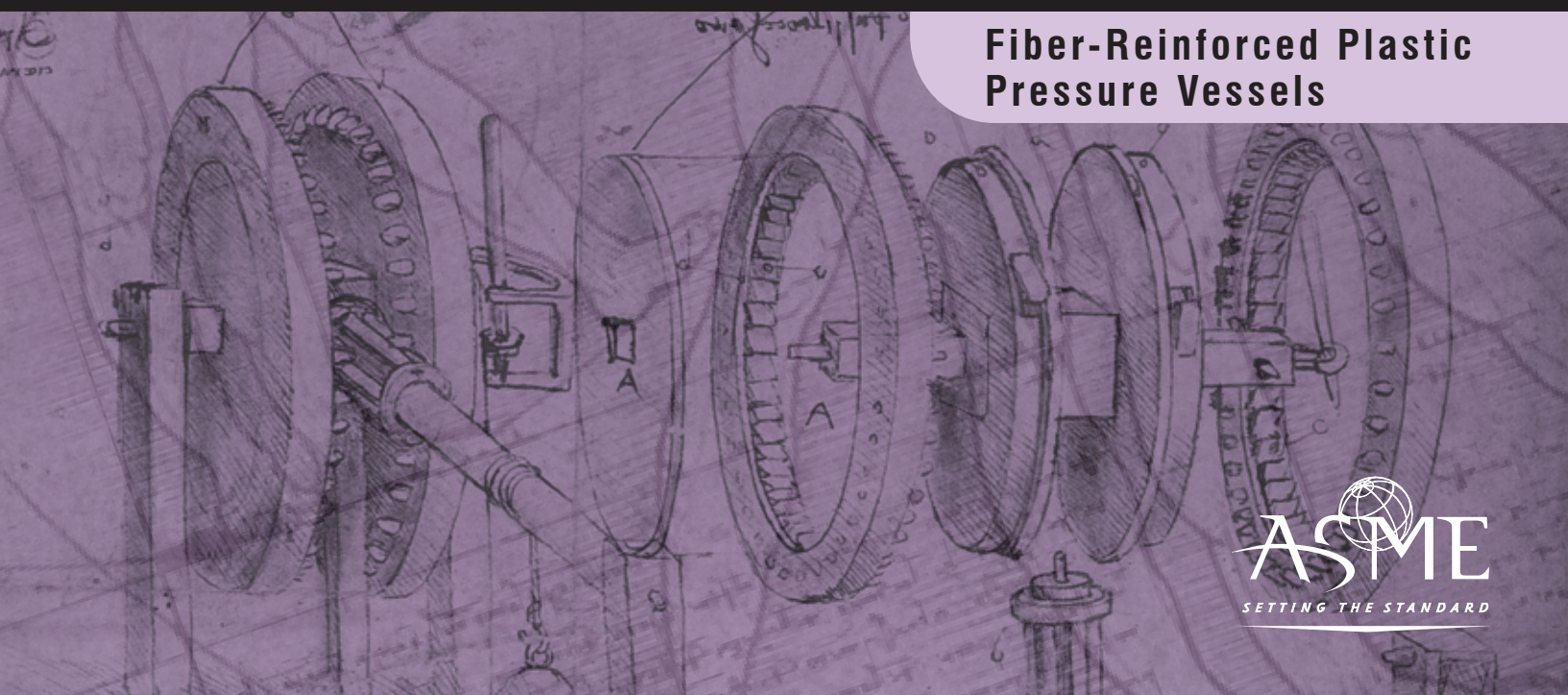
ASME BPVC.X-2021

SECTION X

2021 ASME Boiler and Pressure Vessel Code

An International Code

Fiber-Reinforced Plastic Pressure Vessels



ASME

SETTING THE STANDARD

AN INTERNATIONAL CODE

2021 ASME Boiler & Pressure Vessel Code

2021 Edition July 1, 2021

X

FIBER-REINFORCED PLASTIC PRESSURE VESSELS

ASME Boiler and Pressure Vessel Committee
on Fiber-Reinforced Plastic Pressure Vessels

The American Society of Mechanical Engineers

Two Park Avenue • New York, NY • 10016 USA

Date of Issuance: July 1, 2021

This international code or standard was developed under procedures accredited as meeting the criteria for American National Standards and it is an American National Standard. The Standards Committee that approved the code or standard was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed code or standard was made available for public review and comment that provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

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ASME accepts responsibility for only those interpretations of this document issued in accordance with the established ASME procedures and policies, which precludes the issuance of interpretations by individuals.

