefin: PE, PP

(2) fluorinated: PVDF, PTFE, FEP, PFA, ETFE, E-CTFE

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 III 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 on 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 4-2.1-1) 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 that meet other requirements of this 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 the 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 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) Combinations of any of the above materials are listed in Chapter 8.

Chapter 4
Standards for Piping Components

4-1 GENERAL

(a) *Standard Piping Components.* Standard piping components are piping components that comply with one or more standards listed in Table 4-2.1-1 or ASME NM.3.1.

(b) *Nonstandard Piping Components.* Nonstandard piping components are piping components that do not comply with one or more standards listed in Table 4-2.1-1; 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 4-2.1-1 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 4-2.1-1 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 4-2.1-1. 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 4-2.1-2.

4-2.2 Additional References

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

ASME PVP2012-78777, Determination of Tensile Elastic Modulus in High Density Polyethylene Piping at Seismic Strain Rates, by D. Munson, T. Adams, and S. Nikholds, in ASME Pressure Vessels and Piping Conference, Volume 1: Codes and Standards, pp. 217–228
Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

PPI Material Handling Guide, Chapter 2, "Inspections, Tests and Safety Considerations"
PPI TN-46, Guidance for Field Hydrostatic Testing of High Density Polyethylene Pressure Pipelines: Owner's Considerations, Planning, Procedures, and Checklists
Publisher: Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062 (www.plasticpipe.org)

Table 4-2.1-1 Specifications and Standards

Designator	Title
	General Standards
49 CFR 192	Code of Federal Regulations; Title 49, Transportation; Part 192, Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards
API 570	Piping Inspection Code and Inspection Certification
ASCE/SEI 7	Minimum Design Loads and Associated Criteria for Buildings and Other Structures
ASME B1.1	Unified Inch Screw Threads (UN and UNR Thread Form)
ASME B1.20.1	Pipe Threads, General Purpose, Inch
ASME B16.1	Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250
ASME B16.5	Pipe Flanges and Flanged Fittings: NPS $\frac{1}{2}$ Through NPS 24 Metric/Inch Standard
ASME B16.9	Factory-Made Wrought Buttwelding Fittings
ASME B16.11	Forged Fittings, Socket-Welding and Threaded
ASME B16.42	Ductile Iron Pipe Flanges and Flanged Fittings: Classes 150 and 300
ASME B16.47	Large Diameter Steel Flanges: NPS 26 Through NPS 60 Metric/Inch Standard
ASME B18.2.1	Square, Hex, Heavy Hex, and Askew Head Bolts and Hex, Heavy Hex, Hex Flange, Lobed Head, and Lag Screws (Inch Series)
ASME B18.2.2	Nuts for General Applications: Machine Screw Nuts, Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)
ASME B18.2.6M	Metric Fasteners for Use in Structural Applications
ASME B31	ASME Code for Pressure Piping
	B31.1, Power Piping
	B31.3, Process Piping
	B31.4, Pipeline Transportation Systems for Liquids and Slurries
	B31.5, Refrigeration Piping and Heat Transfer Components
	B31.8, Gas Transmission and Distribution Piping Systems
	B31.9, Building Services Piping
	B31.12, Hydrogen Piping and Pipelines
ASME B46.1	Surface Texture (Surface Roughness, Waviness, and Lay)
ASME BPVC	ASME Boiler and Pressure Vessel Code
	Section I, Rules for the Construction of Power Boilers
	Section II, Materials, Part D — Properties
	Section III, Rules for Construction of Nuclear Facility Components
	Section V, Nondestructive Examination
	Section VIII, Rules for the Construction of Pressure Vessels, Division 1, and Division 2, Alternative Rules
	Section IX, Qualification Standard for Welding, Brazing, and Fusing Procedures; Welders; Brazers; and Welding, Brazing, and Fusing Operators
ASME NM.3.1	Nonmetallic Materials, Part 1 — Thermoplastic Material Specifications
ASME NM.3.3	Nonmetallic Materials, Part 3 — Properties
ASME PCC-1	Guidelines for Pressure Boundary Bolted Flange Joint Assembly
ASME PCC-2	Repair of Pressure Equipment and Piping
ASME SF-477	Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe
ASTM D638	Standard Test Method for Tensile Properties of Plastics
ASTM D1598	Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
ASTM D1599	Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
ASTM D1600	Standard Terminology for Abbreviated Terms Related to Plastics
ASTM D1603	Standard Test Method for Carbon Black Content in Olefin Plastics
ASTM D2122	Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
ASTM D2321	Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications
ASTM D2444	Standard Practice for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
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 or Pressure Design Basis for Thermoplastic Pipe Products
ASTM D3139	Standard Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals

Table 4-2.1-1 Specifications and Standards (Cont'd)

Designator	Title
General Standards (Cont'd)	
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 Technique
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
AWS G1.10	Guide for the Evaluation of Thermoplastic Welds
AWS QC1	Standard for Certification of Welding Inspectors
AWWA C207	Steel Pipe Flanges for Waterworks Service, Sizes 4 in. Through 144 in. (100 mm Through 3,600 mm)
CSA Z662	Oil and Gas Pipeline Systems
DIN 2501	PN16 Plate Flange
DVS 2207-1	Welding of thermoplastics — Heated element welding of pipes, piping parts and panels made out of polyethylene
DVS 2207-5	Welding of thermoplastic materials — Testing and assessing welded joints in PE casing pipes
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 thermoplastic materials — Heated element welding of pipes, piping parts and panels made of PP
DVS 2207-15	Welding of thermoplastics — Heated tool welding of pipes, piping parts and panels made of PVDF
DVS 2210-1	Industrial piping made of thermoplastics — Design and execution — Above-ground pipe systems — Recommendations for the internal pressure and leak tests
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 12814-3:2014	Testing of welded joints in thermoplastics semi-finished products — Part 3: Tensile creep test
EN 12814-7:2002	Testing of welded joints of thermoplastics semi-finished products — Part 7: 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	Metallic flanges — Part 1: Steel flanges
PPI TR-3	Policies and Procedures for Developing Recommended Hydrostatic Design Basis (HDB), Hydrostatic Design Stresses (HDS), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe
PPI TR-4	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 Polyamide-11 (PA-11) Pipe
ABS Standards	
ASTM D1527	Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80
ASTM D2235	Standard Specification for Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings
ASTM D2282	Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe
ASTM D2468	Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 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 F2806	Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (Metric SDR-PR)
ASTM F2969	Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) IPS Dimensioned Pressure Pipe
CPVC Standards	
ASME SD-1784	Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
ASME SD-2846/SD-2846M	Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Hot-and-Cold-Water Distribution Systems

Table 4-2.1-1 Specifications and Standards (Cont'd)

Designator	Title
	CPVC Standards (Cont'd)
ASME SF-437	Specification for Socket-Type Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40
ASME SF-438	Specification for Threaded Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80
ASME SF-439	Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80
ASME SF-441/SF-441M	Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80
ASME SF-442/SF-442M	Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe (SDR-PR)
ASME SF-1970	Specification for Special Engineered Fittings, Appurtenances or Valves for Use in Poly(Vinyl Chloride) (PVC) or Chlorinated Poly(Vinyl Chloride) (CPVC) Systems
ASTM F493	Standard Specification for Solvent Cements for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe and Fittings
CSA B137.6	CPVC Pipe, Tubing, and Fittings for Hot and Cold Water Distribution Systems
	PE Standards
API 15LE	Specification for Polyethylene Line Pipe (PE)
ASME SD-2239	Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter
ASME SD-2513	Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings
ASME SD-2609	Standard Specification for Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe
ASME SD-2683	Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing
ASME SD-2737	Specification for Polyethylene (PE) Plastic Tubing
ASME SD-3035	Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
ASME SD-3261	Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing
ASME SD-3350	Specification for Polyethylene Plastics Pipe and Fittings Materials
ASME SD-4976	Specification for Polyethylene Plastics Molding and Extrusion Materials
ASME SF-714	Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter
ASME SF-1055	Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Plastic Pipe and Tubing
ASME SF-1924	Specification for Plastic Mechanical Fittings for Use on Outside Diameter Controlled Polyethylene Gas Distribution Pipe and Tubing
ASME SF-2206	Specification for Fabricated Fittings of Butt-Fused Polyethylene (PE) Plastic Pipe, Fittings, Sheet Stock, Plate Stock, or Block Stock
ASME SF-2619/SF-2619M	Specification for High-Density Polyethylene (PE) Line Pipe
ASME SF-2880	Specification for Lap-Joint Type Flange Adapters for Polyethylene Pressure Pipe in Nominal Pipe Sizes $^3/_4$ in. to 65 in.
ASTM F2164	Standard Practice for Field Leak Testing of Polyethylene (PE) and Crosslinked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure
ASTM F2435	Standard Specification for Steel Reinforced Polyethylene (PE) Corrugated Pipe
ASTM F2620	Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings
ASTM F2634	Standard Test Method for Laboratory Testing of Polyethylene (PE) Butt Fusion Joints Using Tensile-Impact Method
ASTM F3123	Standard Specification for Metric Outside Diameter Polyethylene (PE) Plastic Pipe (DR-PN)
AWWA C901	Polyethylene (PE) Pressure Pipe and Tubing, $^3/_4$ in. (19 mm) Through 3 in. (76 mm) for Water Service
AWWA C906	Polyethylene (PE) Pressure Pipe and Fittings, 4 in. Through 65 in. (100 mm Through 1,650 mm), for Waterworks
AWWA M55	PE Pipe — Design and Installation
ISO 13953:2001	Polyethylene (PE) pipes and fittings — Determination of the tensile strength and failure mode of test pieces from a butt-fused joint
PPI MAB-02	Generic Electrofusion Procedure for Field Joining of 14 Inch to 30 Inch Polyethylene (PE) Pipe
PPI TN-38	Bolt Torque for Polyethylene Flanged Joints
PPI TR-33	Generic Butt Fusion Joining Procedure for Field Joining of Polyethylene Pipe
	PE-RT Standards
ASME SF-2623	Standard Specification for Polyethylene of Raised Temperature (PE-RT) SDR 9 Tubing
ASME SF-2769	Standard Specification for Polyethylene of Raised Temperature (PE-RT) Plastic Hot and Cold-Water Tubing and Distribution Systems

Table 4-2.1-1 Specifications and Standards (Cont'd)

Designator	Title
PE-RT Standards (Cont'd)	
ASTM F2735	Standard Specification for Plastic Insert Fittings for SDR9 Cross-Linked Polyethylene (PEX) and Polyethylene of Raised Temperature (PE-RT) Tubing
CSA B137.18	Polyethylene of Raised Temperature Resistance (PE-RT) Tubing Systems for Pressure Applications
PP Standards	
ASME SD-4101	Standard Specification for Polypropylene Injection and Extrusion Materials
ASME SF-2389	Standard Specification for Pressure-Rated Polypropylene (PP) Piping Systems
ASTM D5857	Standard Specification for Polypropylene Injection and Extrusion Materials Using ISO Protocol and Methodology
CSA B137.11	Polypropylene (PP-R) Pipe and Fittings for Pressure Applications
PVC Standards	
ASME SD-1784	Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
ASME SD-1785	Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120
ASME SD-2241	Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)
ASME SD-2464	Specification for Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
ASME SD-2466	Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40
ASME SD-2467	Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
ASME SF-1970	Specification for Special Engineered Fittings, Appurtenances or Valves for Use in Poly(Vinyl Chloride) (PVC) or Chlorinated Poly(Vinyl Chloride) (CPVC) Systems
ASTM D2152	Standard Test Method for Adequacy of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion
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 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 Tapered Sockets
AWWA C900	Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4 in. Through 60 in. (100 mm Through 1,500 mm)
AWWA M23	PVC Pipe — Design and Installation
PVCO Standards	
ASME SF-1483	Standard Specification for Oriented Poly(Vinyl Chloride), PVCO, Pressure Pipe
AWWA C909	Molecularly Oriented Polyvinyl Chloride (PVCO) Pressure Pipe, 4 in. Through 24 in. (100 mm Through 600 mm) for Water, Wastewater, and Reclaimed Water Service
CSA B137.3.1	Molecularly Oriented Polyvinylchloride (PVCO) Pipe for Pressure Applications
PVDF Standards	
ASME SD-3222	Standard Specification for Unmodified Poly(Vinylidene Fluoride) (PVDF) Molding Extrusion and Coating Materials
ASME SD-5575	Standard Classification System for Copolymers of Vinylidene Fluoride (VDF) With Other Fluorinated Monomers
ASME SF-1673	Standard Specification for Polyvinylidene Fluoride (PVDF) Corrosive Waste Drainage Systems
ASTM D6713	Standard Specification for Extruded and Compression Molded Shapes Made From Poly(Vinylidene Fluoride) (PVDF)
CSA B181.3	Polyolefin Laboratory Drainage Systems
Standard for Metals Lined With Thermoplastics	
ASTM F1545	Standard Specification for Plastic-Lined Ferrous Metal Pipe, Fittings, and Flanges
PA Standards	
ASME SF-1733	Standard Specification for Butt Heat Fusion Polyamide (PA) Plastic Fitting for Polyamide (PA) Plastic Pipe and Tubing
ASME SF-2600	Standard Specification for Electrofusion Type Polyamide-11 Fittings for Outside Diameter Controlled Polyamide-11 Pipe and Tubing
ASME SF-2945	Standard Specification for Polyamide 11 Gas Pressure Pipe, Tubing, and Fittings
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 (PA 11) and Polyamide 12 (PA12) Mechanical Fittings for Use on Outside Diameter Controlled Polyamide 11 and Polyamide 12 Pipe and Tubing

Table 4-2.1-1 Specifications and Standards (Cont'd)

Designator	Title
PA Standards (Cont'd)	
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
Standards for Other Thermoplastics	
ASME SD-3307	Standard Specification for Perfluoroalkoxy (PFA)-Fluorocarbon Resin Molding and Extrusion Materials
ASME SD-4894	Standard Specification for Polytetrafluoroethylene (PTFE) Granular Molding and Ram Extrusion Materials
ASME SD-4895	Standard Specification for Polytetrafluoroethylene (PTFE) Resin Produced From Dispersion
ASME SD-6779	Standard Classification System for and Basis of Specification for Polyamide Molding and Extrusion Materials (PA)
ASTM D3159	Standard Specification for Modified ETFE Fluoropolymer Molding and Extrusion Materials
ASTM F1412	Standard Specification for Polyolefin Pipe and Fittings for Corrosive Waste Drainage Systems
ASTM F1498	Standard 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 H_2S-containing environments in oil and gas production — Part 2: Cracking-resistant carbon and low-alloy steels, and the use of cast irons
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 Composite Pressure Pipe Systems
CSA B137.10	Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene Composite Pressure Pipe Systems
Piping Standards	
...	Guidelines for the Design of Buried Steel Pipelines (2001)
ASCE MOP 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
ASTM A234/A234M	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service

Table 4-2.1-1 Specifications and Standards (Cont'd)

Designator	Title
Piping Standards (Cont'd)	
ASTM A312/A312M	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
ASTM A333/A333M	Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications With Required Notch Toughness
ASTM A351/A351M	Standard Specification for Castings, Austenitic, for Pressure-Containing Parts
ASTM A395/A395M	Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures
ASTM A403/A403M	Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
ASTM A513/A513M	Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing
ASTM A536	Standard Specification for Ductile Iron Castings
ASTM A587	Standard Specification for Electric-Resistance-Welded Low-Carbon Steel Pipe for the Chemical Industry
ASTM A796	Standard Practice for Structural Design of Corrugated Steel Pipe, Pipe-Arches, and Arches for Storm and Sanitary Sewers and Other Buried Applications
ASTM E94	Standard Guide for Radiographic Examination Using Industrial Radiographic Film
ASTM E114	Standard Practice for Ultrasonic Pulse-Echo Straight-Beam Contact Testing
ASTM E125	Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings
ASTM E165/E165M	Standard Practice for Liquid Penetrant Examination for General Industry
ASTM E186	Standard Reference Radiographs for Heavy-Walled [2 to 4$\frac{1}{2}$ in. (50.8 to 114 mm)] Steel Castings
ASTM E280	Standard Reference Radiographs for Heavy-Walled [4$\frac{1}{2}$ to 12 in. (114 to 305 mm)] Steel Castings
ASTM E446	Standard Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness
ASTM E709	Standard Guide for Magnetic Particle Testing
MSS SP-43	Wrought Stainless Steel Butt-Welding Fittings
MSS SP-53	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Magnetic Particle Exam Method
MSS SP-97	Integrally Reinforced Forged Branch Outlet Fittings — Socket Welding, Threaded, and Buttwelding Ends

GENERAL NOTES:
(a) All ASME SD and SF specifications are published in ASME NM.3.1.
(b) As it is not practical to refer to a specific edition of each standard or specification throughout the text of this Standard, unless otherwise specified, the latest edition shall apply.

Table 4-2.1-2 Procurement Information

Organization	Contact Information
ASCE	The American Society of Civil Engineers 1801 Alexander Bell Drive Reston, VA 20191 (www.asce.org)
ASME	The American Society of Mechanical Engineers Two Park Avenue New York, NY 10016-5990 (www.asme.org)
ASTM International	American Society for Testing and Materials 100 Barr Harbor Drive P.O. Box C700 West Conshohocken, PA 19428-2959 (www.astm.org)
CSA	Canadian Standards Association 178 Rexdale Boulevard Toronto, Ontario M9W 1R3, Canada (www.csagroup.org)
DIN	Deutsches Institut für Normung e. V. Am DIN-Platz Burggrafenstraße 6 10787 Berlin Germany (www.din.de)
ISO	International Organization for Standardization Central Secretariat Chemin de Blandonnet 8 Case Postale 401 1214 Vernier, Geneva Switzerland (www.iso.org)
MSS	Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. 127 Park Street, NE Vienna, VA 22180 (www.msshq.org)
NACE International	National Association of Corrosion Engineers 15835 Park Ten Place Houston, TX 77084-4906 (www.nace.org)
PPI	Plastics Pipe Institute 105 Decker Court, Suite 825 Irving, TX 75062 (www.plasticpipe.org)

Chapter 5
Fabrication, Assembly, and Erection

5-1 GENERAL

(a) Thermoplastic piping materials and components shall be prepared for assembly and erection by one or more of the fabrication processes covered in section 5-2, as applicable.

(b) The requirements for the processes used for assembly and/or erection shall be the same as those used for fabrication.

(c) The joiner (also called welder or fusing operator) shall be employed by an entity that is responsible for fabrication, assembly, and/or erection.

(d) The acceptable joining procedure qualification requirements (PQR) for different thermoplastics shall be as specified in para. 5-2.1.

5-1.1 Thermoplastic Joining Methods

The joining of thermoplastic piping systems shall comply with the requirements of this Standard and its Appendices.

5-1.2 Responsibilities

Employers shall be responsible for all joining of thermoplastic components and subassemblies by their personnel. In addition, employers shall

(a) conduct the qualification tests required to qualify the Joining Procedure Specification (JPS), Welding Procedure Specification (WPS), or Fusing Procedure Specification (FPS) used by their personnel, except as provided in para. 5-1.3.1 or para. 5-1.3.2

(b) conduct the qualification tests required to qualify thermoplastic fusing operators and thermoplastic welders or joiners, except as provided in para. 5-1.3.3 or para. 5-1.3.4

(c) train and qualify Inspectors and examiners in accordance with the requirements of Chapter 6

(d) conduct the requalification tests required to maintain qualification of thermoplastic fusing operators and thermoplastic welders or joiners as specified in Chapter 8; Mandatory Appendix I; ASME BPVC, Section IX, Article XXII; AWS B2.4; CSA Z662; or DVS 2212-1

5-1.3 Thermoplastic Joining Qualifications

5-1.3.1 Qualification of Joining, Welding, or Fusing Procedure Specifications. The JPS, WPS, or FPS to be used for joining thermoplastic pipe, fittings, and components in production shall be prepared and qualified by the employer as required in Chapter 8; Mandatory Appendix I; ASME BPVC, Section IX, Article XXII; AWS B2.4; CSA Z662; ASME BPE, Part MJ; or DVS 2212-1.

5-1.3.2 Qualification of Joining, Welding, or Fusing Procedure Specifications by Others. A JPS, WPS, or FPS qualified by a technically competent group or agency may be used, provided it complies with the following:

(a) The procedure specification meets the requirements of Chapter 8; Mandatory Appendix I; ASME BPVC, Section IX, Article XXII; AWS B2.4; CSA Z662; ASME BPE, Part MJ; or DVS 2207.

(b) The employer shall have qualified at least one fusing operator, welder, or joiner trained to use the qualified JPS, WPS, FPS, or equivalent requirements.

(c) The employer's trade name or mark shall be shown on the qualified JPS, WPS, or FPS to be used and on each procedure qualification record (PQR). In addition, the PQRs shall be signed and dated by the employer, who thereby accepts responsibility for the qualification performed by others.

(d) Owner's approval for using the procedure specification qualified by others shall be documented prior to its use.

5-1.3.3 Performance Qualification of Fusing Operator, Welder, or Joiner. Thermoplastic fusing operators, welders, and joiners shall be qualified in accordance with Chapter 8; Mandatory Appendix I; ASME BPVC, Section IX; or AWS B2.4.

NOTES:
(1) Chapter 8 provides the JPS for qualifying joiners of mechanical connections for multilayered reinforced thermoplastic piping systems.
(2) AWS and ASME use different terms to describe the same methods of heat joining. The term used by the AWS is "fused." When ASME Standards are referenced, the term used is "fusing."

5-1.3.4 Performance Qualification of Fusing Operator, Welder, or Joiner by Others

(a) An employer may accept the performance qualification of a fusing operator, welder, or joiner granted by a previous employer. This acceptance shall be limited to performance qualifications that were made on pipe

test coupons. Pipe test coupons shall include those made with couplings, saddles, and fittings.

(b) The new employer shall have a copy of the JPS, WPS, or FPS that was followed during qualification, or an equivalent JPS, WPS, or FPS that is within the limits of the essential variables set forth in Chapter 8; Mandatory Appendix I; ASME BPVC, Section IX, Article XXII; AWS B2.4; or fusing standards in CSA Z662 or DVS 2212-1. An employer accepting such qualification tests shall obtain a copy of the PQTR from the previous employer. The PQTR shall show the name of the employer by whom the fusing operator, thermoplastic welder, or joiner was qualified and the date of that qualification.

(c) Evidence shall also be provided that the fusing operator, welder, or joiner has maintained qualification in accordance with Chapter 8; Mandatory Appendix I; ASME BPVC, Section IX; AWS B2.4; CSA Z662; or DVS 2212-1, except that this evidence may be provided by an employer responsible for the individual's fusing or thermoplastic welding or joining performance even if not the original qualifying employer.

(d) The current employer's business name shall be shown on the qualification record, and it shall be signed and dated by the employer, who thereby accepts responsibility for the qualifications performed by others.

(e) Owner's approval for performance qualification of fusing operator, welder, or joiner by others shall be documented prior to being used.

5-1.3.5 Qualification Records

(a) The employer shall maintain copies of the procedure and performance qualification records specified in Chapter 8; Mandatory Appendix I; ASME BPVC, Section IX, Article XXII; AWS B2.4; CSA Z662; and DVS 2212-1. These copies shall be available to the owner at the location where fabrication, assembly, and erection are being done.

(b) The owner shall be responsible for maintaining records.

(c) The retention period for qualification records shall be 5 yr after qualification.

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 (LJTFs).

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

NOTE: The terms "hot plate" and "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 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. Pipes or components made of thermoplastic compounds with the same physical properties, as shown by ASTM cell classification or by comparison of physical properties, shall be joined using a WPS, FPS, or JPS that has been qualified as required by para. 5-1.3.1 or para. 5-1.3.2.