The endnotes and preamble in this document (if any) are part of this American National Standard.

ASME Collective Membership Mark

ASME Single Certification Mark

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The American Society of Mechanical Engineers
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INTERPRETATIONS

Interpretations are issued in real time in ASME's Interpretations Database at http://go.asme.org/Interpretations. Historical BPVC interpretations may also be found in the Database.

CODE CASES

The Boiler and Pressure Vessel Code committees meet regularly to consider proposed additions and revisions to the Code and to formulate Cases to clarify the intent of existing requirements or provide, when the need is urgent, rules for materials or constructions not covered by existing Code rules. Those Cases that have been adopted will appear in the appropriate 2021 Code Cases book: "Boilers and Pressure Vessels" or "Nuclear Components." Each Code Cases book is updated with seven Supplements. Supplements will be sent or made available automatically to the purchasers of the Code Cases books up to the publication of the 2023 Code. Annulments of Code Cases become effective six months after the first announcement of the annulment in a Code Case Supplement or Edition of the appropriate Code Case book. Code Case users can check the current status of any Code Case at http://go.asme.org/BPVCCDatabase. Code Case users can also view an index of the complete list of Boiler and Pressure Vessel Code Cases and Nuclear Code Cases at http://go.asme.org/BPVCC.

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FOREWORD*

In 1911, The American Society of Mechanical Engineers established the Boiler and Pressure Vessel Committee to formulate standard rules for the construction of steam boilers and other pressure vessels. In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees:

(a) Committee on Power Boilers (I)
(b) Committee on Materials (II)
(c) Committee on Construction of Nuclear Facility Components (III)
(d) Committee on Heating Boilers (IV)
(e) Committee on Nondestructive Examination (V)
(f) Committee on Pressure Vessels (VIII)
(g) Committee on Welding, Brazing, and Fusing (IX)
(h) Committee on Fiber-Reinforced Plastic Pressure Vessels (X)
(i) Committee on Nuclear Inservice Inspection (XI)
(j) Committee on Transport Tanks (XII)
(k) Committee on Overpressure Protection (XIII)
(l) Technical Oversight Management Committee (TOMC)

Where reference is made to "the Committee" in this Foreword, each of these committees is included individually and collectively.

The Committee's function is to establish rules of safety relating to pressure integrity, which govern the construction** of boilers, pressure vessels, transport tanks, and nuclear components, and the inservice inspection of nuclear components and transport tanks. The Committee also interprets these rules when questions arise regarding their intent. The technical consistency of the Sections of the Code and coordination of standards development activities of the Committees is supported and guided by the Technical Oversight Management Committee. This Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks, or nuclear components, or the inservice inspection of nuclear components or transport tanks. Users of the Code should refer to the pertinent codes, standards, laws, regulations, or other relevant documents for safety issues other than those relating to pressure integrity. Except for Sections XI and XII, and with a few other exceptions, the rules do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of pressure vessels. The objective of the rules is to afford reasonably certain protection of life and property, and to provide a margin for deterioration in service to give a reasonably long, safe period of usefulness. Advancements in design and materials and evidence of experience have been recognized.

This Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities and inservice inspection and testing activities. The Code does not address all aspects of these activities and those aspects that are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase *engineering judgment* refers to technical judgments made by knowledgeable engineers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy, and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code neither requires nor prohibits the use of computers for the design or analysis of components constructed to the requirements of the Code. 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 the application of these programs to their design.

* The information contained in this Foreword is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. Therefore, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Code.

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

The rules established by the Committee 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 Code rules.

The Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code Cases, and requests for interpretations. Only the Committee has the authority to provide official interpretations of this Code. Requests for revisions, new rules, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action (see Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees). Proposed revisions to the Code resulting from inquiries will be presented to the Committee for appropriate action. The action of the Committee becomes effective only after confirmation by ballot of the Committee and approval by ASME. Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute (ANSI) and published at http://go.asme.org/BPVCPublicReview to invite comments from all interested persons. After public review and final approval by ASME, revisions are published at regular intervals in Editions of the Code.

The Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed to the Committee. ASME is to be notified should questions arise concerning improper use of the ASME Single Certification Mark.

When required by context in this Section, the singular shall be interpreted as the plural, and vice versa, and the feminine, masculine, or neuter gender shall be treated as such other gender as appropriate.

The words "shall," "should," and "may" are used in this Standard as follows:

- *Shall* is used to denote a requirement.
- *Should* is used to denote a recommendation.
- *May* is used to denote permission, neither a requirement nor a recommendation.

STATEMENT OF POLICY ON THE USE OF THE ASME SINGLE CERTIFICATION MARK AND CODE AUTHORIZATION IN ADVERTISING

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use the ASME Single Certification Mark for marking items or constructions that have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the ASME Single Certification Mark for the benefit of the users, the enforcement jurisdictions, and the holders of the ASME Single Certification Mark who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the ASME Single Certification Mark, Certificates of Authorization, and reference to Code construction. The American Society of Mechanical Engineers does not "approve," "certify," "rate," or "endorse" any item, construction, or activity and there shall be no statements or implications that might so indicate. An organization holding the ASME Single Certification Mark and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities "are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code," or "meet the requirements of the ASME Boiler and Pressure Vessel Code." An ASME corporate logo shall not be used by any organization other than ASME.

The ASME Single Certification Mark shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of the ASME Single Certification Mark who may also use the facsimile in advertising to show that clearly specified items will carry the ASME Single Certification Mark.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the ASME Single Certification Mark described in the governing Section of the Code.

Markings such as "ASME," "ASME Standard," or any other marking including "ASME" or the ASME Single Certification Mark shall not be used on any item that is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME that tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

SUBMITTAL OF TECHNICAL INQUIRIES TO THE BOILER AND PRESSURE VESSEL STANDARDS COMMITTEES (21)

1 INTRODUCTION

(a) The following information provides guidance to Code users for submitting technical inquiries to the applicable Boiler and Pressure Vessel (BPV) Standards Committee (hereinafter referred to as the Committee). See the guidelines on approval of new materials under the ASME Boiler and Pressure Vessel Code in Section II, Part D for requirements for requests that involve adding new materials to the Code. See the guidelines on approval of new welding and brazing materials in Section II, Part C for requirements for requests that involve adding new welding and brazing materials ("consumables") to the Code.

Technical inquiries can include requests for revisions or additions to the Code requirements, requests for Code Cases, or requests for Code Interpretations, as described below:

(1) Code Revisions. Code revisions are considered to accommodate technological developments, to address administrative requirements, to incorporate Code Cases, or to clarify Code intent.

(2) Code Cases. Code Cases represent alternatives or additions to existing Code requirements. Code Cases are written as a Question and Reply, and are usually intended to be incorporated into the Code at a later date. When used, Code Cases prescribe mandatory requirements in the same sense as the text of the Code. However, users are cautioned that not all regulators, jurisdictions, or Owners automatically accept Code Cases. The most common applications for Code Cases are as follows:

(-a) to permit early implementation of an approved Code revision based on an urgent need

(-b) to permit use of a new material for Code construction

(-c) to gain experience with new materials or alternative requirements prior to incorporation directly into the Code

(3) Code Interpretations

(-a) Code Interpretations provide clarification of the meaning of existing requirements in the Code and are presented in Inquiry and Reply format. Interpretations do not introduce new requirements.

(-b) Interpretations will be issued only if existing Code text is ambiguous or conveys conflicting requirements. If a revision of the requirements is required to support the Interpretation, an Intent Interpretation will be issued in parallel with a revision to the Code.

(b) Code requirements, Code Cases, and Code Interpretations established by the Committee are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or Owners to choose any method of design or any form of construction that conforms to the Code requirements.

(c) Inquiries that do not comply with the following guidance or that do not provide sufficient information for the Committee's full understanding may result in the request being returned to the Inquirer with no action.