5.2.2.5 Differing Physical Properties. Pipes or components made of thermoplastic compounds of the same or similar (copolymers and homopolymers) polymeric compound with different ASTM cell classifications or slightly different physical properties shall be joined using a WPS, FPS, or JPS that has been qualified as required by para. 5-1.3.1 or para. 5-1.3.2 and approved by the owner or the owner's representative or both.

NOTE: PA-11 shall not be joined to PA-12 using heat fusion. PP shall not be fused to PE using heat fusion. However, medium-density PE may be fused to high-density PE using heat fusion, as indicated in ASME BPVC, Section IX, Articles XXI through XXIV.

5-2.2.6 Products From Different Manufacturers. At the user's option, an FPS, WPS, or JPS for thermoplastic compounds with the same or slightly different physical properties but made by different manufacturers should be qualified using combinations of the two manufacturers' pipe and components. Qualified test data as found in PPI TR-33 or similar technical reports or standards may be used as an alternative to testing.

5-2.3 Thermoplastic Joint Properties for Heat Fusion

5-2.3.1 Joint Quality. The quality of the thermoplastic joint depends on the qualification of the welder or fusing operator, the equipment used, environmental influences, and the welder's or fusing operator's adherence to the WPS, FPS, or JPS. Every welder or fusing operator shall be trained to the appropriate WPS, FPS, or JPS by qualified personnel who have been trained and tested as required in ASME BPVC, Section IX, Article XXIII or AWS B2.4, or as required for fusing in CSA Z662 or DVS 2207.

5-2.3.2 Joining Area. The joining area shall be protected against adverse environmental conditions such as dirt, moisture, material shavings, oil, and other contaminants. Environment conditions shall be addressed in the WPS, FPS, or JPS for the thermoplastic.

5-2.4 Application-Specific Joint Requirements for Heat Fusion

5-2.4.1 Bead or Crevice. Some applications do not permit the presence of an inside bead or indention (sometimes called a crevice) on the inside surface of the pipe. Depending on these limitations, various methods shall be used to prevent or eliminate beads or indentations, including fusing with the aid of a bladder or using heated or nonheated inside bead removers. The user or the designer shall be consulted for bead-size allowance.

5-2.4.2 Other Joining Processes

(a) Other joining processes that create a bead, indention, or other change in the inside or outside surface of the thermoplastic pipe or fitting that does not affect the joint strength may be used as long as the difference in alignment is less than 10% of the wall thickness.

NOTE: Infrared heat is used as a noncontact method of joining a limited number of thermoplastics. These requirements apply to noncontact methods of butt-fusion joining.

(b) An indention below the nominal I.D. of the pipe may be acceptable provided the indention or misalignment does not infringe on the minimum wall thickness required for hoop or axial strength.

5-2.4.3 Removal of I.D. Bead. For butt-fusion joints, removal of the I.D. beads shall be at the option of the user, purchaser, or designer.

5-2.4.4 Size of Bead

(a) Removal or reduction in size of the O.D. bead created during heat fusion may be performed as long as the minimum wall thickness required for hoop or axial strength or tensile load is not reduced.

(b) When O.D. bead removal is planned, inspection or examination of the bead shall be done during or after the heat-fusion process and before bead removal.

(c) No more than a 10% misalignment shall be allowed on outside beads even if minimum wall thickness requirements are met.

5-2.5 Requirements for Thermoplastic Pipe and Fittings Joints Using Heat Fusion

(a) Joining surfaces shall be prepared by cutting, facing, scraping, or machining to provide a clean, smooth end or external pipe surface.

(b) Joining of thermoplastics shall be performed in accordance with a documented JPS, FPS, or WPS that has been qualified in accordance with para. 5-1.3.1 or para. 5-1.3.2.

(c) The owner or user and the contractor shall agree that the WPS, FPS, or JPS selected will provide the desired results.

5-2.6 Thermoplastic Joining Using Solvent-Cement Welding Methods

5-2.6.1 PVC–CPVC Limitations

(a) The joining of PVC to CPVC shall not be allowed in pressure piping systems.

(b) There are some nonpressure applications in which polymers such as PVC and CPVC can be solvent-welded to each other. The manufacturer of the thermoplastic material should be consulted before attempting to join different polymers using solvent-cement welding.

5-2.6.2 Same Physical Properties. Pipes or components made of thermoplastic compounds with the same physical properties, as shown by ASTM cell classification or by comparison of physical properties, shall be joined using a WPS or JPS that has been qualified as required by para. 5-1.3.1 or para. 5-1.3.2.

5-2.6.3 Different Physical Properties. The same or similar polymeric compounds may have different ASTM cell classifications or slightly different physical properties. Pipes or components made of such compounds shall be joined using a WPS or JPS that has been qualified as required by para. 5-1.3.1 or para. 5-1.3.2 and approved by the owner or the owner's representative or both.

5-2.6.4 Products From Different Manufacturers. At the user's option, a WPS or JPS for thermoplastic components with the same or slightly different physical properties but made by different manufacturers should be qualified using combinations of the manufacturers' pipe, components, and solvent cements. Qualified test data or technical reports or standards may be used as an alternative to testing.

5-2.7 Thermoplastic Joint Design and Properties for Solvent-Cement Welding

(a) The quality of the thermoplastic joint depends on the qualification of the welder, the equipment used, environmental influences, and the welder's accurate adherence to the WPS or JPS. Every welder shall be trained to the appropriate WPS or JPS by qualified personnel who have been trained and tested in accordance with para. 5-1.3.3.

(b) The joining area shall be protected against adverse environmental conditions such as dirt, moisture, material shavings, oil, and other contaminants. Environment conditions shall be addressed in the WPS or JPS for the thermoplastic.

5-2.8 Requirements for Thermoplastic Pipe and Fittings Joints Using Solvent-Cement Welding

(a) Joining surfaces shall be prepared to provide a clean, smooth end or external pipe surface.

(b) Joining of thermoplastics shall be performed in accordance with a documented WPS or JPS that has been qualified in accordance with para. 5-1.3.1 or para. 5-1.3.2.

(c) The owner or user and the contractor shall agree that the WPS or JPS selected will provide the desired results.

5-2.9 Noncontact Heat Joining Methods

5-2.9.1 Infrared for PVDF or PVDF Copolymers. The WPS for joining PVDF or PVDF copolymers using infrared (IR) shall be qualified per AWS B2.4.

5-2.9.2 IR for PP. The WPS for joining PP using IR shall be qualified per AWS B2.4.

5-2.9.3 Beadless Welding. The WPS for joining PP or PVDF pipe and fittings using beadless welding shall be qualified per para. 5-1.3.1.

5-2.10 Records

The data related to the critical parameters and essential variables shall be recorded to create a quality control record to be turned over to the owner. This data shall be retained as required by the owner or the owner's representative.

5-2.10.1 Butt-Fusion Equipment (Contact or Noncontact) With Data Logger. Butt-fusion equipment shall monitor and record critical parameters or essential variables such as heat, cool time, and temperature. Procedure specifications qualified using ASME BPVC, Section IX, Article XXI (for PE only) or AWS B2.4 (for other materials) may require recording of additional data.

5-2.10.2 Butt-Fusion Equipment (Contact or Noncontact) Without Data Logger. If the equipment does not have monitoring or recording capabilities, data shall be manually recorded in quality control records.

5-2.10.3 Electrofusion Controllers. Electrofusion controllers shall monitor input power, output voltage and current, and ambient temperature. A record of each fusion shall be recorded and shall include, at a minimum, the fusion identification number and date, fusion voltage, ambient temperature at fusion, nominal fusion time, adjusted fusion time, elapsed fusion time, cooling time, and any fusion termination reason.

5-2.10.4 Solvent-Cement Welds. Data related to critical variables shall be recorded as required in AWS B2.4.

5-3 PROCEDURE QUALIFICATION

Thermoplastic joining procedures shall be qualified in accordance with ASME BPVC, Section IX; AWS B2.4; or Chapters 7 and 8 or other requirements in this Standard. Paragraphs (a) through (p) and Table 5-3-1 specify the acceptable joining procedure qualification requirements for various thermoplastics.

(a) When ABS pipe or fittings are joined using a solvent-cement welding procedure, the procedure shall be qualified in accordance with AWS B2.4. Environmental condition recommendations shall be included in the WPS.

(b) When CPVC pipe or fittings are joined using a solvent-cement welding procedure, the procedure shall be qualified in accordance with AWS B2.4. Environmental condition recommendations shall be included in the WPS.

(c) When PVC pipe or fittings are joined using a solvent-cement welding procedure, the procedure shall be qualified in accordance with AWS B2.4 or the manufacturer's procedure qualification. Environmental condition recommendations shall be included in the WPS.

(d) When PVC pipe or fittings are joined using a contact heat-fusing method, the procedure shall be qualified in accordance with AWS B2.4.

(e) When PP pipe and fittings are joined using a contact or noncontact fusing method, the procedure shall be qualified in accordance with AWS B2.4. Environmental condition recommendations shall be included in the WPS.

(f) When PP pipe and fittings are joined using socket fusion, the procedure shall be qualified in accordance with AWS B2.4. Environmental condition recommendations shall be included in the WPS.

(g) When PP pipe and fittings are joined using electrofusion, the procedure shall be qualified in accordance with AWS B2.4. Environmental condition recommendations shall be included in the WPS.

(h) When PVDF or PVDF copolymer pipe and fittings are joined using a contact or noncontact fusing method, the procedure shall be qualified in accordance with AWS B2.4. Environmental condition recommendations shall be included in the WPS.

(i) When PVDF or PVDF copolymer pipe and fittings are joined using socket fusion, the procedure shall be qualified in accordance with AWS B2.4. Environmental condition recommendations shall be included in the WPS.

(j) When PVDF or PVDF copolymer pipe and fittings are joined using electrofusion, the procedure shall be qualified in accordance with AWS B2.4. Environmental condition recommendations shall be included in the WPS.

(k) When PA-11 pipe and fittings are joined using a contact fusing method, the procedure shall be qualified as required in Mandatory Appendix I. Environmental condition recommendations shall be included in the JPS.

(l) When PA-11 pipe and fittings are joined using electrofusion, the procedure shall be qualified as required in Mandatory Appendix I. Environmental condition recommendations shall be included in the JPS.

(m) When PE pipe and fittings are joined using a contact fusion method, the procedure shall be qualified in accordance with ASME BPVC, Section IX or AWS B2.4. Environmental condition recommendations shall be included in the FPS or WPS.

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	AWS B2.4	WPS
	Socket fusion		
	Electrofusion		
PVDF or PVDF copolymer	Heat fusion or noncontact fusing	AWS B2.4	WPS
	Socket fusion		
	Electrofusion		
PA-11	Contact fusing	Mandatory Appendix I	JPS
	Electrofusion		
PE	Contact fusing	ASME BPVC, Section IX or AWS B2.4	FPS or WPS
	Saddle fusion	Mandatory Appendix I	FPS
	Electrofusion	ASME BPVC, Section IX or AWS B2.4	FPS or WPS
For Liners			
PP, PVDF (homopolymer or copolymer), PFA, or PTFE	Butt fusion	Chapter 7	JPS

GENERAL NOTE: The term "fusing" is used in ASME BPVC, Section IX, and "fusion" is used in AWS B2.4. Both terms are defined the same.

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

(n) When PE pipe and fittings are joined using saddle fusion, the procedure shall be qualified using Mandatory Appendix I. Environmental condition recommendations shall be included in the FPS.

(o) When PE pipe, fittings, or saddles are joined using electrofusion, the procedure shall be qualified in accordance with ASME BPVC, Section IX or AWS B2.4. Environmental condition recommendations shall be included in the FPS or WPS.

(p) When PP, PVDF (homopolymer or copolymer), PFA, or PTFE liners are joined using contact butt fusion, the procedure shall be qualified in accordance with the requirements in Chapter 7. Environmental condition recommendations shall be included in the JPS.

5-4 OPERATOR QUALIFICATION

Paragraphs (a) through (p) and Table 5-4-1 specify the standard, Chapter, or Appendix that contains requirements to qualify persons to join various thermoplastics.

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

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

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

(d) When PVC pipe and fitting are joined using contact heat fusing, the welder shall be qualified in accordance with AWS B2.4.

(e) When PP pipe and fitting are joined using a contact or noncontact fusing method, the welder shall be qualified using AWS B2.4.

(f) When PP pipe and fitting are joined using socket fusion, the welder shall be qualified using AWS B2.4.

(g) When PP pipe and fitting are joined using electrofusion, the welder shall be qualified using AWS B2.4.

(h) When PVDF or PVDF copolymer pipe and fitting are joined using a contact or noncontact fusing method, the welder shall be qualified using AWS B2.4.

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

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	Welder	AWS B2.4
	Contact heat fusing		
PP	Contact or noncontact fusing	Welder	AWS B2.4
	Socket fusion		
	Electrofusion		
PVDF or PVDF copolymer	Contact or noncontact fusing	Welder	AWS B2.4
	Socket fusion		
	Electrofusion		
PA-11	Contact fusing	Fusing machine operator or joiner	Mandatory Appendix I
	Electrofusion		
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	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 (homopolymer or copolymer), PFA, or PTFE	Heat fusion	Joiner	JPS and Chapter 7

(j) When PVDF or PVDF copolymer is joined using socket fusion, the welder shall be qualified using AWS B2.4.

(k) When PVDF or PVDF copolymer is joined using electrofusion, the welder shall be qualified using AWS B2.4.

(l) When PA-11 is joined using a contact fusing method, the fusing machine operator or joiner shall be qualified as required in Mandatory Appendix I.

(m) When PA-11 is joined using electrofusion, the fusing machine operator or joiner shall be qualified as required in Mandatory Appendix I.

(n) When PE is joined using a heat fusion method, the fusing operator or welder shall be qualified using ASME BPVC, Section IX, Article XXII or AWS B2.4.

(o) When PE is joined using saddle fusion, the fusing operator or welder shall be qualified using Mandatory Appendix I or AWS B2.4.

(p) When PE is joined using electrofusion, the fusing operator or welder shall be qualified using ASME BPVC, Section IX or AWS B2.4.

Chapter 6
Inspection, Examination, and Testing

6-1 INSPECTION

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 this Standard; additional requirements and exceptions for thermoplastic-lined metals and multilayered reinforced thermoplastic piping systems are in Chapters 7 and 8, respectively.

6-1.1 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.

6-1.2 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 work shall include 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. 6-1.1.

6-1.3 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 an employee 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 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 experience of the 8 yr required.

(2) have a professional engineering registration or nationally recognized equivalent with at least 3 yr experience in the design, fabrication, or examination of industrial thermoplastic pressure piping systems.

(c) In delegating performance of inspection, the owner's Inspector shall be responsible for determining that any person to whom an inspection function is delegated is qualified to perform that function.

6-2 EXAMINATION

Examination applies to quality control functions performed by the thermoplastic piping systems manufacturer (for piping components only), fabricator, or erector. Reference in this Standard to an examiner shall be to a person who performs quality control examinations.

6-2.1 Responsibility for Examination

Inspection shall not relieve the thermoplastic piping system manufacturer, the fabricator, or the erector of the responsibility for

(a) providing thermoplastic materials, components, and workmanship in accordance with the requirements of this Standard and of the engineering design (see Chapter 2)

(b) performing all required examinations

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

6-2.2 Examination Requirements

6-2.2.1 General. Prior to initial operation, each thermoplastic piping system installation, including components and workmanship, shall be examined in accordance with the applicable requirements of section 6-2. The type and extent of any additional examination required by engineering design, and the acceptance criteria to be applied, shall be specified. Thermoplastic joints not included in examinations required by para. 6-2.3 or by engineering design may be accepted if they pass the leak test requirements in section 6-3.

(a) Examination of thermoplastic items shall be performed after the items have passed final inspection following extrusion, injection molding, or other forming process.

(b) Examination of fabricated items shall be performed after final assembly and inspection.

6-2.2.2 Acceptance Criteria. Acceptance criteria shall be as stated in the engineering design and shall meet the applicable requirements in Mandatory Appendix III. AWS G1.10 may also be used to evaluate thermoplastic welds.

6-2.2.3 Defective Piping Components and Workmanship. If examination of an item reveals defects (imperfections of a type or magnitude exceeding the acceptance criteria for joints and material in this Standard), the item shall be replaced, and the replacement item shall be subject to the same examination and acceptance criteria as the original.

6-2.2.4 Progressive Sampling for Examination. When required spot or random examination reveals a defect, the following steps shall be taken:

Step 1. Two additional samples of the same kind of item or from the same lot shall be given the same examination. For a fused item, the sample should be from the same fusion equipment operator. For a solvent-welded or adhesive-joined item, the sample should be from the same thermoplastic assembler.

Step 2

(a) If the items examined as required by Step 1 are acceptable, the defective item shall be replaced and the replacement item examined as specified in para. 6-2.2.3, and all items represented by the two additional samples shall be accepted.

(b) If any of the items examined as required by Step 1 reveals a defect, two further samples of the same kind shall be examined for each defective item found by that grouping.

Step 3

(a) If all the items examined as required by Step 2(b) are acceptable, the defective item(s) shall be replaced and the replacement item examined as specified in para. 6-2.2.3, and all items represented by the additional sampling shall be accepted.

(b) If any of the items examined as required by Step 2(b) reveals a defect, all items represented by progressive sampling shall be either

(1) replaced and the replacement items examined as required, or

(2) fully examined and replaced as necessary and the replacement items examined as necessary to meet the requirements of this Standard

Step 4. If any of the defective items are replaced and the replacement items examined, and a defect is detected in a replacement item, continued progressive sampling in accordance with Steps 1, 2(b), and 3(b) is not required based on the defects found in the replacements. The defective item(s) shall be replaced and the replacement item(s) examined until acceptance as specified in para. 6-2.2.3 is reached. Spot or random examination (whichever is applicable) shall then be performed on the remaining unexamined joints, items, or components.

6-2.3 Extent of Required Examination

Thermoplastic piping in fluid service shall be examined to the extent specified herein or to any greater extent specified in the engineering design. Acceptance criteria are as stated in para. 6-2.2.2 and in Mandatory Appendix III for fluid service.

(a) Visual Examination. At minimum, the following shall be examined in accordance with para. 6-2.7.2:

(1) sufficient materials and components, as agreed on by the owner, selected at random, to satisfy the examiner that they conform to the specifications and are free from defects.

(2) at least 5% of fabrication. For fused, solvent-welded, and adhesive joints, each operator's or assembler's work shall be represented and shall meet the requirements of Mandatory Appendix III. AWS G1.10 may also be used to evaluate thermoplastic welds for acceptance.

(3) random examination of the assembly of threaded, bolted, and other mechanical joints to satisfy the examiner that they conform to the applicable requirements of the engineering design.

(4) random examination of joint alignment. Pipe hangers and supports, where applicable, shall be examined to ensure spacing is at intervals per the designer's requirements.

(5) installed thermoplastic piping and components for evidence of defects that would require replacement, and for other evident deviations from the intent of the design.

(b) Certification and Records. The examiner shall be assured by review of certifications, records, and other evidence that the thermoplastic piping components meet the requirements of the specifications. The examiner shall provide the Inspector with a certification that all of the quality control requirements of the specifications,

applicable standard(s), and engineering design have been carried out.

6-2.4 Supplementary Examination

6-2.4.1 General. Any of the methods of examination described in para. 6-2.7 may be specified by the engineering design to supplement the examination required by para. 6-2.3. The extent of the supplementary examination to be performed and the acceptance criteria that differ from those in para. 6-2.2.2 shall be specified in the engineering design.

6-2.4.2 Examination to Resolve Uncertainty. Any method may be used to resolve doubtful indications. Acceptance criteria shall be those for the required examination.

6-2.5 Examination Personnel

6-2.5.1 Personnel Qualification and Certification

(a) Examiners shall be trained and shall possess a valid qualification certificate from the manufacturer for the process to be used and the material being welded or shall have experience with nondestructive examination techniques commensurate with the needs of the specified examinations.

(b) Personnel performing nondestructive examination (NDE) to the requirements of this Standard shall be qualified and certified for the method to be used following a procedure as described in ASME BPVC, Section V, Article 1, T-120(e) or T-120(f).

6-2.5.2 Specific Requirements. For in-process examination, the examination shall be performed by personnel other than those performing the production work.

6-2.6 Examination Procedures

(a) Any examination shall be performed in accordance with a written procedure that conforms to one of the methods specified in paras. 6-2.7.1(a) and 6-2.7.1(b).

(b) Procedure shall be written as required in ASME BPVC, Section V, Article 1, T-150.

(c) The employer shall certify records of the examination procedures used, showing dates and results of procedure qualifications, and shall maintain them and make them available to the Inspector.

6-2.7 Types of Examination

6-2.7.1 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) Special Methods Not Specified in This Standard. If a method not specified herein is to be used, then the method and its acceptance criteria shall be specified in the engineering design in enough detail to permit qualification of the necessary procedures and examinations.

6-2.7.2 Visual Examination

(a) Visual examination of thermoplastic piping systems includes verification of standards, code, and engineering design requirements for

(1) materials, components, and dimensions

(2) preparation and alignment of joints

(3) alignment of materials and components

(4) method of joining, i.e., fusion, solvent welding, adhesive joining, bell-and-spigot joints, bolting, threading, etc.

(5) assembly of supports

(6) erection

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

(c) A joint shall receive a visual examination of all accessible pipe, fitting, and component surfaces. Acceptance criteria are as follows:

(1) There shall be no evidence of cracks, voids, inclusions, defects or flaws, lack of fusion, or incomplete joining. AWS G1.10 may be used to evaluate thermoplastic welds for acceptance. Either the designer or the owner or owner's representative shall identify which acceptance level from AWS G1.10 is applicable.

(2) Joints shall exhibit proper design configuration.

(3) Any data record as a result of the fusing or joining process shall be reviewed and compared to design requirements.

(d) Visual examination results shall be recorded and submitted to the owner or owner's delegate on completion. The records shall include the following information:

(1) date of examination

(2) identification of piping system examined

(3) examination procedure

(4) certification of results by examiner

6-2.7.3 Ultrasonic Examination. Ultrasonic examination of welds or joints shall be performed in accordance with ASME BPVC, Section V, Article 4, as required by the engineering design.

6-2.7.4 In-Process Examination

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

(1) joint preparation and cleanliness

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

(3) variables (such as temperatures, cooling or cure times, environmental conditions) specified in the FPS, JPS, or this Standard

(4) appearance of the finished joint

(b) In-process examination shall be visual in accordance with para. 6-2.7.2 unless additional methods are specified in the engineering design.

6-3 TESTING

6-3.1 Required Leakage Test

Prior to initial operation and after completion of the applicable examinations required by section 6-2, each piping system shall be tested to ensure tightness. The test shall be a hydrostatic leakage test in accordance with para. 6-3.4, except as provided in paras. 6-3.1.1 and 6-3.1.2.

6-3.1.1 Exception to Hydrostatic Test. If hydrostatic testing would create a hazardous situation or risk of contamination, the owner may choose to subject the piping system to a pneumatic leakage test, in accordance with para. 6-3.5, in lieu of the hydrostatic leakage test. Where pneumatic tests are performed, consideration shall be given to the hazard, precautions, and safety measures associated with the energy stored in compressed gas.

6-3.1.2 Allowance for NDE Test

(a) Where the owner considers both hydrostatic and pneumatic leakage testing impracticable, an alternative NDE test may be used if both of the following conditions apply:

(1) a hydrostatic test would

(-a) damage the piping system or linings in the piping system

(-b) contaminate a process that would be hazardous, corrosive, or inoperative in the presence of moisture

(-c) require significant support modifications for the hydrostatic test load, or

(-d) present the danger of brittle fracture due to low temperature during the test

(2) a pneumatic test would

(-a) present an undue hazard of possible release of energy stored in the system, or

(-b) present the danger of brittle fracture during the test

(b) The NDE test shall be approved by the owner, and shall be followed by an initial service leakage test in accordance with para. 6-3.6.