2 INQUIRY FORMAT

Submittals to the Committee should include the following information:

(a) Purpose. Specify one of the following:

(1) request for revision of present Code requirements

(2) request for new or additional Code requirements

(3) request for Code Case

(4) request for Code Interpretation

(b) Background. The Inquirer should provide the information needed for the Committee's understanding of the Inquiry, being sure to include reference to the applicable Code Section, Division, Edition, Addenda (if applicable), paragraphs, figures, and tables. This information should include a statement indicating why the included paragraphs, figures, or tables are ambiguous or convey conflicting requirements. Preferably, the Inquirer should provide a copy of, or relevant extracts from, the specific referenced portions of the Code.

(c) Presentations. The Inquirer may desire to attend or be asked to attend a meeting of the Committee to make a formal presentation or to answer questions from the Committee members with regard to the Inquiry. Attendance at a BPV Standards Committee meeting shall be at the expense of the Inquirer. The Inquirer's attendance or lack of attendance at a meeting will not be used by the Committee as a basis for acceptance or rejection of the Inquiry by the Committee. However, if the Inquirer's request is unclear, attendance by the Inquirer or a representative may be necessary for the Committee to understand the request sufficiently to be able to provide an Interpretation. If the Inquirer desires to make a presentation at a Committee meeting, the Inquirer should provide advance notice to the Committee Secretary, to ensure time will be allotted for the presentation in the meeting agenda. The Inquirer should consider the need for additional audiovisual equipment that might not otherwise be provided by the Committee. With sufficient advance notice to the Committee Secretary, such equipment may be made available.

3 CODE REVISIONS OR ADDITIONS

Requests for Code revisions or additions should include the following information:

(a) Requested Revisions or Additions. For requested revisions, the Inquirer should identify those requirements of the Code that they believe should be revised, and should submit a copy of, or relevant extracts from, the appropriate requirements as they appear in the Code, marked up with the requested revision. For requested additions to the Code, the Inquirer should provide the recommended wording and should clearly indicate where they believe the additions should be located in the Code requirements.

(b) Statement of Need. The Inquirer should provide a brief explanation of the need for the revision or addition.

(c) Background Information. The Inquirer should provide background information to support the revision or addition, including any data or changes in technology that form the basis for the request, that will allow the Committee to adequately evaluate the requested revision or addition. Sketches, tables, figures, and graphs should be submitted, as appropriate. The Inquirer should identify any pertinent portions of the Code that would be affected by the revision or addition and any portions of the Code that reference the requested revised or added paragraphs.

4 CODE CASES

Requests for Code Cases should be accompanied by a statement of need and background information similar to that described in 3(b) and 3(c), respectively, for Code revisions or additions. The urgency of the Code Case (e.g., project underway or imminent, new procedure) should be described. In addition, it is important that the request is in connection with equipment that will bear the ASME Single Certification Mark, with the exception of Section XI applications. The proposed Code Case should identify the Code Section and Division, and should be written as a Question and a Reply, in the same format as existing Code Cases. Requests for Code Cases should also indicate the applicable Code Editions and Addenda (if applicable) to which the requested Code Case applies.

5 CODE INTERPRETATIONS

(a) Requests for Code Interpretations should be accompanied by the following information:

(1) Inquiry. The Inquirer should propose a condensed and precise Inquiry, omitting superfluous background information and, when possible, composing the Inquiry in such a way that a "yes" or a "no" Reply, with brief limitations or conditions, if needed, can be provided by the Committee. The proposed question should be technically and editorially correct.

(2) Reply. The Inquirer should propose a Reply that clearly and concisely answers the proposed Inquiry question. Preferably, the Reply should be "yes" or "no," with brief limitations or conditions, if needed.

(3) Background Information. The Inquirer should include a statement indicating why the included paragraphs, figures, or tables are ambiguous or convey conflicting requirements. The Inquirer should provide any need or background information, such as described in 3(b) and 3(c), respectively, for Code revisions or additions, that will assist the Committee in understanding the proposed Inquiry and Reply.

If the Inquirer believes a revision of the Code requirements would be helpful to support the Interpretation, the Inquirer may propose such a revision for consideration by the Committee. In most cases, such a proposal is not necessary.