6-3.1.3 Nonpressure Piping. Unless otherwise specified in the engineering design, lines open to the atmosphere, such as vents or drains downstream of the last shutoff valve, shall be leak tested.

NOTE: Testing to full hydrostatic requirements may not apply due to limitations in the pressure rating of nonpressure piping components.

6-3.2 General Requirements for Leakage Tests

Requirements in para. 6-3.2 may apply to more than one type of leakage test.

6-3.2.1 Limitations on Pressure

(a) Exceeding Piping Component Strength. If the test pressure would produce a nominal pressure in excess of 1.5 times rated pressure of the weakest or lowest-rated component at test temperature, the test pressure may be reduced to the maximum pressure that will not exceed the pressure rating at test temperature.

(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.

6-3.2.2 Other Test Requirements

(a) Examination for Leakage. A leakage test shall be maintained for at least 1 h. All joints and connections shall be examined for leakage after the 1-h 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 on 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 on 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, an 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 501 provides comprehensive requirements for conducting pressure tests.

6-3.2.3 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. 6-3.1.

(c) Closure Joints. The final joint connecting piping systems or components that have been successfully tested in accordance with para. 6-3.1 are not required to be leakage tested provided the joint is examined in-process in accordance with para. 6-2.7.4 and an initial service leakage test in accordance with para. 6-3.6.

6-3.2.4 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.

(2) In simultaneous welded systems, i.e., systems where the joining of the carrier pipe and the joining of the containment pipe are done at the same time, the requirement for visual access to joints of the carrier pipe may be waived during carrier pipe testing.

(b) The containment pipe should be leakage tested, by either hydrostatic or pneumatic methods, as specified by the designer.

(1) For systems in which a dry annulus indicates the absence of leaks, hydrostatic testing may not be practical.

(2) The product manufacturer may be consulted for the suitability of and their specific test procedures for low-pressure pneumatic test.

(3) Precautions for pneumatic testing, including those for low pressures, outlined in para. 6-3.5(a) shall apply.

6-3.2.5 Jacketed and Insulated Piping

(a) The internal pipe shall be leakage tested on the basis of the internal or external design pressure, whichever is critical. This test shall be performed before the jacket or insulation is completed if visual access to joints of the internal pipe is required by para. 6-3.3(a).

(b) The requirements in (a) are not intended to apply to multilayered reinforced piping systems, dual contained piping systems, or casing pipes. Relined piping systems should be evaluated for the ability to withstand pressure testing capacity based on the liner's structural capacity and on the structural capacity the existing host pipe is expected to provide in the relined system.

6-3.2.6 Repairs or Additions After Leakage Testing

(a) If repairs or additions are made following the leakage test, the affected piping shall be retested.

(b) For minor repairs that do not breach the pressure boundary (e.g., gouges, scratches) or additions such as supports or brackets, the owner may waive retest requirements when precautionary measures (e.g., para. 6-2.7.4) are taken to ensure sound construction.

6-3.2.7 Test Records. Records shall be made during the testing of each piping system and submitted to the owner or owner's delegate on completion. The records shall include the following information:

(a) date of test
(b) identification of piping system tested
(c) test procedure, including duration
(d) test medium
(e) test pressure
(f) certification of results by examiner

6-3.3 Preparation for Leakage Test

(a) Joints Exposed. All joints, welds (including structural attachment welds to pressure-containing components), and bonds shall be left uninsulated and exposed for inspection and examination during leakage testing, except where agreed to by the owner due to, but not limited to, the following:

(1) accessibility

(2) installation methods such as directional drilling or relining of existing piping

(3) containment piping

(4) direct burial of lines that require immediate cover

(b) Temporary Supports. Piping designed for vapor or gas shall be provided with additional temporary supports, if required, to support the weight of test liquid.

(c) Piping With Expansion Joints. Piping systems with expansion joints should be tested within the allowable pressure and temperature range to prevent damage.

(d) Limits of Tested Piping. Equipment that is not to be tested shall be either disconnected from the piping or isolated by blinds or other means during the test. A valve may be used, provided the valve (including its closure mechanism) is suitable for the test pressure.

6-3.4 Hydrostatic Leakage Test

(a) Test Fluid. The fluid shall be water unless there is the possibility of damage due to freezing or to adverse effects of water on the piping or the process. The selection of an alternative fluid shall be approved by the designer after review and consideration of chemical compatibility, flammability, and toxicity.

(b) *Test Pressure.* The hydrostatic test pressure in a thermoplastic piping system shall not be less than 1.25 times the design pressure at the highest elevation, except where paras. 6-3.2.1 and 6-3.2.2 apply.

6-3.5 Pneumatic Leakage Test

(a) *Precautions.* The thermoplastic piping systems and components covered by this Standard are intended primarily for use in the distribution of pressurized liquids. Pressurized (compressed) air or other compressed gases contain large amounts of stored energy that would present serious safety hazards if a system were to fail for any reason. Liquids and gas conveyed by thermoplastic piping systems shall be chemically compatible with the piping materials. Pressure relief devices and calibrated or redundant pressure measurement (multiple gauges) shall be considered as part of the testing protocol. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases, some manufacturers do not allow pneumatic testing of their products. Established written guidelines for specific testing procedures shall be consulted prior to pneumatic testing (e.g., ASME PCC-2, Part 5, Article 501).

(b) *Test Medium.* The gas used as test medium, if not air, shall be nonflammable and nontoxic, as approved by the designer.

(c) *Test Pressure.* The test pressure shall be not less than 1.1 times nor more than 1.33 times the design pressure, except where the designer allows for a variance due to service or safety concerns. When thermoplastic or multilayered reinforced thermoplastic pipe systems used for fuel gas service are tested, requirements of 49 CFR 192.513 shall apply.

6-3.6 Initial Service Leakage Test

Initial service leakage tests apply only to piping in Category D fluid service, at the owner's option. See para. 6-3.1.2(b).

(a) *Test Fluid.* The test fluid shall be the service fluid.

(b) *Procedure.* During or prior to initial operation, the pressure shall be gradually increased in steps, with the pressure held long enough at each step to equalize piping strains, until the operating pressure is reached. A preliminary check, including examination of joints per para. 6-2.3, shall be made at the midpoint, or as established by the designer, in the pressurization process.

(c) *Examination for Leakage.* The examination for leakage required by para. 6-3.2.2(a) shall be conducted while the system is at operating pressure. Examination for leakage of joints and connections previously tested in accordance with this Standard may be omitted.

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 that are in addition to, or in some cases in lieu of, the requirements in Chapters 1 through 6. These special requirements are detailed further in this Chapter.

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

(d) Columns, vessels, nonpressure 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 4-2.1-1 for a list 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 following materials are accepted for use in thermoplastic-lined metallic piping:

(1) polyethylene (PE) — PE 4710

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

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

(4) ethylene–tetrafluoroethylene copolymer (ETFE)

(5) ethylene chlorotrifluoroethylene (E-CTFE)

(6) poly(tetrafluoroethylene) (PTFE)

(7) modified polytetrafluoroethylene (m-PTFE)

(8) perfluoroalkoxy alkane (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 in (1) through (3).

(1) 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.

(2) 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.

(3) 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 familiar with the requirements of this 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 the 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 ABET-accredited or equivalent engineering degree requiring the equivalent of at least 4 yr study, plus a minimum of 5 yr 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 yr study, plus a minimum of 10 yr experience in the design of related pressure piping

(3) 15 yr experience in the design of related pressure piping (for an individual without a degree and who has 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.

7-4.2.1 Required Pressure Containment or Relief

(a) Provision shall be made to safely contain or relieve any expected pressure to which the piping can be subjected. Piping not protected by a pressure-relieving device, or that can be isolated from a pressure-relieving device, shall be designed for at least the highest pressure that can be developed.

(b) Sources of pressure should include ambient influences, pressure oscillations and surges, improper operation, decomposition of unstable fluids, static head, and failure of control devices.

7-4.2.2 Standard Flanged Connections

(a) For Class 150 and below, the flanged-joint flange connections shall meet the pressure–temperature rating requirements of applicable standards, e.g., ASME B16.5.

(b) For Class 300 and above, the designer shall consult the manufacturer.

7-4.3 Design Temperature

(a) The design temperature requirements of para. 2-1.2.3 shall be applied in their entirety.

(b) The design temperature of each component in a piping system shall be the temperature at which, under the coincident pressure, the greatest thickness or highest component rating is required in accordance with para. 7-4.2 (to satisfy the requirements of para. 7-4.2, different components in the same piping system may have different design temperatures).

(c) In establishing design temperatures, the fluid temperatures, ambient temperatures, solar radiation, heating or cooling medium temperatures, and the applicable provisions of para. 7-4.3.2 shall be considered.

7-4.3.1 Uninsulated Components. The component design temperature of uninsulated components shall be taken as the fluid temperature, unless solar radiation, heat tracing, or other effects result in a higher temperature.

7-4.3.2 Externally Insulated Piping

(a) The component design temperature of externally insulated piping shall be the fluid temperature unless calculations, tests, or service experience based on measurements supports the use of another temperature.

(b) Where piping is heated or cooled by tracing or jacketing, this effect shall be considered in establishing component design temperatures.

7-4.4 Design Criteria

(a) The design criteria requirements of section 2-2 shall be applied in their entirety.

(b) In selection of components and design of the piping system, the designer shall take into account the commercially available piping sizes.

7-4.4.1 Permissible Pressure–Temperature Design Criteria

(a) Standard Components Having Established Ratings

(1) Except as limited elsewhere in this Standard, pressure–temperature ratings contained in standards listed in Table 4-2.1-1 for standard piping components shall be acceptable for design pressures and temperatures in accordance with this Standard.

(2) The provisions of this Standard may be used at the owner's responsibility to extend the pressure–temperature ratings of a component beyond the ratings of the listed standard.

(b) Listed Components Not Having Specific Ratings. Some of the standards for components listed in Table 4-2.1-1 (e.g., ASME B16.9 and ASME B16.11) state that pressure–temperature ratings are based on straight seamless pipe. Except as limited in the standard, such a component, made of a material having the same allowable stress as the pipe, shall be rated using not more than 87.5% of the nominal thickness of seamless pipe corresponding to the schedule, weight, or pressure

class of the fitting, less all allowances applied to the pipe (e.g., thread depth and/or corrosion allowance).

7-4.4.2 Nonstandard Components

(a) Nonstandard components to which the requirements elsewhere in para. 7-4.4 do not apply shall satisfy the pressure design criteria of this Standard.

(b) The designer shall ensure that the pressure design has been substantiated through one or more of the means stated in (1) through (4) below.

NOTE: Designs are also required to be checked for adequacy of mechanical strength as described in para. 7-4.4.5.

(1) extensive, successful service experience under comparable conditions with similarly proportioned components of the same or like material.

(2) experimental stress analysis, such as described in ASME BPVC, Section VIII, Division 2, Annex 5F.

(3) proof test in accordance with ASME B16.9; ASME BPVC, Section VIII, Division 1, UG-101; or MSS SP-97.

(4) detailed stress analysis (e.g., finite element method) with results evaluated as described in ASME BPVC, Section VIII, Division 2, Part 5. The basic allowable stress from ASME B31.3, Tables A-1 and A-1M shall be used in place of the allowable stress, *S*, in ASME BPVC, Section VIII, Division 2, where applicable.

(c) Documentation showing compliance with this paragraph shall be available for the owner's approval.

(d) For any of these methods, the designer may interpolate between sizes, wall thicknesses, and pressure classes, and may determine analogies among related materials.

7-4.4.3 Allowances for Temperature Variations for Plastic Liner. The designer shall take extra precautions to ensure that any design temperature peak excursions are below the maximum permitted temperature of the plastic for a specific chemical service.

7-4.4.4 Allowable Stresses and Other Stress Limits

7-4.4.4.1 General. The allowable stresses defined in (a) through (c) shall be used in design calculations unless modified by other provisions of this Standard.

(a) Tension. Basic allowable stresses, *S*, in tension for metals are listed in ASME B31.3, Tables A-1 and A-1M. Design stresses for bolting materials, *S*, are listed in ASME B31.3, Tables A-2 and A-2M. These shall be determined in accordance with para. 7-4.4.4.2. In equations elsewhere in this Standard where the product *SE* appears, the value *S* shall be multiplied by one of the casting or weld joint quality factors found in ASME B31.3, para. 302.3.

(b) Shear and Bearing. Allowable stresses in shear shall be 0.80 times the basic allowable stress in tension tabulated in ASME B31.3, Tables A-1 and A-1M or Tables A-2 and A-2M. Allowable stress in bearing shall be 1.60 times that value.

(c) Compression. Allowable stresses in compression shall be no greater than the basic allowable stresses in tension as tabulated in ASME B31.3, Tables A-1 and A-1M or Tables A-2 and A-2M. Consideration shall be given to structural stability.

7-4.4.4.2 Bases for Design Stresses. The bases for establishing design stress values for bolting materials and allowable stress values for other metallic materials in this Standard shall be as follows:

(a) Bolting Materials. Design stress values at temperature for bolting materials shall not exceed the lowest of the following:

(1) the lower of one-fourth of the specified minimum tensile strength at room temperature, S_T, and one-fourth of the tensile strength at temperature

(2) the lower of two-thirds of the specified minimum yield strength at room temperature, S_Y, and two-thirds of the yield strength at temperature

(b) Other Materials. Basic allowable stress values at temperature for materials other than bolting materials shall not exceed the lowest of the following:

(1) the lower of one-third of S_T and one-third of the tensile strength at temperature

(2) the lower of two-thirds of S_Y and two-thirds of the yield strength at temperature

7-4.4.4.3 Casting Quality Factor, E_c. The casting quality factor, E_c, defined herein, shall be used for cast components not having pressure–temperature ratings established by standards.

(a) Basic Quality Factors

(1) Castings for flanges and fittings and other piping components shall be assigned a basic casting quality factor, E_c, of 0.80.

(2) Centrifugal castings that meet specification requirements only for chemical analysis; tensile, hydrostatic, and flattening tests; and visual examination shall be assigned a basic casting quality factor of 0.80.

NOTE: Basic casting quality factors are tabulated for listed specifications in ASME B31.3, Tables A-1 and A-1M.

(b) Increased Quality Factors. Casting quality factors may be increased when supplementary examinations are performed on each casting.

(1) Table 7-4.4.4.3-1 states the increased casting quality factors, E_c, that may be used for various combinations of supplementary examination.

(2) Table 7-4.4.4.3-2 states the acceptance criteria for the examination methods specified in the notes to Table 7-4.4.4.3-1.

(3) Quality factors higher than those shown in Table 7-4.4.4.3-1 shall not result from combining the tests in Notes (2)(a) and (2)(b), or Notes (3)(a) and (3)(b) in Table 7-4.4.4.3-1.

(4) In no case shall the quality factor exceed 1.00.

Table 7-4.4.4.3-1 Increased Casting Quality Factor, E_c

Supplementary Examination in Accordance With Note(s)	Factor, E_c
Note (1)	0.85
Note (2)(a) or Note (2)(b)	0.85
Note (3)(a) or Note (3)(b)	0.95
Note (1) and either Note (2)(a) or Note (2)(b)	0.90
Note (1) and either Note (3)(a) or Note (3)(b)	1.00
Note (2)(a) or Note (2)(b) and Note (3)(a) or Note (3)(b)	1.00

NOTES:
(1) Machine all surfaces to a finish of 6.3 μm R_a (250 μin. R_a in accordance with ASME B46.1), thus increasing the effectiveness of surface examination.
(2) *Examinations*
(a) Examine all surfaces of each casting (ferromagnetic material only) by the magnetic particle method in accordance with ASTM E709. Judge acceptability in accordance with MSS SP-53, Table 1, using reference photos in ASTM E125.
(b) Examine all surfaces of each casting by the liquid penetrant method, in accordance with ASTM E165. Judge acceptability of flaws and weld repairs in accordance with MSS SP-53, Table 1, using reference photographs in ASTM E125 for surface flaws.
(3) *Additional Examinations*
(a) Fully examine each casting ultrasonically in accordance with ASTM E114, accepting a casting only if there is no evidence of depth of defects in excess of 5% of wall thickness.
(b) Fully radiograph each casting in accordance with ASTM E94. Judge in accordance with the stated acceptance levels in Table 7-4.4.4.3-2.

Table 7-4.4.4.3-2 Acceptance Levels for Castings

Thickness of Steel Examined, *T*, mm (in.)	Applicable Standard	Acceptance Level (or Class)	Acceptable Discontinuities
≤25 (≤1)	ASTM E446	1	Types A, B, and C
>25 and ≤51 (>1 and ≤2)	ASTM E446	2	Types A, B, and C
>51 and ≤114 (>2 and ≤4½)	ASTM E186	2	Categories A, B, and C
>114 and ≤305 (>4½ and ≤12)	ASTM E280	2	Categories A, B, and C

7-4.4.4.4 Limits of Calculated Stresses Due to Sustained Loads and Displacement Strains

(a) Internal Pressure Stresses. Stresses due to internal pressure shall be considered safe when the wall thickness of the piping component, including any reinforcement, meets the requirements of para. 7-4.4.6.

(b) External Pressure Stresses. Stresses due to external pressure shall be considered safe when the wall thickness of the piping component, and its means of stiffening, meet the requirements of para. 7-4.4.6.

(c) Stresses Due to Sustained Loads, S_L. The sum of the longitudinal stresses due to sustained loads, S_L, such as pressure and weight in any component in a piping system, shall not exceed S_h, where S_h is taken from ASME B31.3, Tables A-1 and A-1M at the metal temperature of the operating condition being considered.

(d) Allowable Displacement Stress Range, S_A. The computed displacement stress range, S_E, in a piping system shall not exceed the allowable displacement stress range, S_A, calculated by eq. (7-4-1):

$$S_A = f(1.25S_c + 0.25S_h) \tag{7-4-1}$$

When S_h is greater than S_L, the difference between them may be added to the term $0.25S_h$ in eq. (7-4-1). In that case, the allowable stress range shall be calculated by eq. (7-4-2):

$$S_A = f[1.25(S_c + S_h) - S_L] \tag{7-4-2}$$

where

f = stress range factor
= $6.0(N)^{-0.2} \leq f_m$ (see Figure 7-4.4.4.4-1)

NOTES:
(1) Stress range factor applies to essentially noncorroded piping. Corrosion can sharply decrease cyclic life; therefore, corrosion-resistant materials should be considered if a large number of major stress cycles is anticipated.
(2) The minimum value for f shall be 0.15, which results in an allowable displacement stress range, S_A, for an infinitely large number of cycles.

f_m = maximum value of stress range factor
= 1.2 for ferrous materials with specified minimum tensile strengths ≤517 MPa (75 ksi) and at metal temperatures ≤371°C (700°F); otherwise, f_m = 1.0

N = equivalent number of full displacement cycles during the expected service life of the piping system

NOTE: The designer is cautioned that the fatigue life of materials operated at elevated temperature can be reduced.

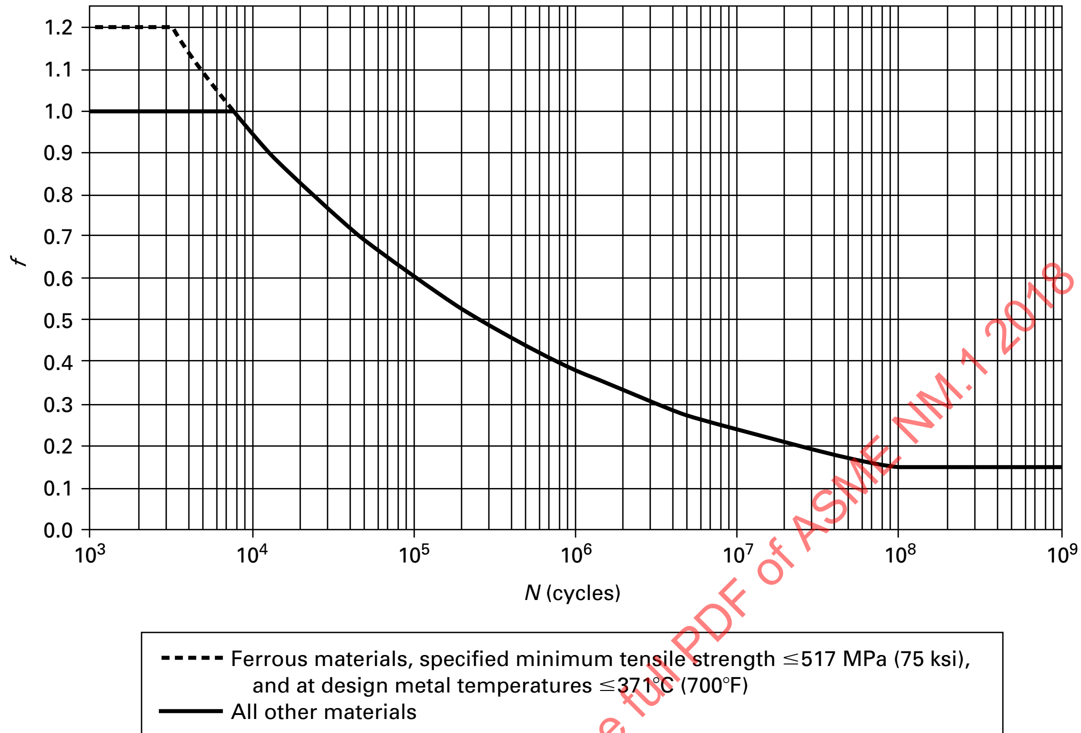
S_c = basic allowable stress at minimum metal temperature expected during the displacement cycle under analysis
= 138 MPa (20 ksi) maximum

NOTE: For castings, the basic allowable stress shall be multiplied by the applicable casting factor, E_c. For longitudinal welds, the basic allowable stress should not be multiplied by the weld quality factor, E_j.

S_h = basic allowable stress at maximum metal temperature expected during the displacement cycle under analysis
= 138 MPa (20 ksi) maximum

S_L = stress due to sustained loads; in systems where supports can be active in some conditions and inactive in others, the maximum value of

Figure 7-4.4.4.4-1 Stress Range Factor, f



sustained stress, considering all support conditions, shall be used

When the computed stress range varies, whether from thermal expansion or other conditions, S_E shall be defined as the greatest computed displacement stress range. The value of N in such cases may be calculated by eq. (7-4-3):

$$N = N_E + \sum (r_i^5 N_i) \text{ for } i = 1, 2, \ldots, n \tag{7-4-3}$$

where

N_E = number of cycles of maximum computed displacement stress range, S_E

N_i = number of cycles associated with displacement stress range, S_i

r_i = S_i/S_E

S_i = any computed displacement stress range smaller than S_E

7-4.4.4.5 Limits of Calculated Stresses Due to Occasional Loads

(a) Operation. The sum of the longitudinal stresses, S_L, due to sustained loads, such as pressure and weight, and of the stresses produced by occasional loads, such as wind or earthquake, may be as much as 1.33 times the basic allowable stress given in ASME B31.3, Tables A-1 and A-1M.

(1) Wind and earthquake forces may not be considered as acting concurrently.

(2) For castings, the basic allowable stress shall be multiplied by the casting quality factor, E_c.

(b) Test. Stresses due to test conditions shall not be subject to the limitations in para. 7-4.4.5. It is not necessary to consider other occasional loads, such as wind and earthquake, as occurring concurrently with test loads.

7-4.4.4.6 Allowances. In determining the minimum required thickness of a piping component, allowances shall be included for corrosion, erosion, and thread depth or groove depth. See definition for c in para. 7-4.4.6.1.

7-4.4.5 Mechanical Strength

(a) Designs shall be checked for adequacy of mechanical strength under applicable loadings.

(b) When necessary, the wall thickness shall be increased to prevent overstress, damage, collapse, or buckling due to superimposed loads from supports, ice formation, backfill, transportation, handling, or other loads enumerated in section 7-4.

(c) If increasing the thickness would excessively increase local stresses or the risk of brittle fracture, or is otherwise impracticable, the impact of applied loads may be mitigated through additional supports, braces,

or other means without requiring an increased wall thickness.

(d) Particular consideration should be given to the mechanical strength of small pipe connections to piping or equipment.

7-4.4.6 Pressure Design of Metallic Host Components

(a) The metallic host pipe shall be designed to sustain 100% of the system design pressure, and the thermoplastic liner shall not be considered the pressure boundary of the pipe.

(b) The overall limiting factor of the system shall be the lesser of the host pipe or fitting and flange end connection or the allowable pressure and temperature of the liner as given by the manufacturer.

7-4.4.6.1 Straight Pipe. The required thickness, t_m, of straight sections of pipe shall be determined in accordance with eq. (7-4-4):

$$t_m = t + c \tag{7-4-4}$$

where

c = sum of the mechanical allowances (thread or groove depth) plus corrosion and erosion allowances. For threaded components, the nominal thread depth (dimension h of ASME B1.20.1, or equivalent) shall apply. For machined surfaces or grooves where the tolerance is not specified, the tolerance shall be assumed to be 0.5 mm (0.02 in.) in addition to the specified depth of the cut.

t = pressure design thickness as calculated in accordance with eqs. (7-4-5) and (7-4-6)

t_m = minimum required thickness, including mechanical, corrosion, and erosion allowances

The minimum thickness, T, for the pipe selected, considering the manufacturer's minus tolerance, shall be not less than t_m.

NOTE: Equation (7-4-4) differs from the thickness equations in Chapter 2.

7-4.4.6.2 Straight Pipe Under Internal Pressure. For $t < D/6$, the internal pressure design thickness for straight pipe shall be not less than that calculated in accordance with either eq. (7-4-5) or eq. (7-4-6):

$$t = \frac{PD}{2(SE + 0.4P)} \tag{7-4-5}$$

$$t = \frac{P(d + 2c)}{2(SE - 0.6P)} \tag{7-4-6}$$

where

D = O.D. of pipe as listed in tables of standards or specifications or as measured

d = I.D. of pipe. For pressure design calculation, the I.D. of the pipe shall be the maximum value allowable under the purchase specification.

E = quality factor from ASME B31.3, Table A-1A or Table A-1B

P = internal design gauge pressure

S = stress value for material from ASME B31.1, Table A-1 or ASME B31.3, Tables A-1 and A-1M

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 aboveground 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) at ambient temperatures are listed for common liner materials in ASTM F1545.

(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.

Table 7-4.4.10-1 Working Pressures for Metallic Flanges and Fittings Lined With Thermoplastics

Temperature		Pressure Class and Flange Material							
		Class 150 Ductile Iron Flanges ASME B16.42		Class 150 Forged Steel ASME B16.5		Class 150 Stainless Steel Type 304L/316L ASME B16.5		Class 300 Forged Steel ASME B16.5	
°F	°C	psig	barg	psig	barg	psig	barg	psig	barg
−20	−29	250	17.2	285	19.7	230	15.9	485	33.4
0	−18	250	17.2	285	19.7	230	15.9	485	33.4
50	10	250	17.2	285	19.7	230	15.9	485	33.4
100	38	250	17.2	285	19.7	230	15.9	485	33.4
150	65	242	16.7	285	19.7	212	14.6	485	33.4
200	93	235	16.2	260	17.9	195	13.4	475	32.8
250	121	225	15.5	245	16.9	185	12.8	460	31.7
300	149	215	14.8	230	15.9	175	12.1	450	31.0
350	177	207	14.3	215	14.8	167	11.5	440	30.3
400	204	200	13.8	200	13.8	160	11.0	425	29.3
450	232	185	12.8	185	12.8	155	10.7	405	27.9

GENERAL NOTES:
(a) The maximum temperature limit may be reduced by the liner material's operating range.
(b) Class 300 pressure–temperature ratings for PP, PVDF, ETFE, E-CTFE, PTFE, and PFA shall be reduced relative to unlined pipe.
(c) Metals lined with HDPE liners have the capability of full ASME pressure rating of the flange used, within their temperature limitations.
(d) Gray cast iron flanges per ASME B16.1 shall not be used.

(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 7-4.4.10-1.

(c) Paragraph 7-4.4.6 shall also apply.

7-4.4.11 Pressure Drop. The designer shall ensure the pressure drop and flow calculations are based on the correct component I.D. These calculations can vary between components even within a single piping size from a single manufacturer.

NOTES:
(1) The I.D. of thermoplastic-lined metallic piping is less than that for unlined metallic piping and is not standardized.
(2) Generally, there is no assumed degradation of the surface roughness factor as a function of time.

7-4.4.12 Permissible Flow Velocity. The designer shall take into account the following fluid flow limits:

(a) *Liquids*. Velocities below 3.7 m/s (12 ft/sec) should not create any adverse effects. The designer should check with the manufacturer if the flow velocity limits exceed the recommended limits.

(b) *Gases*. The manufacturer should be consulted when flows exceed 9.2 m/s (30 ft/sec).

(c) Multiphase flow can cause 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 the scope 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 the 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, the following:

(a) process temperature
(b) media vapor pressure
(c) media molecule size
(d) solubility coefficient
(e) polymer crystallinity
(f) polymer molecular weight
(g) liner wall thickness

7-4.4.15 Permeant Venting

(a) Venting is the removal of permeated gases or liquids that have migrated through the plastic liner. The annular space between the liner and the host pipe acts as a pathway for the permeant molecules to a vent location. Permeant fluids will migrate to the lower-pressure vent areas.

WARNINGS:

(1) When thermoplastic-lined metallic piping is equipped with a venting system

***(a)* the designer should take into consideration how the permeant fluids could interact with personnel and the environment and provide means of preventing harmful interactions**

***(b)* the owner/operator should take into consideration how the permeant fluids could interact with metallic structures and personnel**

(2) Buildup of permeant species or corrosive by-products can clog and disable the venting system. This can lead to deformation of the liner, causing it to collapse or reducing the effective vacuum resistance.

(b) The designer should consider various approaches to venting, including, but not limited to, the following:

(1) open venting via drilled holes in host housing

(2) open venting via a pathway behind flared sealing surface fitted with ridged or formed interstitial collar

(3) open venting via a pathway machined into the flange

(4) custom venting designs for high-pressure HDPE systems

(-a) closed system venting with monitoring

(-b) closed system venting without monitoring (e.g., plugged)

(-c) inline venting through the liner wall

(5) no venting

7-4.4.16 Heat-Tracing Practices

(a) Steam tracing should not be used for liners having a temperature rating less than 121°C (250°F).

(b) Heat tracing shall be designed using sound heat dispersion methods such that it does not create a hot spot that could exceed the liner or host pipe allowable temperature, or a cold spot that could cause fluid freezing, crystallization, or plugging.

7-4.4.17 Insulation. Insulation of the host pipe shall be allowed, provided that pipe that is to be vented shall have vent couplings and/or tubing that protrudes past the insulation to avoid permeant buildup and corrosion under insulation (CUI) of the host pipe O.D. surface.

7-4.4.18 Flangeless or Reduced-Flange Piping

(a) Flangeless or reduced-flange piping may be manufactured by using extended pipe lengths, fusion welding joints, or bent piping to eliminate flange connections.

(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, or 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. Loose-fitting liners 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 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 the 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

7-5.2.1 Standard Flanged Alignment

(a) *Piping Distortions.* Piping shall not be distorted to bring it into alignment for joint assembly, which introduces a detrimental strain in equipment or piping components.

(b) *Flanged Joints.* Unless otherwise specified in the engineering design, flanged joints shall be aligned as follows:

(1) Before bolting, mating gasket contact surfaces shall be aligned to each other within 1 mm/200 mm ($^1\!/_{16}$ in./ft), measured across any diameter.

(2) The flanged joint shall be capable of being bolted such that the gasket contact surfaces bear uniformly on the gasket.

(3) Flange bolt holes shall be aligned within 3 mm ($^1\!/_8$ in.) maximum offset.

NOTE: The gasket contact surfaces for flanged connections without a gasket are considered to be the surface on the liner face on the flange.

7-5.2.2 Preparation for Assembly

(a) Any damage to the sealing surface that would prevent sealing shall be repaired, or the piping component shall be replaced.

(b) Repair of the sealing surface shall be conducted in accordance with the manufacturer's guidelines.

7-5.2.3 Bolting Torque

(a) In assembling flanged joints, the sealing surface shall be uniformly compressed to achieve the material sealing stress at a given temperature.

(b) Bolting shall be installed with a calibrated torque wrench and shall follow the manufacturer's bolt torque guidelines.

(c) Care shall be given to ensure the connection is not overtorqued.

(d) Special care shall be used in assembling flanged joints in which the flanges or liners have differing mechanical properties.

(e) Tightening should be performed to a predetermined torque (see para. 7-5.4).

7-5.2.3.1 Bolt Length. Bolts shall extend completely through their nuts, with at least one thread exposed.

7-5.2.3.2 Bolt Material. Bolts should be made of high-strength material as defined by ASME B16.5, Table 1B, unless it has been verified that a sealed joint can be maintained under the rated working pressure and temperature.

7-5.2.4 Gaskets. For the connection of two lined systems, gaskets may be used at the owner's request.

(a) No more than one gasket shall be used between contact faces in assembling a flanged joint.

(b) Use of gaskets can alter the bolt torque requirement. The guidelines of the manufacturers of both the gasket and the plastic-lined piping should be consulted, and the torque recommendation for the softer material should be used.

7-5.3 Flangeless or Reduced-Flanged Piping

(a) For installation of metallic piping lined with PE, PP, PVDF, or PTFE, the designer shall follow all of the manufacturer's guidelines.

(b) The installer shall follow all guidelines from the manufacturers on the design of a flangeless or reduced-flange piping system. Refer to Mandatory Appendix I for liner FPS and welder qualifications.

(c) When repairing fusion-welded flangeless or reduced-flange systems, the owner should consider the chemical exposure history of the piping and be aware that permeated species can be present in the liner, affecting weld joint quality.

7-5.4 Connections of Thermoplastic-Lined Metallic Piping to Other Types of Piping

(a) Unlined Metallic Piping. A solid thermoplastic spacer or gasket shall be required where thermoplastic-lined metallic piping is connected to unlined metallic piping. Both a gasket and a spacer shall be used if the mating surface is not visibly smooth.

(b) Solid Thermoplastic Piping. A solid thermoplastic spacer or gasket may be used where thermoplastic-lined metallic piping is connected to solid thermoplastic piping.

(c) Unlined Thermoset Piping. Both a solid thermoplastic spacer and gasket shall be required where thermoplastic-lined metallic piping is connected to unlined thermoset piping.

(d) Other Piping. Both a solid thermoplastic spacer and gasket shall be required where thermoplastic-lined metallic piping is connected to types of piping other than those discussed in (a) through (c), such as unlined metallic piping or glass-lined piping.

(e) Butterfly Valves. A taper bore spacer to enable proper clearance for the butterfly wafer shall be required where thermoplastic-lined metallic piping is connected to a butterfly valve.

7-5.5 Cold-Temperature Installation

If thermoplastic-lined piping is to be installed at cold temperatures [see para. 7-6(d)], procedures shall be developed with the manufacturer to prevent liner damage. This shall include heating pipe ends and flanges to no more than 21°C (70°F) to enable mating of flanged ends.

NOTE: Some thermoplastics exhibit brittle characteristics at low ambient temperature conditions, and special handling and installation procedures may be required.

7-5.6 Field Fabrication Certification

Field fabricators shall be certified by the piping manufacturer or the manufacturer's designee. Certification older than 18 months shall require recertification.

7-5.7 Bonder Qualification for Fusion Welding Liners

See Mandatory Appendix I.

7-5.8 Cleaning Procedures

(a) All plastic-lined pipe and fitting lines shall be cleared of any debris or obstructions and cleaned before being placed into service. The cleaning procedure shall meet the requirements of the process as defined by the owner and include any process-specific requirements on dryness or service incompatibilities with cleaning materials or procedures.

(b) Plastic liners may be pressure washed with nozzle-tip pressures less than 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 they enter 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) ASCE MOP 119, Buried Flexible Steel Pipe: Design and Structural Analysis

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.

(c) Plastic-lined and bolted flanged joints shall be buried in a lockable-access corrosion-resistant right-of-way (ROW) manhole or vault, so as to provide access to and inspection of the bolted joints.

7-5.10.3 Field Liner Installation

(a) The cable used to field install the liner by pulling it into the host pipeline, so as to avoid "cutting" the sidewall of the host pipe at sags and overbends, directional turns during pull-cable wire-rope insertion, and liner pull-back, shall be one of the following:

(1) para-aramid cable
(2) polymer fiber cable
(3) smooth-O.D. die-sized wire rope
(4) jacketed wire rope

(b) For field-installed pipe liner, premachined plastic flange adapter liner flanges shall be used.

7-5.10.4 Butt-Fusion-Welded Liner Designs. Flangeless lined piping where the liners are butt-fusion-welded and fitted with mechanical couplings may be buried without the accommodation for inspection mentioned in para. 7-5.10.2(c).

7-6 STORAGE AND HANDLING GUIDELINES

The requirements in (a) through (i) apply to appropriate storage and handling methods for use on metals lined with thermoplastics. The installer shall take the following into consideration:

(a) Store piping indoors or under cover until ready for use.

(b) Never put the lifts of a forklift inside of the pipe to transport. This can damage the plastic liner.

(c) Do not drop piping or roll it off a flatbed as this can damage the liner.

(d) Avoid any mechanical or thermal shock to piping that is stored in cold temperatures, especially in climates where the ambient temperature is below 0°C (32°F). Avoid rough handling of plastic-lined pipe in temperatures below 5°C (40°F). Thermoplastics can become brittle in low temperatures and are more susceptible to cracking during rough handling.

(e) Protective end caps on all pipe and fittings should be left in place until the pipe is ready to be installed. Protective end caps are not designed for prolonged outdoor exposure.

(f) Do not damage the plastic sealing faces when removing the end caps.

(g) If end caps are removed for painting, they shall be reinstalled with bolting as soon as possible.

(h) Avoid storing plastic-lined piping products where the liner will be exposed to ultraviolet light for long periods of time.

(i) Do not stand spools or fittings on the unprotected flange face.

7-7 INSPECTION, EXAMINATION, AND TESTING

This Standard distinguishes between examination and inspection.

7-7.1 Inspection

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.

7-7.1.1 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 piping to the extent necessary to be satisfied that it conforms to all applicable examination requirements of the Standard and of the engineering design.

7-7.1.2 Rights of the Owner's Inspector

(a) The owner's Inspector and the Inspector's delegates shall have access to any place where work concerned with the piping installation is being performed. This includes manufacture, fabrication, heat treatment, assembly, erection, examination, and testing of the piping.

(b) The owner's Inspector and the Inspector's delegates shall have the right to audit any examination, to inspect the piping 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. 7-7.2.

7-7.1.3 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, or 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 piping manufacturer, fabricator, or erector unless the owner is also the manufacturer, fabricator, or erector.

(b) The owner's Inspector shall meet one of the following requirements:

(1) have at least 10 yr experience in the design, fabrication, or examination of industrial pressure piping. Each 20% of satisfactorily completed work toward an accredited engineering degree shall be considered equivalent to 1 yr experience, up to 5 yr total.

(2) have a professional engineering registration or nationally recognized equivalent with at least 5 yr experience in the design, fabrication, or examination of industrial pressure piping.

(3) be a certified welding inspector or a senior certified welding inspector as defined in AWS QC1 or a nationally recognized equivalent with at least 5 yr experience in the design, fabrication, or examination of industrial pressure piping.

(4) be an authorized piping inspector as defined in API 570, with at least 5 yr experience in the design, fabrication, or examination of industrial pressure piping.

(c) In delegating performance of inspection, the owner's Inspector shall be responsible for determining that a person to whom an inspection function is delegated is qualified to perform that function.

NOTE: These requirements are different from those listed in Chapter 6 and are exclusive to thermoplastic-lined metallic piping.

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 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 in (a) through (c) and 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:

Step 1. Two additional samples of the same kind (if welded or bonded joints, by the same welder, bonder, or operator) from the original designated lot shall be given the same type of examination.

Step 2

(a) If the items examined as required by Step 1 are acceptable, the defective item shall be repaired or replaced and reexamined as specified in para. 7-7.2.3.3 and all items represented by these two additional samples shall be accepted.

(b) If any of the items examined as required by Step 1 reveals a defect, two further samples of the same kind shall be examined for each defective item found by that sampling.

Step 3. If all the items examined as required by Step 2(b) are acceptable, the defective item(s) shall be repaired or replaced and reexamined as specified in para. 7-7.2.3.3 and all items represented by the additional sampling shall be accepted, but if any of the items examined as required by Step 2(b) reveals a defect, all items represented by the progressive sampling shall be either

(a) repaired or replaced and reexamined as required, or

(b) fully examined and repaired or replaced as necessary, and reexamined as necessary to meet the requirements of this Standard

Step 4. If any of the defective items are repaired or replaced, reexamined, and a defect is again detected in the repaired or replaced item, continued progressive sampling in accordance with Steps 1, 2(b), and 4 should not be required based on the defects found in the repair.

(a) The defective item(s) shall be repaired or replaced and reexamined until acceptance as specified in para. 7-7.2.3.2.

(b) Spot or random examination (whichever is applicable) shall then be performed on the remaining unexamined joints and vent openings.

7-7.2.4 Extent of Required Examination

7-7.2.4.1 Examination — Normal Fluid Service. Piping in normal fluid service shall be examined to the extent specified herein or to any greater extent specified in the engineering design. Acceptance criteria shall be as stated in para. 7-7.2.3.2 unless otherwise specified.

(a) Visual Examination. At least the following shall be examined in accordance with para. 7-7.2.7.3:

(1) sufficient materials and components, selected at random, to satisfy the examiner that they conform to specifications and are free from defects.

(2) at least 5% of fabrication. For bonds, each type of bond made by each bonder and bonding operator shall be represented.

(3) 100% of fabrication for bonds other than circumferential, except those in standard components.

(4) random examination of the assembly of threaded, bolted, and other joints to satisfy the examiner that they conform to the applicable requirements of assembly and erection elsewhere in this Standard. When pneumatic testing is to be performed, all threaded, bolted, and other mechanical joints, as well as vent openings, shall be examined.

(5) random examination during erection of piping, including checking of alignment, supports, and cold spring.

(6) erected piping for evidence of defects that would require repair or replacement, and for other evident deviations from the intent of the design.

(b) Other Examination. Not less than 5% of all bonded joints shall be examined by in-process examination in accordance with para. 7-7.2.7.5; the joints to be examined shall be selected to ensure that the work of each bonder and bonding operator making the production joints is examined.

(c) Certifications and Records. The examiner shall be assured, by examination of certifications, records, and other evidence, that the materials and components are of the specified grades and that they have received required heat treatment, examination, and testing. The examiner shall provide the Inspector with a certification that all the quality control requirements of this Standard and of the engineering design have been carried out.

7-7.2.4.2 Examination — Category D Fluid Service. Piping and piping elements for Category D fluid service as designated in the engineering design shall be visually examined to the extent necessary to satisfy the examiner that components, materials, and workmanship conform to the requirements of this Standard and the engineering design.

7-7.2.4.3 Supplementary Examination

(a) Any applicable method of examination described in para. 7-7.2.7 may be specified by the engineering design to supplement the examination required by para. 7-7.2.4.

(b) The extent of the supplementary examination and any acceptance criteria that differ from those in para. 7-7.2.3.2 shall be specified in the engineering design.

7-7.2.4.4 Examination to Resolve Uncertainty. Any method may be used to resolve doubtful indications. Acceptance criteria shall be those for the required examination.

7-7.2.5 Examination Personnel

7-7.2.5.1 Personnel Qualification and Certification. Personnel performing nondestructive examination to the requirements of this Standard shall be qualified and certified for the method to be used following a procedure as described in ASME BPVC, Section V, Article 1, T-120(e) or T-120(f).

7-7.2.5.2 In-Process Examination. For in-process examination, the examination shall be performed by personnel other than those performing the production work.

7-7.2.6 Examination Procedures

(a) Any examination shall be performed in accordance with a written procedure that conforms to one of the methods specified in para. 7-7.2.7.1.

(b) Procedures shall be written as required in ASME BPVC, Section V, Article 1, T-150.

(c) The employer shall certify records of the examination procedures used, showing dates and results of procedure qualifications, and shall maintain the records and make them available to the Inspector.

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 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

(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

(6) 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) If the owner considers a hydrostatic leakage test impracticable, either a pneumatic test in accordance with para. 7-7.3.6 or a combined hydrostatic–pneumatic test in accordance with para. 7-7.3.7 may be substituted.

NOTE: There can be a substantial hazard of stored energy in compressed gas. ASME PCC-2, Part 5, Article 501 provides extensive requirements for safely performing compressed-gas testing.

7-7.3.2 General Requirements for Leakage Test. Requirements in paras. 7-7.3.2.1 through 7-7.3.2.7 apply to 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 kPa (25 psig) pressure may be done 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.

(e) For sensitive or pneumatic testing, if the vent opening is soaped, then a steady stream of bubbles can indicate a liner defect. Short-duration or diminishing bubbling can indicate liner seating.

7-7.3.2.3 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. 7-7.3.1.

(c) Closure Welds. The final weld connecting piping systems or components that have been successfully tested in accordance with para. 7-7.3 are not required to be leak tested provided the weld is examined in-process in accordance with para. 7-7.2.7.5 and passes with 100% radiographic examination in accordance

with para. 7-7.2.7.3 or 100% ultrasonic examination in accordance with para. 7-7.2.7.4.

7-7.3.2.4 Externally Pressured Piping. Piping subject to external pressure shall be tested at an internal gauge pressure 1.5 times the external differential pressure, but not less than 105 kPa (15 psi).

7-7.3.2.5 Jacketed Piping

(a) The internal line shall be leakage tested on the basis of the internal or external design pressure, whichever is critical. This test shall be performed before the jacket is completed, to provide visual access to joints of the internal line.

(b) The jacket shall be leakage tested in accordance with para. 7-7.3.1 on the basis of the jacket design pressure unless otherwise specified in the engineering design.

7-7.3.2.6 Repairs or Additions After Leakage Testing. If repairs or additions are made following the leakage test, the affected piping shall be retested, except that for minor repairs or additions, the owner may waive retest requirements when precautionary measures are taken to ensure sound construction.

7-7.3.2.7 Test Records

(a) *Test Data.* Records shall be made during the testing of each piping system, and shall include the following information:

(1) date of test

(2) identification of piping system tested

(3) test fluid

(4) test pressure

(5) certification of results by examiner

These test records are not required to be retained after completion of the test, if a certification by the Inspector that the piping has satisfactorily passed pressure testing as required by this Standard is retained.

(b) *Responsibility for Records.* It shall be the responsibility of the piping designer, the manufacturer, the fabricator, and the erector, as applicable, to prepare the records required by this Standard and by the engineering design.

(c) *Retention of Records.* Unless otherwise specified by the engineering design, the following records shall be retained for at least 5 yr after the record is generated for the project:

(1) examination procedures

(2) examination personnel qualifications

7-7.3.3 Preparation for Leakage Test

(a) *Joints Exposed*

(1) All joints, welds, vent openings, and bonds shall be left uninsulated and exposed for examination during leakage testing, except that joints previously tested in accordance with this Standard may be insulated or covered.

(2) All weld joints may be primed and painted prior to leakage testing unless a sensitive leak test is required.

(b) *Temporary Supports.* Piping designed for vapor or gas shall be provided with additional temporary supports, if necessary, to support the weight of test liquid.

(c) *Limits of Tested Piping.* Equipment that is not to be tested shall be either disconnected from the piping or isolated by blinds or other means during the test. A valve may be used provided the valve (including its closure mechanism) is suitable for the test pressure.