(b) Requests for Code Interpretations should be limited to an Interpretation of a particular requirement in the Code or in a Code Case. Except with regard to interpreting a specific Code requirement, the Committee is not permitted to consider consulting-type requests such as the following:

(1) a review of calculations, design drawings, welding qualifications, or descriptions of equipment or parts to determine compliance with Code requirements

(2) a request for assistance in performing any Code-prescribed functions relating to, but not limited to, material selection, designs, calculations, fabrication, inspection, pressure testing, or installation

(3) a request seeking the rationale for Code requirements

6 SUBMITTALS

(a) Submittal. Requests for Code 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, the Inquirer may mail the request to the following address:

Secretary
ASME Boiler and Pressure Vessel Committee
Two Park Avenue
New York, NY 10016-5990

All other Inquiries should be mailed to the Secretary of the BPV Committee at the address above. Inquiries are unlikely to receive a response if they are not written in clear, legible English. They must also include the name of the Inquirer and the company they represent or are employed by, if applicable, and the Inquirer's address, telephone number, fax number, and e-mail address, if available.

(b) Response. The Secretary of the appropriate Committee will provide a written response, via letter or e-mail, as appropriate, to the Inquirer, upon completion of the requested action by the Committee. Inquirers may track the status of their Interpretation Request at http://go.asme.org/Interpretations.

PERSONNEL

(21)

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January 1, 2021

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INTRODUCTION

1 GENERAL

The use of fiber-reinforced plastics for the manufacture of pressure vessels presents unique materials considerations in the design, fabrication, and testing of these vessels. Metallic vessels, being made from materials that are normally isotropic and ductile, are designed by using well-established allowable stresses based on measured tensile and ductility properties. In contrast, fiber-reinforced plastics are usually anisotropic and the physical properties are dependent upon the fabrication process, the placement and orientation of the reinforcement, and the resin matrix. It is the purpose of this Introduction to describe in a general way the criteria that were used in preparing Section X, Fiber-Reinforced Plastic Pressure Vessels. A list of standards referenced in this Section is provided in Table 1.1.

2 MATERIALS

It is not possible to fabricate a reinforced plastic pressure vessel of a single basic material for which there is an ASTM specification. The vessel parts are made up of various basic materials, such as fiber reinforcement and resin, which are joined in the presence of a catalyst to create a composite material that is formed into a vessel or vessel part by a specified process. The composite material will often have directional properties, which shall be considered in design. General specifications for the basic materials (fiber reinforcement and resin) are stated, as are requirements for determination of elastic properties for the composite material (laminate) produced. Elastic properties of specific laminates used in vessel fabrication are required when mandatory rules are used for vessel design. Metallic materials, when used in conjunction with reinforced fiber laminates, are required to meet ASME Boiler and Pressure Vessel Code specifications, Section VIII, Division 1. That Section must be used for the design, fabrication, quality control, and inspection of such metallic parts. However, for hydrostatic leakage testing, these metallic materials that complete the vessel are required to meet Section X requirements.

3 DESIGN

3.1 GENERAL

3.1.1 Adequacy of specific designs shall be qualified by one of the following methods:[1]

(a) Class I Design — qualification of a vessel design through the pressure testing of a prototype.

(b) Class II Design — mandatory design rules and acceptable testing by nondestructive methods.

(c) Class III Design — qualification of a vessel design through the pressure testing of a prototype, other specified tests of prototypes, mandatory design rules and acceptance testing by nondestructive methods.

3.1.2 Class I designs based on the qualification of a prototype vessel require that the minimum qualification pressure of the prototype be at least six[2] times the design pressure. The maximum design pressure is limited to 150 psi (1 MPa) for bag-molded, centrifugally cast, and contact-molded vessels; 1,500 psi (10 MPa) for filament-wound vessels; and 3,000 psi (20 MPa) for filament-wound vessels with polar boss openings.

3.1.3 Class II designs based on mandatory design rules and acceptance testing must comply with Article RD-11 and Article RT-6. The maximum design pressure allowed under this procedure shall be as specified in RD-1120.

3.1.4 Class III designs include the qualification of a prototype with the minimum qualification pressure of the prototype to be at 2.25 times the design pressure for carbon fiber vessels, and 3.5 times the design pressure for glass fiber vessels. Hybrid designs using more than one type of fiber are covered in 8-400.7. The maximum design pressure is limited to 15,000 psi (103 MPa). The minimum design pressure shall be not less than 3,000 psi (20.7 MPa).