7-7.3.4 Hydrostatic Leakage Test

(a) *Test Fluid*

(1) The fluid shall be water unless there is the possibility of damage due to freezing or to adverse effects of water on the piping or the process. In that case, another suitable nontoxic liquid may be used.

(2) If the liquid is flammable, its flash point shall be at least 49°C (120°F), and consideration shall be given to the test environment.

(b) *Test Pressure*

(1) Except as provided in para. 7-7.3.5, 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. (7-7-1):

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

where

P = internal design gauge pressure

P_T = minimum test gauge pressure

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

S_T = allowable stress at test temperature for the prevalent pipe material; see ASME B31.3, Tables A-1 and A-1M

(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, Tables A-1 and A-1M. 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 eq. (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

(b) Procedure

(1) The pressure shall be gradually increased until a gauge pressure that is the lesser of one half the test pressure or 170 kPa (25 psi) is attained, at which time a preliminary check shall be made, including examination of joints and vent openings, in accordance with para. 7-7.2.7.2.

(2) Thereafter, the pressure shall be gradually increased in steps, with the pressure held long enough at each step to equalize piping strains, until the test pressure is reached.

(3) The pressure shall then be reduced to the design pressure before examining for leakage in accordance with para. 7-7.3.2.2.

7-7.3.7 Hydrostatic–Pneumatic Leakage Test. If a combined hydrostatic–pneumatic leakage test is used, then the requirements of para. 7-7.3.6 shall be met, and the pressure in the liquid-filled part of the piping shall not exceed the values calculated in accordance with para. 7-7.3.4(b).

7-7.3.8 Initial Service Leakage Test. Initial service leakage tests shall be applicable only to piping in Category D fluid service, at the owner's option. See para. 7-7.3.1(a).

(a) Test Fluid. The test fluid shall be the service fluid.

(b) Procedure. During or prior to initial operation, the pressure shall be gradually increased in steps, with the pressure held long enough at each step to equalize piping strains, until the operating pressure is reached. A preliminary check shall be made as described in para. 7-7.3.6 if the service fluid is a gas or vapor.

(c) Examination for Leakage. The examination for leakage required by para. 7-7.3.2.2(a) shall be conducted while the system is at operating pressure. Examination for leakage of joints, vent openings, and connections may be omitted if previously tested in accordance with this Standard.

7-7.3.9 Sensitive Leakage Test

(a) The sensitive leakage test shall be the Bubble Test — Direct Pressure Technique in accordance with ASME BPVC, Section V, Article 10, Appendix I or another leakage test method that has a demonstrated sensitivity not less than 10^{-3} std mL/s under test conditions.

(b) When the Bubble Test — Direct Pressure Technique is used

(1) the test pressure shall be at least the lesser of 105 kPa (15 psi) gauge or 25% of the design pressure.

(2) the pressure shall be gradually increased until a gauge pressure equal to the lesser of one-half the test pressure or 170 kPa (25 psi). Then the pressure shall be gradually increased in steps, with the pressure held long enough at each step to equalize piping strains, until the test pressure is reached.

Chapter 8
Multilayered Reinforced Thermoplastic Piping Systems

8-1 SCOPE

This Chapter pertains to multilayered reinforced thermoplastic piping system(s) (MRTPS) that are composed of pipes with a thermoplastic liner and a distinct reinforcing layer. The reinforcing layer can be made of materials such as dry glass fiber, impregnated glass fiber, carbon fiber, aramid fibers, steel strips, steel cords, and aluminum. MRTPS can be supplied as either stick or spooled pipe. This Chapter

(a) discusses design, materials, fabrication, erection, examination, inspection, and testing of MRTPS. Refer to Nonmandatory Appendix D for operation, maintenance, and repair aspects.

(b) concerns the parts of the piping system between the end connections (i.e., pipe, prime connections, fittings, flanges, and supports). Hangers are excluded as they are typically not used with MRTPS. Valves are excluded as standard valves used for other piping systems are also used for MRTPS.

(c) adopts a performance-based approach and does not prescribe specific materials, constructions, or dimensions.

8-2 APPLICABILITY

(a) This Chapter covers the use of MRTPS in oil and gas applications such as single-phase or multiphase, sweet or sour service for oil gathering, oil transmission, natural-gas gathering, natural-gas transmission, natural-gas distribution, water transfer, water injection, water disposal, and carbon dioxide (CO_2) injection.

(b) Use of MRTPS in high-vapor-pressure applications is permitted in cases where the design engineer considers the application acceptable from a risk/safety perspective.

(c) Other MRTPS applications outside the oil and gas industry are acceptable, provided the requirements of this Standard are met.

(d) MRTPS may be buried, laid on surface, or used in relining applications.

8-3 DESIGN

8-3.1 Project Application Information

The engineer responsible for the design of the piping system shall provide the parameters shown in API 15S, Annex B, Project Application Information, for the MRTPS manufacturer's confirmation of suitability of the MRTPS for the intended service.

8-3.2 Maximum Allowable Operating Pressure

The maximum allowable operating pressure (MAOP) of the piping system shall comply with both the static pressure considerations (see para. 8-3.2.1) and the cyclic pressure considerations (see para. 8-3.2.2).

8-3.2.1 Static Pressure Considerations

(a) The MAOP of the piping system shall comply with eq. (8-3-1):

$$\text{MAOP} \leq \text{NPR} \tag{8-3-1}$$

where

MAOP = maximum allowable operating pressure, kPa (psig)

NPR = nominal pressure rating of the MRTPS, kPa (psig)

(b) For both metallic-reinforced MRTPS and nonmetallic-reinforced MRTPS, the NPR shall be as defined and established by API 15S.

(c) For nonmetallic-reinforced MRTPS, the NPR shall be determined at the maximum qualified temperature and qualified life.

(d) The static pressure shall be determined using pipe samples that include the standard field connectors.

8-3.2.2 Cyclic Pressure Considerations

(a) The ability of an MRTPS to resist the pressure fluctuations anticipated during service shall be verified.

NOTE: Pressure fluctuations are generally the result of operational changes in the pipeline system, such as pump start/stop and valve opening and closure.

(b) A service factor of no greater than 0.1 shall be applied to the number of cycles from the lower confidence limit (LCL) of the cyclic regression analysis per API 15S, Annex G to determine the allowable number of cycles for the specific application.

(c) The cyclic testing shall be done on pipe samples that include the standard field connectors.

8-3.3 Minimum Allowable Operating Pressure

(a) The minimum allowable operating pressure of the piping system shall be equal to or higher than the minimum qualified pressure of the MRTPS (see para. 8-3.4).

(b) The design engineer shall have measures in place to limit the exposure of the piping system to the minimum allowable operating pressure to no more than 1 week per occurrence.

8-3.4 Minimum Qualified Pressure

(a) The minimum qualified pressure of the MRTPS shall be equal to the atmospheric pressure.

(b) Alternatively, for applications with pressure lower than atmospheric pressure, the minimum qualified pressure shall be equal to or higher than the minimum pressure the MRTPS have been proven to resist by qualification testing.

(c) Successful testing shall consist of a hold test under vacuum for 1 week at the maximum qualified temperature without damage to the MRTPS or pressure increase in the test specimen.

(d) The testing shall be performed on the MRTPS size and class combination that is most susceptible to the vacuum effects.

8-3.5 Surge Pressure

The potential for pressure surge resulting from water hammer shall be assessed by the piping system designer, and a protection system shall be implemented such that the highest pressure during a surge event shall not exceed the piping system MAOP plus 10%.

8-3.6 Maximum Allowable Operating Temperature

(a) In establishing the maximum allowable operating temperature (MAOT) of the piping system, the designer shall consider the fluid temperature, ambient temperature, solar radiation, and any other factors that can affect the temperature of the piping system.

(b) The MAOT of the piping system shall be equal to or less than the maximum qualified temperature of the MRTPS (see para. 8-3.7).

8-3.7 Maximum Qualified Temperature

The maximum qualified temperature of the MRTPS shall be the lower of the highest temperature at which the nominal pressure rating of the MRTPS has been established in accordance with API 15S and the highest temperature at which the minimum qualified pressure of the MRTPS has been established in accordance with this Chapter.

8-3.8 Minimum Allowable Operating Temperature

(a) In establishing the minimum allowable operating temperature of the piping system, the designer shall consider the fluid temperature, ambient temperature, and any other factors that can affect the temperature of the piping system.

(b) The minimum allowable operating temperature of the piping system shall be equal to or higher than the minimum qualified temperature of the MRTPS (see para. 8-3.9).

8-3.9 Minimum Qualified Temperature

The minimum qualified temperature of the MRTPS shall be equal to the lowest temperature used in the qualification testing of the MRTPS in accordance with API 15S.

8-3.10 Temperature Fluctuations

(a) Temperature fluctuations, including their magnitude and frequency, shall be considered during the design of the piping system.

(b) Temperature variations outside the range of the minimum allowable operating temperature and the MAOT shall be proven by qualification testing not to adversely affect the performance of the MRTPS.

8-3.11 Design Life and Qualified Life

The design life of the piping system shall be equal to or less than the qualified life of the MRTPS proven during qualification testing.

8-3.12 Fittings and Joints

(a) The jointing system to be used as part of the MRTPS shall have been proven by performance testing and qualification, as per API 15S, to be equal or superior in performance to the pipe being joined.

(b) Metallic fittings for use in constructing the MRTPS shall be designed according to ASME B31.3, or equivalent ASME standard, for the requested MAOP.

(c) Where metallic components are used, coating and/or cathodic protection systems shall be designed and installed that, when properly maintained, will protect the fitting through the life of the piping system.

8-3.13 System Supports

(a) The MRTPS shall be adequately supported such that it will not be subjected to any external mechanical loading from the adjacent piping components.

(b) The MRTPS shall also be protected from the effects of any soil settlement or differential settlement.

8-3.14 Minimum Operating Bend Radius

The minimum operating bend radius (MOBR) used when the MRTPS is pressurized shall be equal to or larger than the MOBR established during the qualification testing of the MRTPS, as per API 15S.

8-3.15 Fluid Composition

The composition of the transported fluid shall be assessed to ensure compatibility with the MRTPS pipe, joints, and fittings. The assessment shall consider, at minimum, gas content; pH; levels of hydrogen sulfide and carbon dioxide; presence of aromatics, solids, and injected chemicals; and any other service or fluid factor that could adversely affect the performance of the MRTPS.

8-3.16 Sour Service

Metallic components used to construct MRTPS subject to sour service shall be compliant with NACE MR0175.

8-3.17 Additional Design Considerations

The designer of the piping system shall, as a minimum, also consider the following:

(a) weather effects, ultraviolet degradation, anchoring stresses, potential corrosion mechanisms, protection from external damage or fire, and any other mechanism that can cause adverse effects on the performance of MRTPS.

(b) external loading and dynamic forces exerted by anticipated traffic and environmentally induced loads. These can require additional burial depths or installation within a casing.

(c) expansion or contraction associated with pressure or temperature fluctuations. The MRTPS manufacturer shall provide the designer with expansion coefficients to adequately compensate for the effects based on the intended installation environment.

(d) for surface installations, requirements for restraining the pipe to prevent movement that can lead to damage. Support designs shall minimize localized stresses.

(e) dimensional compatibility, corrosion control requirements, and the need for spacing centralizers for fittings that can reside within a host pipe as part of a relining project.

(f) for submerged applications, the effects of water external pressure, tide movements, waves, wind, and other loadings, where applicable.

(g) installation methods. The designer shall indicate limits on installation loading related to axial, external pressure and bending capacities of the MRTPS, or combinations thereof. See para. 8-4.3 for additional installation considerations.

8-4 FABRICATION, ASSEMBLY, AND ERECTION

8-4.1 Fabrication

The manufacturer of MRTPS components shall operate a quality management system as required by API 15S.

8-4.2 Assembly and Erection

The assembly and erection, including handling and installation, shall follow the MRTPS manufacturer's recommendations, in addition to the requirements of this Standard.

8-4.2.1 Joining. The assembly and erection contractor shall perform the joining of MRTPS in accordance with a written joining procedure, based on recommendations from the MRTPS manufacturer.

8-4.2.2 Personnel. The personnel responsible for the fabrication, assembly, and erection of MRTPS shall be trained, assessed, and qualified by the MRTPS manufacturer.

8-4.2.2.1 Training. The training program required in para. 8-4.2.2 shall include both a theoretical and a practical section.

(a) The theoretical section shall cover receiving, unloading, handling, storing, laying, joining, backfilling, and tying in pipe and fittings.

(b) The practical section shall cover the details of joining pipe and fittings and the operation of the installation equipment, if any.

8-4.2.2.2 Assessment. The assessment of personnel shall include both a written test and the fabrication of an MRTPS test joint. The joint shall be assessed by the trainer and deemed acceptable.

8-4.2.2.3 Qualification

(a) Upon successful completion of the training and assessment, each individual shall be issued a training certificate or pocket card by the MRTPS manufacturer. The certificate/pocket card shall

(1) be printed on a form containing the logo of the MRTPS manufacturer

(2) have an issue date, an expiry date, and a unique identification number

(3) include the name and photograph of the individual being certified

(4) include a description of the scope of the training and the identification of the product series and product range covered by the training

(5) be signed by an official of the MRTPS manufacturer and by the individual being certified

(b) All training certificates/pocket cards shall be valid for 1 yr from the training date, unless the MRTPS manufacturer operates a process to continuously evaluate the individual's performance. The certification shall expire 1

yr from the training date, or when continuous evaluation ceases, whichever occurs last.

NOTES:
(1) Due to the unique design of MRTPS fittings, the MRTPS manufacturer shall be the sole entity that provides installer certification, monitoring of installer performance, or both.
(2) The installer's continuous evaluation shall be based on the MRTPS manufacturer requirements.

8-4.3 Installation

MRTPS included in the scope of this Chapter may be buried, laid on surface, or used in relining/rehabilitation applications.

8-4.3.1 Buried Installations. MRTPS may be buried by conventional "trench and backfill" methods using conventional trenching equipment, by directional drilling, or by "plowing-in" with specialized trenching plows.

8-4.3.1.1 Installation Specification. The design engineer shall develop an installation specification that provides requirements for factors such as, but not limited to, the following:

(a) pipe system routing, taking into consideration the MOBR of the product
(b) the transition from aboveground piping to underground piping
(c) the use of tracer wire, warning tape, or both in buried applications, in accordance with the manufacturer's recommendations
(d) installation of a cathodic protection system, where required
(e) application of protective wrapping to the fittings
(f) backfill material
(g) burial depth and casing at crossings
(h) methods to minimize soil movement and heave
(i) compaction techniques that will protect the piping material from damage
(j) any additional measures necessary to minimize localized stresses to the MRTPS
(k) installation and placement of buoyancy weights, if necessary

8-4.3.1.2 Co-trenching. If the installation includes co-trenching with other pipelines or other underground infrastructure, the installation specification shall include adequate direction with respect to separation distances. Separation distances shall address potential damage from heat sources and provide adequate clearances to allow for future maintenance or repairs, should they become necessary. Distances shall also provide adequate room for specialized tools without inducing damage to the pipe or adjacent facilities.

8-4.3.1.3 Horizontal Directional Drilling

(a) The maximum allowable axial pull load published by the MRTPS manufacturer shall not be exceeded when horizontal directional drilling (HDD) is used for the piping system installation.
(b) Appropriate pulling heads and tension force gauges/dynamometers shall be installed and monitored during the pipe-pulling activities.
(c) A visual inspection of the pipe after the pulling is complete shall be performed to ensure the fitness for service of the piping system.
(d) Any damages resulting from the installation shall be within the acceptance criteria defined by the piping system designer or MRTPS manufacturer.
(e) A sufficient amount of pipe shall be pulled past the bore exit hole to allow for a 360-deg visual evaluation of the pipe, and to allow for pipe relaxation.
(f) If the examination reveals damages that exceed defined acceptance criteria, further examination shall be executed to ascertain the acceptability of the installed pipe.
(g) If it cannot be satisfactorily determined that the installed pipe is acceptable, the pipe shall be replaced or a new HDD bore performed.

8-4.3.2 Surface Installations

(a) Surface installation shall be performed according to the installation specification.
(b) The recommendations for support types and spans shall be followed, including any recommendations for supporting MRTPS interface materials.
(c) Bends in MRTPS shall always be made with a radius greater than the MOBR of the product.
(d) MRTPS laid on surface shall be adequately restrained to avoid damage from abrasion on the ground surface and to avoid pipeline kinking or excessive movement.

8-4.3.3 Relining Applications

8-4.3.3.1 Relining Preparation. Prior to beginning a relining installation, the installer shall test or examine the host pipeline to confirm there are no obstructions, e.g., any unexpected sharp turns, dents or kinks in the pipe, or internal weld material. (Such defects can reduce the effective internal diameter of the steel line and damage the MRTPS.) The examinations shall also confirm there will be adequate clearance between the O.D. of the MRTPS (including couplings or fittings) and the I.D. of the existing host line.

8-4.3.3.2 Pull Lines. If wire rope is used as the pull line, then a swivel shall be installed between the pull line and the MRTPS to prevent the wire rope from applying torque to the pipe during installation. A pulling-load indicator system, which provides real-time readout of axial pull during installation, shall be used. Actual pulling force shall be limited to the product's published maximum allowable axial load, and should be recorded and retained as part of the installation documentation.

8-4.3.3.3 Centralizers. Installation of centralizers shall be completed if specified in the installation specification.

8-4.3.3.4 Terminations

(a) Upon exit at the termination end of the pull, a sufficient amount of the pipe system shall be pulled past the host pipe to allow for a 360-deg evaluation of the pipe to ensure the pull through the host pipe has not caused any damage that will affect the serviceability of the new pipe system, as well as to allow for the relaxation of the MRTPS.

(b) A 3-m (10-ft) trial MRTPS pipe segment may be pulled through the host pipe in advance of the actual MRTPS pull to verify the status of the host pipe and the feasibility of the liner pull.

(c) MRTPS shall be appropriately supported at the transition points from the host pipe to the soil to avoid shear loads and point loads.

8-4.4 Hydrostatic Test

(a) Test Fluid

(1) The test fluid shall be water unless there is the possibility of damage due to freezing or to adverse effects of water on the piping or the process. The selection of an alternative fluid shall consider flammability, toxicity, and chemical compatibility with the MRTPS, as well as the consequences of a pipe system failure during hydrotest.

(2) If hydrostatic testing would create an undesirable situation or risk of contamination, the owner may subject the piping system to a pneumatic leak test in lieu of the hydrostatic leak test. Where pneumatic tests are performed, consideration shall be given to the hazard of energy stored in compressed gas, and safety precautions shall be implemented as appropriate.

NOTE: ASME PCC-2, Part 5, Article 501 provides guidance for safe pneumatic testing.

(b) Test Pressure

(1) The hydrostatic test pressure at every point in the MRTPS shall be not less than 1.25 times the MAOP.

(2) The effects of the piping system elevation difference shall be taken into consideration when defining the test pressure.

(3) The resulting test pressure along the MRTPS shall not exceed the allowable test pressure stipulated in the standards of material specifications for the pertinent components of the piping system.

(c) Test Duration. The duration of the hydrostatic test pressure of the MRTPS, excluding the conditioning and stabilizing time, shall be a minimum of 8 h.

(d) Test Records

(1) A test record shall be completed of each MRTPS test and shall, at minimum, include the following:

(-a) identification of the piping system tested
(-b) date of test
(-c) test fluid
(-d) test pressure
(-e) test duration
(-f) test temperature
(-g) the pressure test chart
(-h) calibration certificates for testing equipment
(-i) minimum, maximum, and measurement location elevations
(-j) certification of results by the examiner

(2) Testing records shall be retained and stored in the project construction file.

8-5 EXAMINATION, INSPECTION, AND TESTING

Examination, inspection, and testing shall follow the MRTPS manufacturer's recommendations, in addition to the requirements of this Standard.

8-5.1 General

This section distinguishes between examination and inspection.

Examination applies to quality control functions performed by the MRTPS manufacturer, fabricator, or erector. Reference in this Standard to an examiner is to a person who performs quality control examinations.

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.

Inspection shall not relieve the MRTPS 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

8-5.2 Examination

8-5.2.1 Examination at the Manufacturer's Works. The manufacturer of the MRTPS components shall examine the manufactured components at the manufacturing location to ensure the components comply with the design, quality, and marking requirements of API 15S.

8-5.2.2 Examination at the Worksite

8-5.2.2.1 Examination of Incoming Material. The pipes, fittings, and accessories shall be examined prior to the use in the construction of the piping system to ensure the correct material has been delivered and no damage has occurred during transportation and handling. Any damaged items shall be replaced.

8-5.2.2.2 In-Process Examination

(a) The erection activities shall be examined to ensure the piping system is installed in accordance with the design specifications and in such a way as to avoid any damage that may affect the long-term integrity of the piping system.

(b) Wherever the installation methodology allows, the following items, as a minimum, shall be examined during the piping system erection:

(1) pipes, fittings, and accessories to ensure no damage

(2) trench preparation as per the MRTPS manufacturer's recommendations

(3) pipe deployment to verify absence of kinks and damages

(4) joining of couplings and fittings

(5) application of corrosion-protective measures at metallic fittings, if applicable

8-5.2.2.3 Prehydrotest Examination. Upon completion of the erection activities, prior to backfilling and subsequent hydrostatic testing, the piping system shall be examined to ensure that

(a) no damage is present

(b) adequate support and restraint are provided for the MRTPS and adjoining equipment

Backfill shall be performed in a manner that does not damage the installed piping system.

8-5.3 Inspection

Inspection should be performed at each examination milestone outlined in para. 8-5.2. At a minimum, inspection should be performed at the following stages:

(a) completion of the piping system erection

(b) prior to backfilling of the piping system

(c) random checks during the hydrostatic testing of the piping system

8-5.4 Testing

8-5.4.1 Required Testing. After completion of the piping system erection and prior to operation, each piping system shall be hydrostatically tested as per para. 8-4.4 to ensure tightness.

8-5.4.2 Limits of Tested Piping

(a) Equipment not included in the scope of the hydrostatic test shall be either disconnected from the piping system or isolated by blinds or other means during the test. A valve may be used provided the valve (including its closure mechanism) is suitable for the test pressure.

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

(c) 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 leak tested.

8-5.4.3 Preparation for Hydrostatic Testing. Prior to the hydrostatic testing, MRTPS intended for buried applications shall be covered with soil, with the joints left exposed.

MANDATORY APPENDIX I FUSING AND ELECTROFUSING OF POLYAMIDE-11 THERMOPLASTIC PIPING; AND FUSING OF POLYPROPYLENE, POLY(VINYLIDENE FLUORIDE), AND POLY(TETRAFLUOROETHYLENE) 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 fluoride) (PVDF), and poly(tetrafluoroethylene) (PTFE). 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 or PTFE liners of lined steel pipe. This Appendix provides requirements for joining these material types.

NOTES:
(1) The fusion joining of PTFE liners is accomplished by the use of a perfluoroalkoxy alkane (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 electrofusing of PA-11 thermoplastic materials, and PP, PVDF, and PTFE liners of lined steel pipe, and to the performance qualification of the fusing operator joining 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 a 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 electrofusing of PA-11 and the fusing of PP, PVDF,and PTFE liners is provided in paras. 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 provided 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, I-8-2, and I-8-3.

I-4.2 Approval Tests

(a) The approved tests for qualifying a JPS are listed in section I-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 employer's 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 electrofusing 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 electrofusing

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

(c) performance of fusing or electrofusing

(d) recording of the essential variables used in the fusing or electrofusing 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 in (a) through (d).

(a) The fusion of a DN 50 (NPS 2) PA-11 pipe qualifies a fusing operator to fuse DN 13 to DN 100 (NPS $\frac{1}{2}$ to NPS 4) PA-11 pipe.

(b) The fusion of a DN 150 (NPS 6) PA-11 pipe qualifies a fusing operator to fuse DN 100 to DN 200 (NPS 4 to NPS 8) PA-11 pipe.