[1] These three methods shall not be intermixed.

[2] An exception to this six times factor is applicable to vessels per (Filament Winding — Polar Boss Openings Only).

(21)

Table 1.1
Referenced Standards in This Section

Title	Number
Cast Iron Pipe Flanges and Flanged Fittings	ASME B16.1
Pipe Flanges and Flanged Fittings	ASME B16.5
Plain Washers	ASME B18.22.1
Conformity Assessment Requirements	ASME CA-1
Standard Test Method for Kinematic Viscosity and Opaque Liquids (the Calculation of Dynamic Viscosity)	ASTM D445
Standard Test Method for Tensile Properties of Plastics	ASTM D638
Standard Test Method for Compressive Properties of Rigid Plastics	ASTM D695
Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement	ASTM D792
Standard Test Methods for Sampling and Testing Plasticizers Used in Plastics	ASTM D1045
Standard Test Methods for Epoxy Content of Epoxy Resins	ASTM D1652
Standard Test Method for Tensile Properties of Glass Strands, Yarns, and Rovings Used in Reinforced Plastics	ASTM D2343
Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates	ASTM D2344
Standard Test Method for Epoxy Resins and Related Components	ASTM D2393
Standard Test Method for Gel Time and Peak Exothermic Temperature of Reacting Thermosetting Resins	ASTM D2471
Standard Test Method for Indentation Hardness of Rigid Plastics by Means of Barcol Impressor	ASTM D2583
Standard Test Method for Ignition Loss of Cured Reinforced Resins	ASTM D2584
Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for “Fiberglass” (Glass- Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings	ASTM D2992
Standard Test Method for Volatile Matter (Including Water) of Vinyl Chloride Resins	ASTM D3030
Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials	ASTM D3039
Standard Test Method for Constituent Content of Composite Materials	ASTM D3171
Standard Test Method for Compressive Properties for Polymer Matrix Composite Materials With Unsupported Gage Section by Shear Loading	ASTM D3410
Standard Test Method for In-Plane Shear Strength of Reinforced Plastics	ASTM D3846
Standard Test Method for Specific Gravity	ASTM D4052
Standard Specification for Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Corrosion- Resistant Tanks	ASTM D4097
Standard Guide for Testing In-Plane Shear Properties of Polymer Matrix Composite Materials by the Rail Shear Method	ASTM D4255
Standard Test Method for Inplane Shear Properties of Hoop Wound Polymer Matrix Composite Cylinders	ASTM D5448
Standard Test Method for Transverse Compressive Properties of Hoop Wound Polymer Matrix Composite Cylinders	ASTM D5449
Standard Test Method for Transverse Tensile Properties of Hoop Wound Polymer Matrix Composite Cylinders	ASTM D5450
Standard Test Method for Shear Properties of Composite Materials by V-Notched Rail Shear Method	ASTM D7078
Standard Practice for Acoustic Emission Examination of Fiberglass Reinforced Plastic Resin (FRP) Tanks/Vessels	ASTM E1067
Standard Practice for Determining Damage-Based Design for Fiberglass Reinforced Plastic (FRP) Materials Using Acoustic Emission	ASTM E2478
Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing	SNT-TC-1A

GENERAL NOTES:
(a) The most recently approved version of the above referenced standards apply.
(b) Additional standards referenced for Class III vessels are listed in 8-200.4.

3.2 LOW MODULUS CHARACTERISTICS

Fiber-reinforced plastic laminates may have a modulus of elasticity as low as 1.0×10^6 psi (6 900 MPa), compared with that of ferrous materials which may be of the order of 30×10^6 psi (2.1×10^5 MPa). This low modulus characteristic requires careful consideration of vessel profile in order to minimize bending and avoid buckling. Spherical heads or elliptical heads having an ellipse ratio not greater than 2:1 are suggested. Spherical heads are suggested when the material has isotropic properties. Elliptical heads are preferred when the material has anisotropic properties.