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

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

I-6.2 Electrofusion Test Specimens

The limits of electrofusion test specimens are as provided in (a) and (b).

(a) The qualified joining of a DN 50 (NPS 2) PA-11 electrofusion coupling qualifies a fusing operator to join DN 13 to DN 100 (NPS $\frac{1}{2}$ to NPS 4) PA-11 couplings.

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

I-7 TEST METHODS REQUIRED FOR PROCEDURE QUALIFICATION

I-7.1 Visual Examination

(a) All fused joints or electrofused 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 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 Couplings

(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 ASME SF-1733).

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

This test shall be conducted using the requirements in ASTM D1598. 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 h without failure.

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

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

(2) The sustained pressure shall be a pipe fiber stress of 1.0 MPa (1,450 psi).

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

(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, using the requirements from ASME SF-2600.

(a) Four samples shall be selected at random.

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

(c) The minimum hydraulic burst pressure shall not be less than that required to produce 26.9-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 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 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 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 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) The tensile test shall be made on the specimen as joined.

(c) Results shall be reported as required in ASTM D638.

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.

(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–strain 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 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 be installed on the fusion-joined lined steel sample sections that are to be hydrostatically tested.

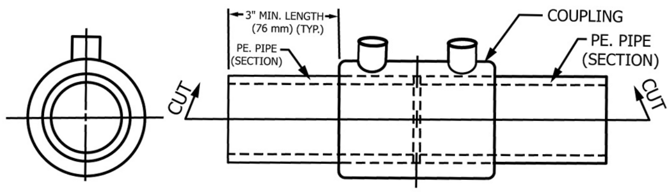
I-7.6.4 Fusion-Joined Lined Steel Pipe Samples

(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 3.103 MPa (450 psig) for a minimum of 10 min per the requirements of ASME B31.3, para. A345.4.

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

Figure I-7.7-1 Instruction on Preparing and Cutting Electrofusion Coupling for Crush Test



GENERAL NOTE: Figure from ASTM F1055. Used with permission of ASTM International, West Conshohocken, PA.

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-7.7-1 shows a half coupling.

(c) Instructions for specimen preparation are provided in 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.

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 Figure I-7.8-1) as described in ASME SF-2600, and the results shall be 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.

I-7.9 Saddle-Type Joint Crush Test

Electrofusion saddles shall be tested using a saddle-type joint crush test as described in ASME SF-2600, and the results shall be reported as required in 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 [2 944 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):

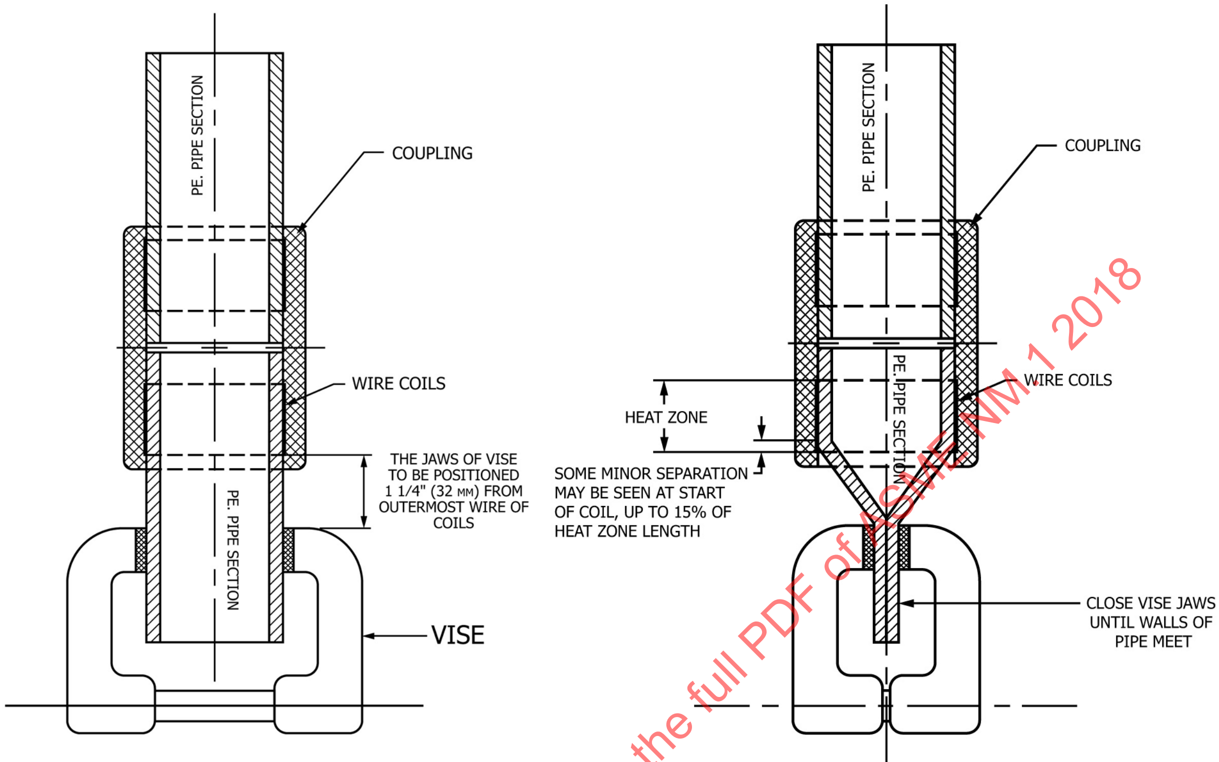
$$P_T = 1.5PS_T/S \tag{I-7-1}$$

where

P = internal design gauge pressure, kPa (psig)
P_T = minimum test gauge pressure, kPa (psig)
S = allowable stress at component design temperature for the prevalent pipe material, kPa (psi); see ASME B31.3, Tables A-1 and A-1M
S_T = allowable stress at test temperature for the prevalent pipe material, kPa (psi); see ASME B31.3, Tables A-1 and A-1M

(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, Tables A-1 and A-1M. 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.

Figure I-7.8-1 Joint Crush Specimens in Vise



GENERAL NOTE: Figure from ASTM F1055. Used with permission of ASTM International, West Conshohocken, PA.

If the test pressure as defined in (b) 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 electrofusing 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.

I-8.1 Heater Removal Time

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

Pipe Wall Thickness, mm (in.)	Maximum Heater Removal Time, s [Note (1)]
1 to <9 (0.18 to <0.40)	8
9 to <15 (0.40 to <0.60)	10
15 to 31 (0.60 to 1.20)	15

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

Table I-8-1 Essential Variables for Heat-Fusing JPS for PA-11

Description of Variable	Essential	Nonessential
Joint type: butt fusion	X	...
Pipe surface alignment	X	...
Material	X	...
Wall thickness	X	...
Cross-sectional area	X	...
Position	X	...
Heater surface temperature	X	...
Interfacial pressure	X	...
Bead size as specified	X	...
Bead appearance	...	X
Open time between heater removal and welding	X	...
Cooldown time	X	...
Fusing equipment manufacturer	...	X

I-8.1.2 Butt-Fusion Welding of PP, PVDF, and PTFE Liners. The following table provides the maximum heater removal times that shall be used for butt-fusion welding of 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 bringing together 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-8.2-1.

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.

Table I-8-2 Essential Variables for Electrofusion JPS for PA-11 Electrofusion Couplings

Description of Variable	Essential	Nonessential
Joint type [Note (1)]		
Coupling	X	...
Saddle	X	...
Fit-up gap	X	...
Material	X	...
Wall thickness	...	X
Coupling or saddle manufacturer	X	...
Pipe diameter	X	...
Cooldown time	X	...
Fusion voltage	X	...
Fusing time	X	...
Material temperature range	X	...
Power supply	...	X
Power cord	X	...
Processor	...	X
Saddle clamp	X	...
Cleaning agent	...	X
Scraping device	X	...

NOTE: (1) There are electrofusion couplings to join pipe to pipe and electrofusion saddles for branch connections.

(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 $^1/_{16}$)
>40 to <90 (>1.25 to <3)	3 to <5 ($^1/_8$ to <$^5/_{16}$)
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 $^5/_{32}$)

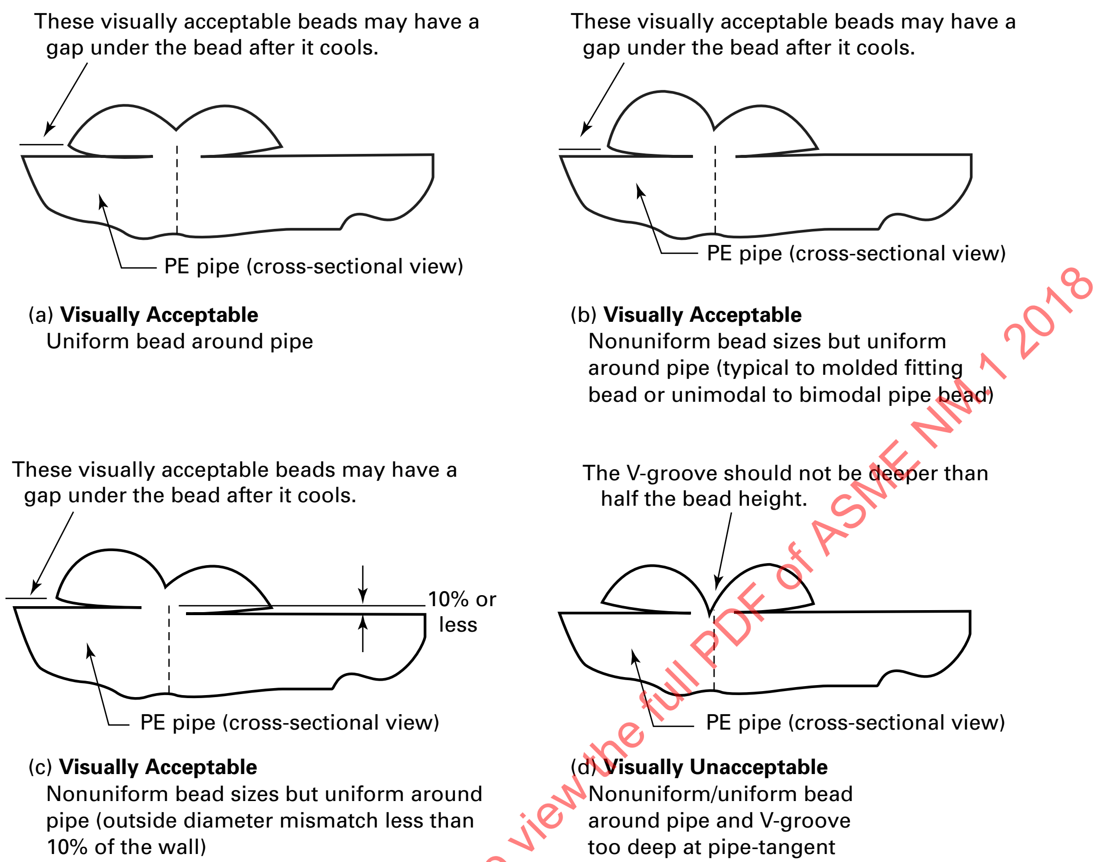
GENERAL NOTES:
(a) There is no bead formed when PTFE liners are butt fused together with a PFA film interface.
(b) The dimensions in this table refer to bead size on the liner after fusion.

Table I-8-3 Essential Variables for Heat Fusion JPS for 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 onionskin-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

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

Figure I-8.2-1 Polyethylene Pipe Butt-Fusion Joint O.D. Bead (Cross-Sectional View)



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 liner joints shall meet the size criteria shown in 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

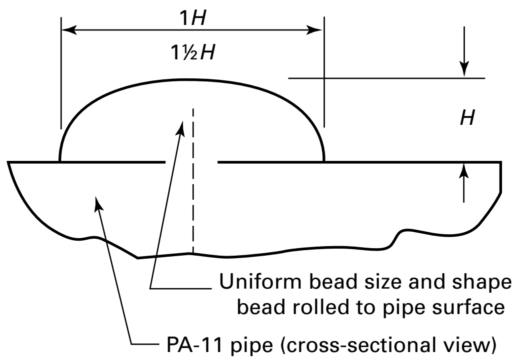
The essential variables for butt fusion of PA-11 plastic piping are discussed in para. I-9.1; those for electrofusion of PA-11, in para. I-9.2; and those for butt fusion of PP, PVDF, and PTFE/PFA pipe and fitting liners, in para. I-9.3.

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

The PA-11 fusion joint shall be made by heating the ends of PA-11 pipe as described in the JPS.

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

Figure I-9.1-1 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.

(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 ASME SD-6779.

(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 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°F 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-8.2.1(a). See also Figure I-9.1-1.

NOTES:

(1) This bead-size data is provided in PPI TR-45.

(2) The shape of the bead is different from that for PE pipe.

(h) Cooldown Time. Cooldown time for a PA-11 butt fusion shall be 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 Figure I-9.2-1. 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:

(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-9.2-2.

(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 ASME SD-6779.

(c) Coupling or Saddle Manufacturer. Each manufacturer uses its own distinct processes to make its electrofusion couplings or saddles. While the bar code on the coupling or saddle automatically sets the electrofusion processor, the tolerance of the pipe that the coupling or saddle can join or can be attached to may vary.

(d) Pipe Diameter. Different couplings or saddles shall be used for each pipe size.

(e) Cooldown Time. The coupling shall be allowed to cool down per the recommendations of the electrofusion coupling or saddle manufacturer.

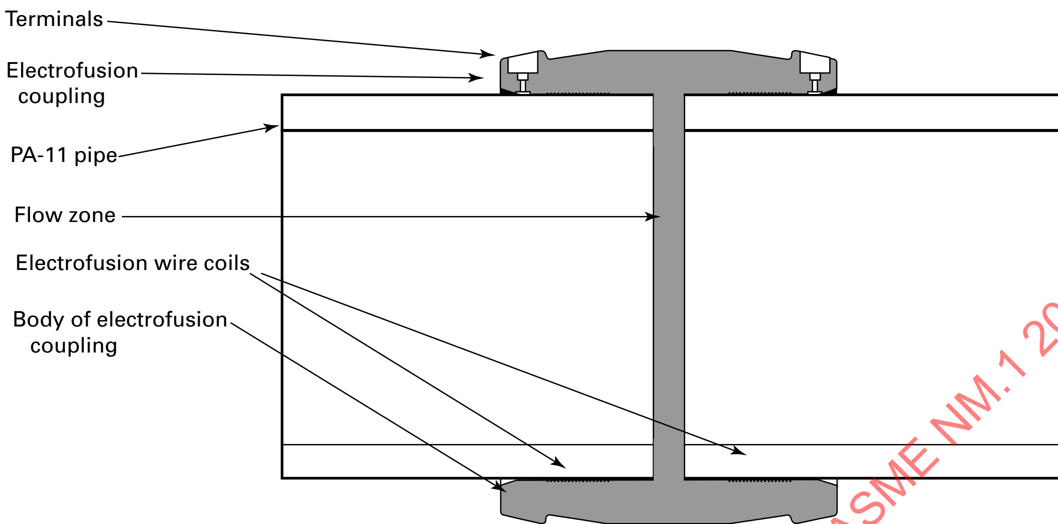
NOTE: Differences in the thickness or the amount of heat used in the joining process can influence the time needed for cooling.

(f) Fusion Voltage. The fusion voltage may be set by the bar code on the fitting or may be set manually. The recommended voltage for the specific electrofusion component shall be used.

(g) Fusing Time. The fusing time may be set by the bar code on the coupling or saddle or may be set manually.

(h) Power Supply. Either a portable generator or an electric wall plug may be used to supply power to the electrofusion processor provided the generator or plug satisfies the processor's specified voltage and amperage requirements.

Figure I-9.2-1 Cross-Sectional View of an Electrofusion Coupling



GENERAL NOTE: Figure is adapted with permission from PPI MAB-02 [MAB-02-2017; Generic Electrofusion Procedure for Field Joining of 14 Inch to 30 Inch Polyethylene (PE) Pipe, page 50, Appendix H].

(i) Power Cord. A power cord with the correct gauge wire to meet the voltage and amperage requirements of the electrofusion processor shall be used.

(j) Processor. Electrofusion processors are interchangeable as long as they can read the bar code for the electrofusion component.

(k) Saddle Clamps. Electrofusion saddles are available in a variety of types and sizes, and the clamping device for each is unique. The saddle clamp used shall be specific to the electrofusion saddle used.

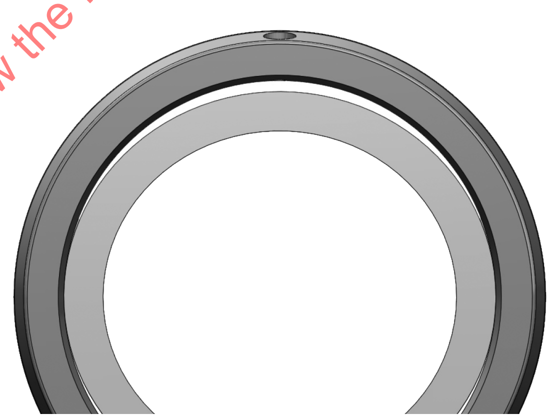
(l) Cleaning Agent. Though the cleaning agent is a nonessential variable, a clean pipe surface is essential to electrofusion. Various cleaning agents are available for preparing pipe surfaces for electrofusion; the cleaning agent recommended by the electrofusion coupling manufacturer should be used.

(m) Scraping Device. The dimensional requirements needed to make a good electrofusion joint are critical. The purpose of the scraping device is to remove the oxidation layer from the pipe surface and expose virgin material for fusion. Use of the scraping device ensures uniform removal of surface oxidation.

I-9.3 Essential Variables for Butt Fusing of PP, PVDF, and PTFE/PFA Pipe and Fitting Liners

Butt fusing of PP, PVDF, and PTFE/PFA pipe and fitting liners is limited to pipes with a maximum nominal liner size of 100 mm (4 in.). The essential variables are as follows:

Figure I-9.2-2 Fit-Up Gap



GENERAL NOTE: Figure is adapted with permission from PPI MAB-02 [MAB-02-2017; Generic Electrofusion Procedure for Field Joining of 14 Inch to 30 Inch Polyethylene (PE) Pipe, page 56, Appendix H].

(a) Warming the Steel Pipe Ends. If ambient outside temperatures are below 7°C (45°F), the steel pipe ends should be warmed before making the liner fusion joint, since the steel ends can act as a heat sink and remove heat from the fusing during the joining process. A hot air gun warm to the touch [23°C (73°F) or higher] should be used to warm the steel ends.

(b) Installation of a Shelter to Protect the Fusing Area. Fusion joining performed in an open plant environment shall be protected by a shelter or other means such that

Table I-9.3-1 Steel Pipe Liner Thickness for PP, PVDF, and PTFE/PFA Liners

DN (NPS)	PP and PVDF Liner Thickness, mm (in.)	PTFE/PFA Liner Thickness, mm (in.)
25 (1)	3.8 (0.150)	3.3 (0.130)
40 (1.5)	4.1 (0.160)	3.3 (0.130)
50 (2)	4.4 (0.172)	3.3 (0.130)
75 (3)	4.4 (0.175)	3.3 (0.130)
100 (4)	5.3 (0.207)	4.1 (0.160)

GENERAL NOTE: The same liner thickness is used for 25-mm to 75-mm PTFE liners.

rain, sleet, snow, dust, and other foreign materials cannot contaminate the fusion joint.

NOTE: A shelter constructed of PE film or other similar film (onionskin) may be used to provide a clean atmosphere. Failure to do so can result in fusion welds that leak.

(c) Fusing Equipment Manufacturer. The manual or hydraulic fusing machine used to fuse plastic-lined steel piping shall use custom die inserts. The inserts shall attach firmly to the housing.

Each fusing equipment manufacturer provides die inserts unique to its equipment. Inserts are not interchangeable between manufacturers in most cases.

The fusing machine shall meet the following requirements:

(1) The heater's electronic temperature-control system shall be capable of holding the temperature tolerances required for the thermoplastic liner to be fused.

(2) The thermometer and temperature controller shall be calibrated to have a temperature range as required for the thermoplastic liner to be fused.

(3) If a hydraulic machine is used, it shall have a calibrated hydraulic gauge. The range for the gauge shall cover the pressure required for the thermoplastic to be fused.

(d) Pipe Surface and Wall Thickness Alignment. The maximum misalignment of the PP, PVDF, or PTFE/PFA pipe liners shall be <5% of the published plastic liner wall thickness (see Table I-9.3-1).

NOTE: The alignment of the thermoplastic liner is important. This alignment shall be checked before inserting the heater plate.

(e) Material

(1) Only PP liners shall be fused to PP liners, PVDF to PVDF, and PTFE to PTFE with the PFA film interface.

(2) Plastic liners shall conform to the following requirements:

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

(-b) PVDF copolymer per ASME SD-5575

(-c) PTFE (ram-extruded pipe liner) per ASME SD-4894, Type V; and PTFE fittings (isostatically molded liner) per 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 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.

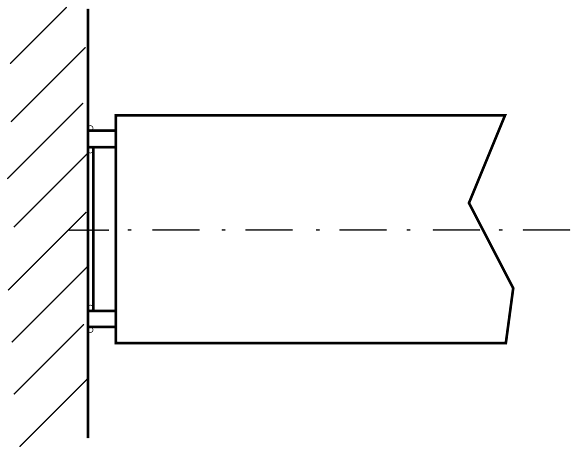
(h) Initial PP and PVDF Bead Size in Contact With the Heater Plate. A small, uniform 2-mm ($^{1}/_{16}$-in.) diameter bead shall be formed all the way around each PP or PVDF liner end. A uniform bead indicates that there is a positive contact with the heater plate (see Figure I-9.3-1).

(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.

(i) Initial Interfacial Pressure of the PTFE Liner Against the PFA Film Next to the Heater Plate. For the first 30 s when heating the PTFE liner ends to make 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 sandwiched

Figure I-9.3-1 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.

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: 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 bringing together 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-8.2.1(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 tensile strength. Applying too little weld-forming pressure will produce a too-small bead size, resulting in a weld with poor tensile strength.
(3) For hydraulic machines, use the interfacial pressure recommended by the manufacturer of the thermoplastic-lined pipe for the type of material, wall thickness, and diameter.

(2) For making a PTFE liner fusion weld, the fusion operator shall apply enough even contact pressure to bring the liner ends together such that the weld region rises outward about 2 mm ($^1/_{16}$ in.).

NOTE: Applying too much contact pressure will result in a V-shaped weld that is susceptible to a peel failure mode. Applying too little contact pressure, where there is no perceptible outward movement of the PTFE weld region, will result in a weld with low tensile strength.

(m) Proper Cooldown Time for the PP, PVDF, and PTFE Liner Fusion Welds. The fusion operator shall allow the fusion-welded liners to cool 10 min to 15 min before removing the fusion machine.

(n) Recording of Essential Variables

(1) All essential variables shall be recorded in the Fusion Weld Log or using a fusing log and a data logger. This applies to all liners listed in Mandatory Appendix I.

(2) The parameters to be verified shall be recorded.

I-10 JOINING PROCEDURE SPECIFICATION

I-10.1 Joining Procedure Specification (JPS) or Standard Joining Procedure Specification (SJPS)

Any JPS or SJPS shall be qualified in accordance with the requirements in section I-10.