3.3 FATIGUE

3.3.1 Like metallic materials, the composite material (laminate) of fiber-reinforced plastic vessels, when stressed at sufficiently low levels, exhibits good fatigue life. However, its low modulus of elasticity provides a higher strain per unit of stress than metals used for metallic vessels.

3.3.2 Section X, therefore, requires that a Class I design that is qualified by testing of a prototype vessel be pressure cycled 100,000 times over a pressure range of atmospheric to the design pressure; after this, the test vessel must withstand a hydrostatic qualification test not less than six times the design pressure. An exception to this 100,000 cycle requirement is applicable to vessels per RG-404.2 (Filament Winding — Polar Boss Openings Only). That classification of vessels is designed for a 5:1 factor of safety which requires cycling from atmospheric to the design pressure for 33,000 cycles; after this, the test vessel must withstand a hydrostatic qualification test not less than five times the design pressure.

3.3.3 Class II vessels qualified using mandatory design rules and acceptance testing are not required to be subjected to the above cyclic and qualification pressure test criteria.

3.3.4 Section X requires that a Class III design qualification include testing of a prototype vessel that is pressure cycled for "N" cycles as prescribed in 8-700.5.4.1 over a pressure range of 10% of design pressure to 100% of design pressure without leakage or rupture.

3.4 CREEP, STRESS-RUPTURE, AND TEMPERATURE EFFECTS

Fiber-reinforced plastic composite material (laminate) is not subject to creep or failure due to low stress-to-rupture characteristics as are some other materials. The material does, however, lose ultimate strength as the temperature is increased and gains strength but becomes more brittle as the temperature is lowered. Its low thermal conductivity and ablative properties are other factors significantly affecting the behavior of this material in the event of fire or other high-temperature environment. The maximum design, operating, and test temperatures of Class I vessels are set as follows:

(a) 150°F (65°C) for design temperatures less than or equal to 150°F (65°C);

(b) 250°F (120°C) or to within 35°F (19°C) of the glass transition temperature (whichever is lower) for design temperatures in excess of 150°F (65°C).

The maximum design, operating, and test temperatures of Class II vessels are limited to an inside wall temperature of 250°F (120°C) or to within 35°F (19°C) of the glass transition temperature of the resin (whichever is lower). The maximum design temperature of Class III vessels shall be 35°F (19°C) below the maximum use temperature of the resin as documented in the Manufacturing Specifications, but in no case shall it exceed 185°F (85°C). The minimum design temperature of Class I, Class II, and Class III vessels shall be −65°F (−54°C) (see RD-112).

3.5 FABRICATION

3.5.1 Many processes are used in the fabrication of fiber-reinforced composite materials (laminates). Class I vessels are limited to four processes, namely, filament winding, bag molding, contact molding, and centrifugal casting. Class II vessels are limited to two processes, namely, filament winding and contact molding.

3.5.2 The fabrication of more than one Class I vessel may be required to comply with the requirements for qualifying a design using the prototype vessel[3] method. Once a specific design has been qualified, the quality of subsequent vessels of the same dimension and design is to be assured by carefully controlled fabrication procedures and rigid Quality Control Programs.

3.5.3 Every Class II vessel must be acceptance tested as specified in Article RT-6. Such tests must be documented as having met the acceptance criteria of Article RT-6 and shall become part of the Fabricator's Design Report.

[3] Prototype vessels used to qualify a design shall not be stamped with the Certification Mark.

3.5.4 Class III vessels are limited to filament-wound construction with polar loss openings.

3.6 INSPECTION

3.6.1 The general philosophy of Section VIII, Division 1, regarding inspection during fabrication is continued in this Section. Familiarity with the laminate production processes and the nature of vessel imperfections is required of the Inspector. Reliance is placed upon careful auditing of the Fabricator's Quality Control Program, close visual inspection of completed vessels by both Fabricator personnel and the Inspector, and acceptance testing where required by this Section.

3.6.2 This Section requires that all laminate and secondary bonding work be without use of pigments, fillers, or resin putty mixtures except as permitted by the Procedure Specification used in fabricating the vessel or vessel part.

3.7 LINERS

Liners may be used in Section X vessels as a barrier between the laminate and the vessel contents. Such liners shall not be considered part of the structural component of the vessel.