(a) Published data as provided in PPI TR-45 for elevated temperature and sustained pressure may be used to satisfy the requirements in section I-10. Manufacturer's testing data may be used if verified by a third party.

(b) An SJPS shall be qualified using published data or manufacturer's data.

I-10.2 International Procedure Qualification

(a) International Joining Procedure Specifications shall be qualified using one of the following equivalent test methods:

(1) EN 12814-7

(2) ISO 13953

One of these test methods may be used in place of high-speed tensile impact testing.

The acceptance criteria for EN 12814-7 or ISO 13953 shall be the achievement of 0.8 welding factor or higher and a ductile rupture.

(b) A visual examination and elevated-temperature test are required. The requirements for these tests are as follows:

(1) Visual examination in accordance with the requirements of EN 13100-1.

(2) An elevated-temperature sustained-pressure test shall be used as described in PPI TR-45.

(3) In place of the elevated-temperature sustained-pressure test, the manufacturer of the pipe or of the resin may 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 SJPS 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 an 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 I-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 an SJPS beyond the limits specified in Table I-8-1, Table I-8-2, or Table I-8-3 shall require the qualification of a new JPS.

I-11 QUALIFICATION OF A FUSING JPS

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 12814-3) by prior testing (see para. I-7.4.1).

(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-7.5 or as required in EN 12814-7 or ISO 13953. The specimen shall be ductile and have a welding factor of 0.8 or higher.

I-11.2 Coupons for Acceptance of the JPS

If the coupons described in para. I-11.1 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 JPS

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 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 ASME SF-2600. There shall be no failures in a 170-h test period.

(c) Four electrofusion couplings selected at random shall be tested using the tensile test described in 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.

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

(d) A joint integrity test shall be conducted on four electrofusion couplings and four electrofusion saddles as described in 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.

(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 ASME SF-2600 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 from the same manufacturer as that used in the field.

NOTE: An automated data logger or manual record of the fusing parameters used to make the test specimen shall be provided 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 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 (b) 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 the 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 testing 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. 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 a 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

(c) The supervisor shall be trained to the requirements of paras. I-13.2.1(b) through I-13.2.1(d). The trained supervisor shall supervise the testing.

I-13.2.4 Acceptance of Test Results

(a) Acceptance of test results shall be the 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 the 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 or 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 retake 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 6 months, his or her qualifications for this process shall be considered expired.

(2) A fusing operator whose qualification expires as a result of (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 (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.

I-13.4 Requirements for Performance Qualification Tests

This section lists the essential variables that apply to fusing machine operator performance qualifications. The fusing operator qualification is limited by the essential variables given for the fusing process. These variables are listed in Tables I-8-1, I-8-2, and I-8-3.

I-13.4.1 Intent of Tests. The fusing operator performance qualification tests shall determine the ability of fusing operators to make sound fused joints when following a qualified JPS or SJPS.

I-13.4.2 Use of Procedure Specifications in Qualification Tests

(a) Each organization shall qualify each fusing operator for the fusing process to be used in production.

(b) The performance qualification tests shall be completed using a qualified JPS.

(c) A fusing operator qualified for fusing in accordance with a qualified JPS or SJPS shall be qualified for fusing in accordance with other qualified JPSs or SJPSs within the limits of the fusing operator essential performance variables. The fusing operator shall pass visual and mechanical examination requirements described in para. I-13.4.6.1. Procedures for renewal of qualifications are given in para. I-13.3.

(d) The fusing operator responsible for fusing JPS qualification test coupons for qualifying the JPS shall be also qualified as a fusing operator within the limits of the essential performance qualification variables given in

(1) para. I-9.1 for PA-11 butt fusion

(2) para. I-9.2 for electrofusion

(3) para. I-9.3 for fusion welding of PP, PVDF, and PTFE liners

I-13.4.3 Identification of Fusing Machine Operators. Each qualified fusing operator shall be assigned an identifying number, letter, or symbol by the organization that shall be used to identify production fused joints completed by the fusing operator (see para. I-13.2.3). The identification of Fusing Machine Operators shall be applied as follows:

(a) PA-11 fusing operators shall identify the butt-fusion weld on the PA-11 pipe or fusion joint.

(b) Lined-pipe fusing operators shall mark the steel pipe once the mechanical coupling has been installed.

I-13.4.4 Record of Tests. The record of the fusing operator's joining performance qualification tests shall include

(a) the qualified ranges of essential performance variables

(b) the type of tests performed

(c) test results for each fusing operator

I-13.4.5 Fusing Machine Operator Qualification Records Required for Butt-Fusion Joining

(a) Butt-Fusion Joint for Evaluation

(1) The following data shall be recorded:

(-a) interfacial fusing pressure within the JPS or SJPS range.

(-b) heater surface temperature within the JPS or SJPS range.

(-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 SJPS. 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 in (1), for PA-11, documentation of the essential variables listed in Table I-8-1 shall be noted. The additional data listed in (1) 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 Tables I-8-1 and 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. Fusion beads shall exhibit proper fused bead configuration. See Figure I-9.1-1 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 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-8.2-1 for 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 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 ASME SF-2600):

(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 ASME SF-2600).

NOTE: With the owner's approval, NDE can be used as an alternative to using sectioned electrofusion joints.

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).

(b) The hydrostatic test pressure at any point in the thermoplastic-lined metallic piping system shall not be less than 1.5 times the design pressure, but shall not

exceed 1.5 times the maximum rated pressure of the lowest rated component in the system.

(c) The test shall be conducted for a minimum of 10 min.

I-13.4.7.3 Performance Test for Electrofusion. One electrofusion coupon shall be prepared, on which either of the following tests may be performed at ambient temperature between 16°C and 27°C (60°F and 80°F):

(a) Electrofusion Bend Test. Four electrofusion bend test specimens shall be removed in accordance with ASME SF-2600.

(b) Crush Test. Test specimens shall be prepared and tested in accordance with ASME SF-2600.

I-13.4.8 Requalification. After 1 yr, a fusing operator shall be requalified by passing the required written test and performance test.

(a) The butt-fusion and electrofusion performance tests shall be conducted for the size or size range to be qualified.

(1) One butt-fusion joint or electrofusion coupling shall be made of the size or range to be qualified. When a size range is to be qualified, the smallest size and largest size shall be tested.

(2) When more than one size pipe is qualified, more than one butt-fusion machine may be required. For electrofusion, the same equipment is used to qualify the smallest size and the largest size to be tested.

NOTE: If a butt-fusion joint of only one size is required on a butt-fusion machine, the joint shall be made on the manufacturer's machine to be used in the field.

(3) The performance test shall include making one butt-fused joint. The joint shall be inspected and destructively tested.

(4) The results of the test shall demonstrate an acceptable joint.

(5) The performance tests are detailed in the following paragraphs:

(-a) for fusing PA-11, para. I-13.4.7.1

(-b) for fusing liners, para. I-13.4.7.2

(-c) for electrofusion, para. I-13.4.7.3

(b) The requirements for passing the written test are in para. I-13.2.1.

MANDATORY APPENDIX II THREADED THERMOPLASTIC CONNECTIONS

II-1 SCOPE

This Appendix provides information for threaded thermoplastic components manufactured in accordance with existing ASME standards.

Manufactured threaded thermoplastic components for which no 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 ASME standards and those not manufactured to 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 thermoplastics, 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-1.3-1.

II-1.4 Temperature Limitations

The temperature range of the application shall be reviewed 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 or as 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.

(3) The taper shall be compatible for each male and female size component.

(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 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 1 379 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 by 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 ASME SD-2464 or ASME SD-2467.

(4) Molded CPVC threaded adapters shall meet the requirements of ASME SF-437.

(5) Molded threaded adapters shall be tested as required in the applicable specification [see (2) and (3)]. 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-1.3-1.

(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 specified by the 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 (and shall be identified as not conforming to ASME NM.3.1).

(3) The design engineer shall specify the requirements for molded threaded 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 Table II-2.5.2-1 for materials with an ASME standard or if the pipe material complies with an ASME specification; if there is no 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

Table II-1.3-1 Pressure Ratings for Molded PVC and CPVC Threaded Adapters

Nominal Pipe Size, DN (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)
		PVC Sch. 80/CPVC Sch. 80	2 930.27 (425)
19 (0.75)	26.670 (1.050)	PVC Sch. 40	1 654.74 (240)
		PVC Sch. 80/CPVC Sch. 80	2 378.69 (345)
25 (1.00)	33.401 (1.315)	PVC Sch. 40	1 551.32 (225)
		PVC Sch. 80/CPVC Sch. 80	2 171.85 (315)
32 (1.25)	42.164 (1.660)	PVC Sch. 40	1 275.53 (185)
		PVC Sch. 80/CPVC Sch. 80	1 792.64 (260)
38 (1.50)	48.260 (1.900)	PVC Sch. 40	1 137.63 (165)
		PVC Sch. 80/CPVC Sch. 80	1 620.27 (235)
51 (2.00)	60.325 (2.375)	PVC Sch. 40	925.27 (140)
		PVC Sch. 80/CPVC Sch. 80	1 378.95 (200)
76 (3.00)	88.900 (3.500)	PVC Sch. 40	896.32 (130)
		PVC Sch. 80/CPVC Sch. 80	1 275.53 (185)
102 (4.00)	114.300 (4.500)	PVC Sch. 40	758.42 (110)
		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.

Table II-2.5.2-1 Pressure Ratings for PVC and CPVC Field-Threaded Pipe Ends

Nominal Pipe Size, DN (NPS)	Actual Pipe Size, mm (in.)	Type of Threaded Pipe Ends	Pressure–Temperature Rating, kPa (psi) at 23°C (73°F) [Note(1)]	
			Before Threading	Threaded Pipe End
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 temperatures higher than ratings.

together and the resulting assembly tested for joint tightness using ASME SF-1970, 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.

See Table II-2.5.2-1 for pressure rating of molded PVC and CPVC field-threaded pipe.

(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 paras. II-2.5.2(a)(4) and II-2.5.2(b)(4) and that verifies the following:

(1) The threaded connections are being used only in approved applications.

(2) Thermoplastic threads conform to ASTM F1498. Metallic threads to be used with thermoplastic components conform to ASME B1.20.1. Threads other than those conforming to this paragraph may be used; if such 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 adapters 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.

(b) For other thermoplastics (ABS, PP, and PVDF), the design engineer shall provide the tests needed. In addition to the details in (a), the design engineer's test report shall include the following:

(1) a description of the thermoplastic material

(2) a description of the thermoplastic threaded form

(3) a description of each test (including duration and pressure)

(4) a statement indicating whether there was leakage or breakage

(c) The test report shall be retained as required by the design engineer for all phases of the project.

MANDATORY APPENDIX III
ACCEPTANCE CRITERIA FOR THERMOPLASTIC JOINTS

III-1 SCOPE

The requirements in this Appendix apply to visual inspection for acceptance or rejection of HDPE butt-fusion joints and PVC/CPVC solvent-welded joints.

III-2 POLYETHYLENE (HDPE) BUTT-FUSED JOINTS

Butt-fused joints shall meet the following:

(a) Fused butt joints shall exhibit proper fusion bead configuration. Figure I-8.2-1 in Mandatory Appendix I depicts acceptable and unacceptable thermally fused bead configurations.

(b) There shall be no evidence of cracks or incomplete fusion.

(c) Fusion joints, except for miter joints, shall not be visually angled or offset >3 deg. The O.D. mismatch shall be less than 10% of the nominal wall thickness.

(d) The cleavage between fusion beads shall not extend to or below the O.D. pipe surface (see Figure I-8.2-1 in Mandatory Appendix I).

(e) When available from the equipment used to monitor hydraulic and thermal variables, the data acquisition record for the fused joint may be compared with the FPS to verify that parameters and procedures were followed in making the fused joint. This provision may become mandatory when specified.

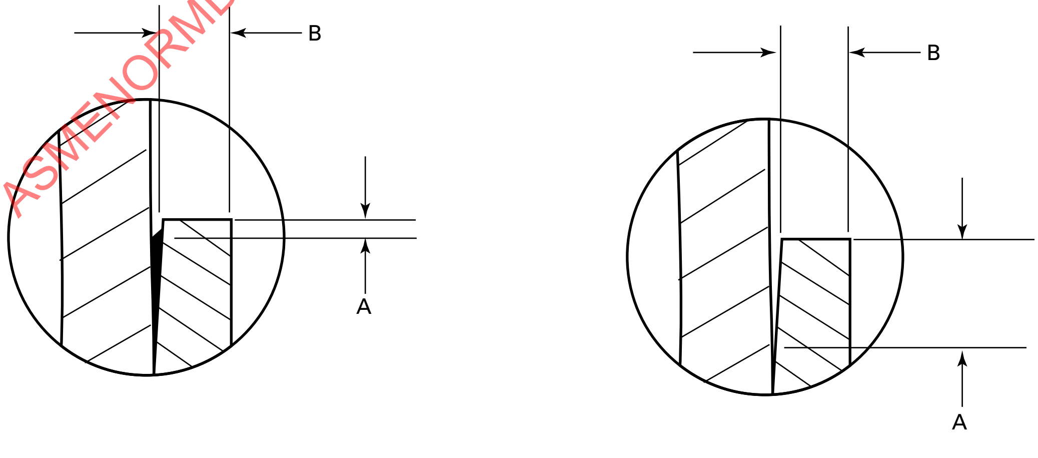
III-3 PVC AND CPVC SOLVENT-CEMENT-WELDED JOINTS

Solvent-cement-welded joints shall meet the following:

(a) As a result of the solvent-welding process, a bead of solvent cement can sometimes be found at the socket entrance. Excessive cement will slow the cure time, and the bead should be removed immediately after the solvent-welding process, while the cement is still wet.

(b) In cases where a cement bead did not form at the socket entrance, there is a possibility for the cement to shrink back down into the socket. If shrink-back is observed at the socket entrance, then the depth of the pocket ("A" in Figure III-3-1) shall not be greater than the thickness of the socket wall ("B" in Figure III-3-1).

Figure III-3-1 Solvent-Cement-Weld Shrink-Back Appearance (Cross-Sectional View)



(a) Acceptable: A ≤ B **(b) Unacceptable: A > B**

MANDATORY APPENDIX IV
STRESS INTENSIFICATION FACTORS AND FLEXIBILITY FACTORS

Table IV-1 begins on the following page.

Table IV-1 Stress Intensification Factors, *i*, and Flexibility Factors, *k*, for High-Density Polyethylene

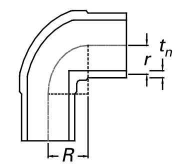
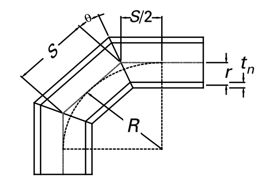
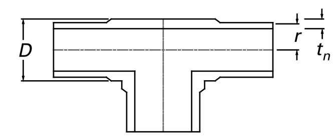
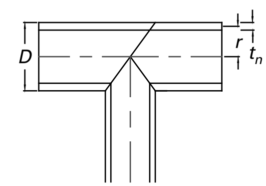
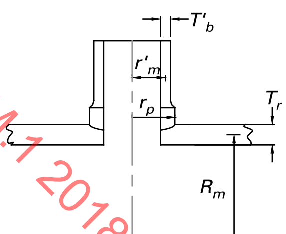
Description	Flexibility Characteristic, *h*	Flexibility Factor, *k* [Note (1)]	Stress Intensification Factor, *i* [Note (1)]	Sketch
Straight pipe	N/A	1.0	1.0	N/A
Butt-fusion joint	N/A	1.0	1.0	N/A
Molded elbow	$\frac{t_n R}{r^2}$	...	$\frac{1.25}{h^{2/3}}$	
Miter elbow $s \geq r(1 + \tan \theta)$ [Note (2)]	$\frac{(1+\cot\theta)}{\text{DR}-1}$ or $\frac{t_n(1+\cot\theta)}{2r}$	In-plane loading [Note (3)] $\frac{1.1}{h^{5/6}}$	$\frac{1.7}{h^{2/3}}$	 $R = \frac{s\cot\theta}{2}$
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 $\frac{8.8}{\text{DR}-1}$	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	$i_b = 1.74\left(\frac{R_m}{T_r}\right)^{2/3}\left(\frac{T'_b}{T_r}\right)\left(\frac{r'_m}{r_p}\right) \geq 1.5$ $i_r = 1.54\left(\frac{R_m}{T_r}\right)^{2/3}\left(\frac{r_p}{R_m}\right) \geq 1.5$	

Table IV-1 Stress Intensification Factors, *i*, and Flexibility Factors, *k*, for High-Density Polyethylene (Cont'd)

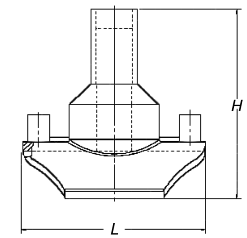
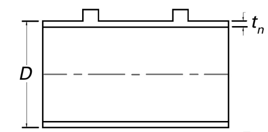
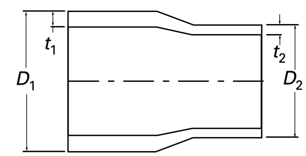
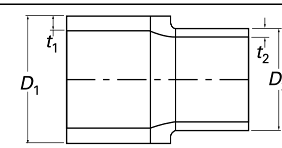
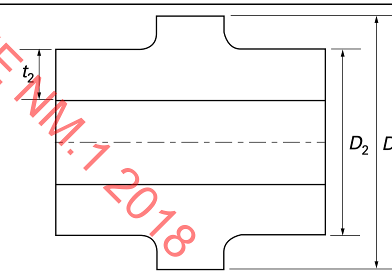
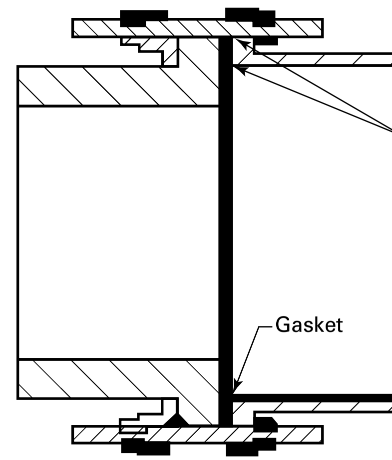
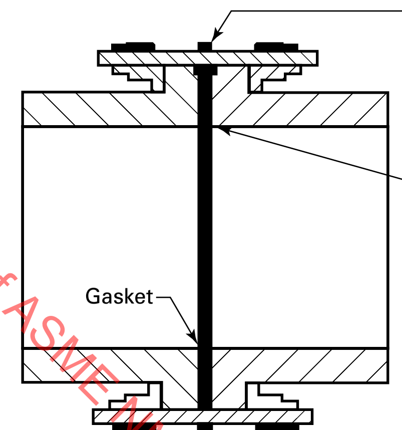
Description	Flexibility Characteristic, *h*	Flexibility Factor, *k* [Note (1)]	Stress Intensification Factor, *i* [Note (1)]	Sketch
Electrofusion saddle fitting [Note (6)]	N/A	1.0	1.0	
Electrofusion coupling	N/A	1.0	1.0	
Concentric monolithic reducers	N/A	1.0	$0.5 + 0.32\left(\frac{D_1}{D_2}\right)\left(\frac{D_2}{t_2}\right)^{1/2} \leq 2.5$	
Concentric fabricated reducers	N/A	1.0	$0.5 + 0.40\left(\frac{D_1}{D_2}\right)\left(\frac{D_2}{t_2}\right)^{1/2} \leq 3.0$	
Fabricated, machined, or molded thrust collar	N/A	1.0	$0.5 + 0.40\left(\frac{D_1}{D_2}\right)\left(\frac{D_2}{t_2}\right)^{1/2} \leq 3.0$	

Table IV-1 Stress Intensification Factors, *i*, and Flexibility Factors, *k*, for High-Density Polyethylene (Cont'd)

Description	Flexibility Characteristic, *h*	Flexibility Factor, *k* [Note (1)]	Stress Intensification Factor, *i* [Note (1)]	Sketch
Metallic-to-PE bolted flange connection	N/A	1.0	1.0	
HDPE-to-HDPE bolted flanged connections	N/A	1.0	1.0	

GENERAL NOTES:

(a) The following nomenclature applies to this Table only for use in determining stress indices, stress intensification factors, and flexibility factors:

D_1 = nominal O.D. of the larger side of a concentric fabricated reducer or the diameter of the thrust collar

D_2 = nominal O.D. of the smaller side of a concentric fabricated reducer or the nominal pipe diameter of a thrust collar

D_O = pipe O.D.

DR = pipe dimension ratio = D_o/T_n

Table IV-1 Stress Intensification Factors, *i*, and Flexibility Factors, *k*, for High-Density Polyethylene (Cont'd)

GENERAL NOTES: (Cont'd):

R = nominal bend radius of elbow or pipe bend, mm (in.)
r = mean radius of pipe, mm (in.) (matching pipe for elbows and tees)
S = miter spacing at centerline, mm (in.)
T_2 = nominal thickness of the smaller side of a concentric fabricated reducer or the nominal pipe thickness of a thrust collar
T_n = nominal wall thickness of pipe, mm (in.) (matching pipe for elbows and tees)
T_r = nominal wall thickness of run pipe, mm (in.)
θ = one-half angle between adjacent miter axes, deg

(b) All abutting piping fittings of differing DRs shall meet the requirements of Figure 2-3.2.4-1, illustration (a) or illustration (b), as applicable.

NOTES:

(1) The stress intensification factors, i, and the flexibility factors, k, shall not be taken as less than 1.0. They are applicable to moments in any plane for fittings except as noted.
(2) One-half miter angle, θ, shall be limited to ≤11.25 deg.
(3) The flexibility factor, k, is applicable only for in-plane bending moment loading.
(4) The tee thickness, t_n, shall be 1.4 times the pipe thickness, T_r ($1.4T_r$).
(5) The ratio OD_{branch}/OD_{run} shall be <0.4.
(6) The ratio OD_{branch}/OD_{run} shall be <0.6.

MANDATORY APPENDIX V
ONE-PIECE THERMOPLASTIC FLANGES

V-1 SCOPE

This Appendix covers one-piece thermoplastic flanges. These one-piece flanges shall be made from ABS, CPVC, PP, PVC, or PVDF thermoplastics. The joining methods that shall be used to join one-piece flanges to thermoplastic pipe are solvent-cement welding, heat fusion, or threaded connections.

NOTES:
(1) One-piece thermoplastic flanges are generally manufactured using injection molding or fabrication methods.
(2) One-piece thermoplastic flange connections are intended for use in systems normally conveying liquids. One-piece thermoplastic flanges specifically designed and manufactured for compressed-air or other compressed-gas applications may be used in compressed-gas applications.

V-1.1 Typical Drawings of One-Piece Thermoplastic Flanges

Figure V-1.1-1 shows a thermoplastic flange used for solvent-cement connections and socket connections made with heat.

V-1.2 Threaded Configuration

Figure V-1.2-1 shows threaded connections used with various thermoplastics.

V-2 DESIGN

The following loads shall be considered in determining the force needed to make a leak-free seal with a one-piece flange:

(a) hydraulic pressure
(b) surge pressure at the highest design flow
(c) thermal expansion and contractions
(d) bending forces
(e) misalignment of the flanges
(f) force specific to the application

V-2.1 Total Forces

(a) For calculation purposes, the following equation may be used to determine the total force:

$$\text{total force} = \text{WP}_{\text{fl}} + \text{SP}_{\text{fl}} + T_{\text{ex-con}} + B + F_a$$

where

B = bending stress, kPa (psi)
F_a = force applications specific forces (earthquake, vibration, etc.), kPa (psi)
F_{ma} = misalignment, kPa (psi)
SP_{fl} = surge pressure at the highest velocity, kPa (psi)
$T_{\text{ex-con}}$ = thermal expansion and contraction for the design operating temperature range, kPa (psi)
WP_{fl} = working pressure rating of the components, kPa (psi)

(b) The equation in (a) shall require modification based on characteristics of the specific thermoplastic material or application-related requirements.

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 ½ to NPS 24).

(b) Metric. Metric bolt circles may be used. Dimensions are provided in Nonmandatory Appendix A, Table A-2.1-2.

V-2.3 Reinforcing Rings

(a) Metallic or nonmetallic reinforcing rings may be used with one-piece thermoplastic flanges. See Figure V-2.3-1.

(b) The pressure rating of the one-piece flange shall not be increased when reinforcing rings are used.

Figure V-1.1-1 Socket Configuration

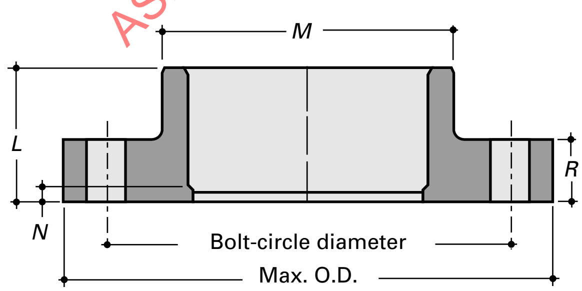
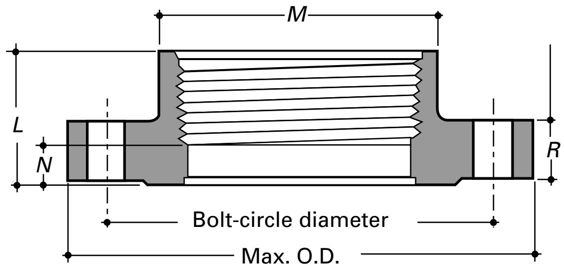


Figure V-1.2-1 Threaded Configuration



V-2.4 Washers

Washers shall be used between the nut or bolt head and the one-piece thermoplastic flange or reinforcing ring.

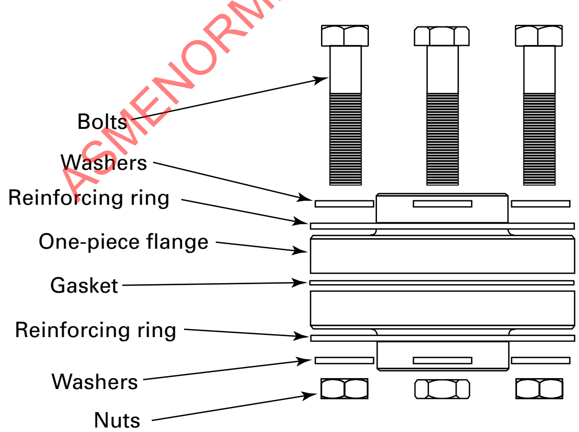
V-2.5 Stress Relaxation of Thermoplastics

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 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.

Figure V-2.3-1 One-Piece Thermoplastic Flange With Reinforcing Rings



GENERAL NOTE: Hex head bolts are shown above. Studs or hex head bolts may be used.

V-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:

Material	Types
ABS	N/A
CPVC	N/A
PP	Homopolymer, copolymer
PVC	N/A
PVDF	Homopolymer, copolymer

(b) Unlisted Materials. Unlisted thermoplastic materials may be approved for use by following the requirements in ASME NM.3.3, Mandatory Appendix III.

V-3.2 Testing Requirements

V-3.2.1 Testing. Testing shall be conducted following the requirements listed in ASTM D1598, with the following exceptions:

(a) The test pressure shall be 3.2 times the marked operating pressure for the one-piece flange.

(b) The test shall only be conducted for 5 min after reaching constant pressure.

(c) The report shall only contain information related to the above test. A plot showing pressure equalization and constant pressure is required. No calculations of hoop stress or plots of hoop stress are required.

V-3.2.2 Pressure Ratings

(a) General. The pressure rating of the one-piece flange shall be based on the standard dimension ratio (SDR) or dimension ratio (DR) or the Schedule of the components being used. The SDR, DR, or Schedule of flange adapter shall be determined using the highest temperature at which the piping system is expected to operate.

NOTE: The pressure rating of PVC and CPVC lap-joint flange connections shall be limited to 1 034 kPa (150 psi) for Schedule 80 unless otherwise rated higher by the manufacturer following the requirements of this Standard.

(b) Thermoplastic-Lined Metal Pipe. Connections of thermoplastic-lined metal pipe to one-piece flanges shall have the pressure rating of the component with the lower rating. This pressure rating shall be used to determine the proof-test pressure.

V-3.2.3 Gaskets. Gaskets, when used, shall be full face for flange adapters not made to metric designs. Metric designs shall follow the requirements in DVS 2210-1, Supplement 3.

V-3.2.4 Sampling. A sufficient quantity of flange connections as agreed on by the seller and purchaser shall be selected at random from each lot or shipment and tested to determine that the flange connections will pass the proof test.

V-3.2.5 One-Piece Flange Connection

(a) A one-piece flange connection is defined as containing a flange, a metallic or nonmetallic reinforcing ring, a gasket (if required), bolts, nuts, and washers, plus a joining method.

(b) The following identified joining methods for thermoplastic lap-joint flanges may be used:

(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 either on sealing forces plus expected stress relaxation or on gasket sealing stress plus expected stress relaxation.

(b) Bolt Lubrication and Friction-Reducing Coated Bolts

(1) When method (a)(1) or (a)(2) is 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 (1)(-a) or (1)(-b).

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 include dimensions as indicated below.

(a) If the one-piece flange is for socket joining, dimensions shall conform to 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 Mandatory Appendix II.

(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 for CPVC one-piece flanges shall include dimensions as indicated below.

(a) If the one-piece flange is for socket joining, dimensions shall conform to 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 Mandatory Appendix II.

(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 owner's 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 Mandatory Appendix II. For materials not listed in

Mandatory Appendix II, the manufacturer may provide equivalent test data and descriptive information.

(d) The bolt circle shall conform to ASME B16.5; or for metric-dimension flange standards, ISO 7005 or EN 1092-1 shall be used. Other bolt-circle 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 or PP pipe dimensions.

(b) If the one-piece flange is for threaded joining, the threads shall meet the requirements of Mandatory Appendix II. For materials not listed in Mandatory Appendix II, the manufacturer may provide equivalent test data and descriptive information.

(c) The bolt circle shall conform to ASME B16.5; or for metric-dimension flange standards, ISO 7005 or EN 1092 shall be used. Other bolt-circle dimensions may be used if required in the owner's design specifications.

(d) The O.D. and the I.D. of the flange face shall be provided.

V-4.5 ABS

Submittal information for ABS one-piece flanges shall be provided with dimensions as indicated below.

(a) If the one-piece flange is for female socket solvent welding, the dimensions shall conform to published socket dimensions.

(b) Pipe used for the male socket connection shall have an O.D. that conforms to published dimensions needed for socket solvent welding.

(c) If the one-piece flange is for female threaded connections, the threads shall meet the requirements of Mandatory Appendix II. For materials not listed in Mandatory Appendix II, the manufacturer may provide equivalent test data and descriptive information.

(d) The bolt circle shall conform to ASME B16.5; or for metric-dimension flange standards, ISO 7005 or EN 1092 shall be used. Other bolt-circle 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.

NONMANDATORY APPENDIX A
COMPONENTS FOR THERMOPLASTIC LAP-JOINT FLANGE CONNECTIONS

A-1 SCOPE

(a) This Appendix is limited to components for thermoplastic lap-joint flange (TLJF) connections (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 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 radii 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; 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 the following:

(1) ASME B16.5 Class 150 dimensions for nominal pipe sizes DN 15 to DN 600 (NPS $\frac{1}{2}$ 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

For metric sizes, the bolt circles shall be drilled to the dimensions in ISO 7005 and EN 1092.

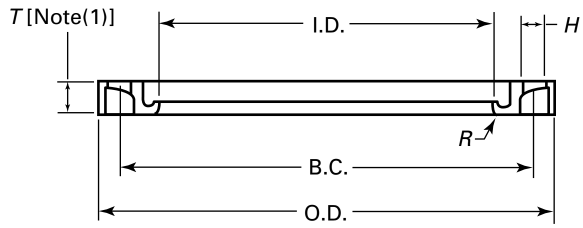
NOTE: When the user's design specification specifies bolt-circle and bolt-hole dimensions, these dimensions shall be made to conform to these requirements. The requirements of this Standard not related to dimensions shall be met.

(f) The backup ring's effective thickness shall be adequate to provide the initial and long-term seating stress for leak-free service. See test requirements in Table A-3-1.

(1) Thermoplastic components for fire lines shall pass Factory Mutual or National Fire Protection Association (NFPA) requirements in addition to the requirements in this Standard. When the requirements are the same, additional testing may be omitted.

(2) The backup ring shall have a chamfer or radius that approximately matches the crotch radius of the thermoplastic flange adapter when required.

Table A-2.1-1 NPS Backup Rings for Thermoplastic Pipe



Nominal Pipe Size	Pipe O.D., mm (in.)	Backup Ring O.D., mm (in.) [Note (2)]	Backup Ring I.D., mm (in.)	No. of Bolts	Bolt-Hole Size, *H*, mm (in.) [Note (2)]	Bolt Circle, B.C., mm (in.) [Note (2)]	Radius, *R*, mm (in.)
½	21.34 (0.84)	88.90 (3.50)	22.86 (0.90)	4	15.88 (0.625)	60.452 (2.38)	2.5 to 3.8 (0.1 to 0.15)
¾	26.67 (1.05)	98.55 (3.88)	28.19 (1.11)	4	15.88 (0.625)	69.85 (2.75)	2.5 to 3.8 (0.1 to 0.15)
1	33.40 (1.315)	107.95 (4.25)	35.05 (1.38)	4	15.88 (0.625)	79.502 (3.13)	2.5 to 3.8 (0.1 to 0.15)
1¼	42.16 (1.66)	117.60 (4.63)	43.69 (1.72)	4	15.88 (0.625)	88.9 (3.50)	2.5 to 5.0 (0.1 to 0.20)
1½	48.26 (1.90)	127.00 (5.00)	50.04 (1.97)	4	15.88 (0.625)	98.552 (3.88)	2.5 to 7.6 (0.1 to 0.30)
2	60.33 (2.375)	152.40 (6.00)	62.48 (2.46)	4	19.05 (0.75)	120.65 (4.75)	2.5 to 11.4 (0.1 to 0.45)
3	88.90 (3.50)	190.50 (7.50)	95.25 (3.75)	4	19.05 (0.75)	152.4 (6.00)	2.5 to 11.4 (0.1 to 0.45)
4	114.30 (4.50)	228.60 (9.00)	120.65 (4.75)	8	19.05 (0.75)	190.5 (7.50)	2.5 to 11.4 (0.1 to 0.45)
6	168.28 (6.625)	279.40 (11.00)	174.75 (6.88)	8	22.23 (0.875)	241.3 (9.50)	2.5 to 11.4 (0.1 to 0.45)
8	219.08 (8.625)	342.90 (13.50)	225.55 (8.88)	8	22.23 (0.875)	298.45 (11.75)	3.8 to 11.4 (0.15 to 0.45)
10	273.05 (10.75)	406.40 (16.00)	279.40 (11.00)	12	25.4 (1.00)	361.95 (14.25)	3.8 to 11.4 (0.15 to 0.45)
12	323.85 (12.75)	482.60 (19.00)	327.66 (12.90)	12	25.4 (1.00)	431.8 (17.00)	3.8 to 11.4 (0.15 to 0.45)
14	355.6 (14.00)	533.40 (21.00)	360.17 (14.18)	12	28.58 (1.125)	476.25 (18.75)	5 to 11.4 (0.2 to 0.45)
16	406.4 (16.00)	596.90 (23.5)	416.05 (16.38)	16	28.58 (1.125)	539.242 (21.23)	5 to 11.4 (0.2 to 0.45)
18	457.2 (18.00)	635.00 (25.00)	462.28 (18.20)	16	31.75 (1.25)	577.85 (22.75)	5 to 14 (0.2 to 0.55)
20	508 (20.00)	698.50 (27.50)	517.65 (20.38)	20	31.75 (1.25)	635 (25.00)	8 to 14 (0.3 to 0.55)
22	558.8 (22.00)	749.30 (29.50)	568.33 (22.375)	20	34.93 (1.375)	692.15 (27.25)	5 to 10 (0.2 to 0.40)
24	609.6 (24.00)	812.80 (32.00)	619.13 (24.375)	20	34.93 (1.375)	749.3 (29.50)	5 to 10 (0.2 to 0.40)
28	711.2 (28.00)	927.10 (36.50)	720.85 (28.38)	28	34.93 (1.375)	863.6 (34.00)	5 to 13 (0.2 to 0.50)
30	762 (30.00)	984.25 (38.75)	771.65 (30.38)	28	34.93 (1.375)	914.4 (36.00)	3.8 to 13 (0.15 to 0.50)
32	812.8 (32.00)	1 060.45 (41.75)	822.45 (32.38)	28	41.4 (1.63)	977.9 (38.50)	3.8 to 14 (0.15 to 0.55)
36	914.4 (36.00)	1 168.40 (46.00)	924.05 (36.38)	32	41.4 (1.63)	1 085.85 (42.75)	3.8 to 10 (0.15 to 0.40)
42	1 066.8 (42.00)	1 346.20 (53.00)	1 076.45 (42.38)	36	41.4 (1.63)	1 257.3 (49.50)	3.8 to 10 (0.15 to 0.40)
48	1 219.2 (48.00)	1 511.30 (59.50)	1 231.90 (48.50)	44	41.4 (1.63)	1 422.4 (56.00)	3.8 to 7.6 (0.15 to 0.30)
54	1 371.6 (54.00)	1 682.75 (66.25)	1 387.35 (54.62)	44	47.75 (1.88)	1 593.85 (62.75)	3.8 to 6 (0.15 to 0.25)
63	1 605.51 (63.209)	1 854.20 (73.00)	1 625.60 (64.00)	52	47.75 (1.88)	1 758.95 (69.25)	3.8 to 6 (0.15 to 0.25)

GENERAL NOTES:
(a) This Table applies to backup rings used with heat-fused thermoplastic pipes such as PE, PP, and PVDF pipes.
(b) Lap-joint flange connections are made using backup rings and thermoplastic flange adapters.
(c) The most commonly used backup rings are made from ductile iron (A536), steel (A53), and stainless steel (316). The selection of materials of construction or for coatings for backup rings is based on the application. The user, owner, or design engineer is responsible for material selection.
(d) The following coatings may be used to encapsulate or coat the materials in General Note (c) if selected by the user, owner, or design engineer:
(1) PP reinforced with glass fibers, paint, or galvanizing
(2) other protective coating at the direction of the user, owner, or design engineer
(e) Convoluted, plate, and thermoplastic backup rings may be used provided the chosen materials meet the requirements of this Standard and the design specification.

Table A-2.1-1 NPS Backup Rings for Thermoplastic Pipe (Cont'd)

NOTES:
(1) The required thickness, *T*, of the backup ring and the pressure rating of the backup ring are not provided in the Table. The design requirements shall determine the thickness and type of backup ring to be used.
(2) The bolt holes and O.D. shall meet the requirements of ASME B16.5 and ASME B16.47. The bolt-circle dimensions may also be made to these requirements.

A-2.2 Backup Rings for Solvent-Cement-Welded Joints

Backup rings for the solvent-cement welding method of joining shall conform to the following general requirements:

(a) Both metallic and nonmetallic backup rings may be used.

(b) Metallic backup rings, including those with nonmetallic coatings or encapsulation, may be used.

(c) Backup rings made of metallic or nonmetallic materials, 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.

(d) When needed, additional design requirements for the backup rings shall be provided in the owner's specification.

(e) Backup rings and flange adapters shall be compatible with each other.

NOTE: There are differences in design from manufacturer to manufacturer. Backup rings from different manufacturers might not be compatible.

(f) The backup ring O.D., bolt-hole diameter, and bolt-circle dimensions shall conform to ASME B16.5 Class 150 dimensions for nominal pipe sizes DN 15 to DN 600 (NPS $^1/_2$ to NPS 24). Other flange standards may be used as required by the user's design specifications. However, the other requirements of this Standard, not related to dimensions, shall be met.

(g) The backup ring's effective thickness shall be adequate to provide the initial and long-term seating stress for leak-free service. See test requirements in Table A-3-1. Thermoplastic components for fire lines shall pass Factory Mutual or NFPA requirements in addition to the requirements in this Standard. When the requirements are the same, additional testing may be omitted.

A-2.3 Design Requirements for Backup Rings to Be Used With Thermoplastic Flange Adapters Joined by Heat Fusing

The following items shall be evaluated in the design of a backup ring used with a thermoplastic flange adapter:

(a) Compressive Strength. The area of the backup ring in contact with the flange adapter shall not exceed compressive strength at a strain of 1% to 5%, dependent on the thermoplastic and the application.

(1) Short-term loads such as hydraulic shock or surge shall be calculated using a short-term compressive strength.

(2) Long-term loads such as design operating pressure shall be evaluated using long-term compressive strength.

(3) Figure A-2.3-1 shows the contact area between flange adapter and backup rings.

(b) Bolt Dimensions. The bolt-circle diameter, bolt-hole size, number of bolts, and bolt diameter shall be determined by the requirements in ASME B16.5 or ASME B16.47 for iron-pipe-sized (IPS) applications. These NPS dimensions are provided in Table A-2.1-1. Metric dimensions are provided in Table A-2.1-2.

(c) Radius. The radii for PE, PP, and PVDF between the flange face and the barrel of the flange adapter should be as provided in Tables A-2.1-1 and A-2.1-2. Figures A-2.3-2 and A-2.3-3 show the location of radii on backup rings. When the backup ring is not in contact with the corner or radius of the flange adapter, no radius is required.

(d) Inside Diameter. Tables A-2.1-1 and A-2.1-2 provide typical I.D.s for PE, PP, and PVDF NPS and metric sizes.

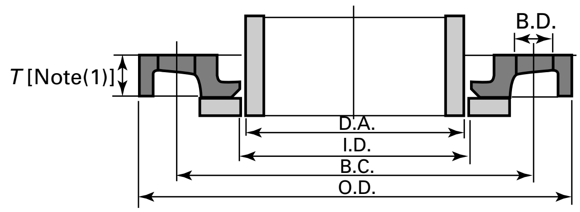
(e) Thickness. The thickness of backup rings varies by size, design, type of material, and pressure rating. The thickness requirements are not shown in Tables A-2.1-1 and A-2.1-2; the user or designer shall select thickness based on design, operating, and test requirements.

(f) Allowable Backup Ring Designs. Plate-flange, convoluted, thermoplastic, and reinforced-thermoplastic backup rings may be used. Figures A-2.3-1 and A-2.3-2 show plate-flange backup rings; Figure A-2.3-3 shows a convoluted backup ring.

A-2.4 Design Requirements for Backup Rings to Be Used With Thermoplastic Flange Adapters Joined by Solvent-Cement Welding

The following items shall be evaluated in the design of a backup ring used with a thermoplastic flange adapter joined to thermoplastic pipe using solvent-cement welding:

Table A-2.1-2 Metric Backup Rings for Thermoplastic Pipe



Nominal Diameter	DA, mm (in.)	Backup Ring O.D., mm (in.) [Note (2)]	Backup Ring I.D., mm (in.)	No. of Bolts	Bolt-Hole Size, *H*, mm (in.) [Note (2)]	Bolt Circle, B.C., mm (in.) [Note (2)]	Radius, *R*, mm (in.)
15	20 (0.787)	106 (4.173)	28 (1.102)	4	14 (0.551)	65 (2.559)	3 (0.118)
20	25 (0.984)	118 (4.646)	34 (1.339)	4	14 (0.551)	75 (2.953)	3 (0.118)
25	32 (1.260)	122 (4.803)	42 (1.654)	4	14 (0.551)	85 (3.346)	3 (0.118)
32	40 (1.575)	142 (5.591)	51 (2.008)	4	18 (0.709)	100 (3.937)	3 (0.118)
40	50 (1.969)	156 (6.142)	62 (2.441)	4	18 (0.709)	110 (4.331)	3 (0.118)
50	63 (2.480)	171 (6.732)	78 (3.071)	4	18 (0.709)	125 (4.921)	3 (0.118)
65	75 (2.953)	191 (7.520)	92 (3.622)	4	18 (0.709)	145 (5.709)	3 (0.118)
80	90 (3.543)	206 (8.110)	108 (4.252)	8	18 (0.709)	160 (6.299)	3 (0.118)
100	110 (4.331)	226 (8.898)	128 (5.039)	8	18 (0.709)	180 (7.087)	3 (0.118)
	125 (4.921)	226 (8.898)	135 (5.315)	8	18 (0.709)	180 (7.087)	3 (0.118)
125	140 (5.512)	261 (10.276)	158 (6.220)	8	18 (0.709)	210 (8.268)	3 (0.118)
150	160 (6.299)	296 (11.654)	178 (7.008)	8	22 (0.866)	240 (9.449)	3 (0.118)
	180 (7.087)	296 (11.654)	188 (7.402)	8	22 (0.866)	240 (9.449)	4 (0.157)
200	200 (7.874)	350 (13.780)	235 (9.252)	8	22 (0.866)	295 (11.614)	4 (0.157)
	225 (8.858)	350 (13.780)	238 (9.370)	8	22 (0.866)	295 (11.614)	4 (0.157)
250	250 (9.843)	412 (16.220)	288 (11.339)	12	22 (0.866)	350 (13.780)	4 (0.157)
	280 (11.024)	412 (16.220)	294 (11.575)	12	22 (0.866)	350 (13.780)	4 (0.157)
300	315 (12.402)	452 (17.795)	338 (13.307)	12	22 (0.866)	400 (15.748)	4 (0.157)
350	355 (13.976)	525 (20.669)	376 (14.803)	16	22 (0.866)	460 (18.110)	6 (0.236)
400	400 (15.748)	586 (23.071)	430 (16.929)	16	26 (1.024)	515 (20.276)	6 (0.236)
500	450 (17.717)	690 (27.165)	514 (20.236)	20	27 (1.063)	620 (24.409)	6 (0.236)
	500 (19.685)	690 (27.165)	530 (20.866)	20	27 (1.063)	620 (24.409)	6 (0.236)
600	560 (22.047)	804 (31.654)	615 (24.213)	20	30 (1.181)	725 (28.543)	6 (0.236)
	630 (24.803)	804 (31.654)	642 (25.276)	20	30 (1.181)	725 (28.543)	6 (0.236)
700	710 (27.953)	912 (35.906)	740 (29.134)	24	30 (1.181)	840 (33.071)	5 (0.197)
800	800 (31.496)	1 026 (40.394)	843 (33.189)	24	33 (1.299)	950 (37.402)	5 (0.197)
900	900 (35.433)	1 129 (44.449)	947 (37.283)	28	33 (1.299)	1 050 (41.339)	5 (0.197)
1 000	1 000 (39.370)	1 245 (49.016)	1 050 (41.339)	28	36 (1.417)	1 160 (45.669)	5 (0.197)

GENERAL NOTES:

(a) This Table applies to backup rings used with heat-fused thermoplastic pipes, such as PE, PP, and PVDF pipes.

(b) Socket-fused flange adapters in sizes DA20 through DA75 are also available.

(c) Lap-joint flange connections are made using backup rings and thermoplastic flange adapters.

(d) Convoluted backup rings may be made from ductile iron (GGG 40, DIN 1693), steel (A53), and stainless steel (316). The user, owner, or design engineer shall be responsible for the selection of materials of construction for backup rings.

(e) The following coatings may be used to encapsulate or coat the materials in General Note (d) if selected by the user, owner, or design engineer:
(1) PP with or without glass fibers, paint, or galvanized
(2) other protective coating at the direction of the user, owner, or design engineer

(f) Convoluted, plate, and thermoplastic backup rings may be used provided the chosen materials meet the requirements of this Standard and the design specification.