3.8 UNITS

3.8.1 Either U.S. Customary, SI, or any local customary units may be used to demonstrate compliance with all requirements of this Edition (e.g., materials, design, fabrication, examination, inspection, testing, certification, and overpressure protection).

3.8.2 In general, it is expected that a single system of units shall be used for all aspects of design except where unfeasible or impractical. When components are manufactured at different locations where local customary units are different than those used for the general design, the local units may be used for the design and documentation of that component. Similarly, for proprietary components or those uniquely associated with a system of units different than that used for the general design, the alternate units may be used for the design and documentation of that component.

3.8.3 For any single equation, all variables shall be expressed in a single system of units. When separate equations are provided for U.S. Customary units and SI units, those equations must be executed using variables in the units associated with the specific equation. Data expressed in other units shall be converted to U.S. Customary units or SI units for use in these equations. The result obtained from execution of these equations may be converted to other units.

3.8.4 Production, measurement and test equipment, drawings, welding procedure specifications, welding procedure and performance qualifications, and other fabrication documents may be in U.S. Customary, SI, or local customary units in accordance with the Fabricator's practice. When values shown in calculations and analysis, fabrication documents, or measurement and test equipment are in different units, any conversions necessary for verification of Code compliance and to ensure that dimensional consistency is maintained, shall be in accordance with the following:

(a) Conversion factors shall be accurate to at least four significant figures.

(b) The results of conversions of units shall be expressed to a minimum of three significant figures.

3.8.5 Material that has been manufactured and certified to either the U.S. Customary or SI material specification (e.g., SA-516M) may be used regardless of the unit system used in design. Standard fittings (e.g., flanges, elbows, etc.) that have been certified to either U.S. Customary units or SI units may be used regardless of the units system used in design.

3.8.6 Conversion of units, using the precision specified in para. 20, shall be performed to assure that dimensional consistency is maintained. Conversion factors between U.S. Customary units and SI units may be found in the Nonmandatory Appendix, Guidance for the Use of U.S. Customary and SI units in the ASME Boiler and Pressure Vessel Code. Whenever local customary units are used, the Manufacturer shall provide the source of the conversion factors which shall be subject to verification and acceptance by the Authorized Inspector or Certified Individual.

3.8.7 All entries on a Manufacturer's Data Report and data for Code required nameplate marking shall be in units consistent with the fabrication drawings for the component using U.S. Customary, SI, or local customary units. It is acceptable to show alternate units parenthetically. Users of this Code are cautioned that the receiving Jurisdiction should be contacted to ensure the units are acceptable.

SUMMARY OF CHANGES

Errata to the BPV Code may be posted on the ASME website to provide corrections to incorrectly published items, or to correct typographical or grammatical errors in the BPV Code. Such Errata shall be used on the date posted.

Information regarding Special Notices and Errata is published by ASME at http://go.asme.org/BPVCerrata.

Changes given below are identified on the pages by a margin note, **(21)**, placed next to the affected area.

Page	*Location*	*Change*
xiv	List of Sections	(1) Listing for Section III updated (2) Section XIII added (3) Code Case information updated
xvi	Foreword	(1) Subparagraph (k) added, and subsequent subparagraph redesignated (2) Second footnote revised (3) Last paragraph added
xix	Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees	Paragraphs 1(a)(3)(-b), 2(b), and 5(a)(3) revised
xxii	Personnel	Updated
xliv	Table 1.1	ASTM E1067 added
1	RG-111	Subparagraphs (a) and (c) revised
3	RG-201	Subparagraph (f) revised
8	RM-121	(1) Subparagraph (d) deleted (2) Third and fourth paragraphs after subpara. (c) revised
9	Table RM-120.1	(1) "Acid number" entry deleted, and subsequent entry renumbered (2) Note (1) added
9	Table RM-120.2	Note (1) added
13	RD-111	Second paragraph revised
13	RD-116	Revised
25	Figure RD-620.5	"$6t_b$," "$6t_i$," and "$6t_p$" revised to "$4t_b$," "$4t_i$," and "$4t_p$," respectively
26	Figure RD-620.6	"$6t_b$," "$6t_i$," and "$6t_p$" revised to "$4t_b$," "$4t_i$," and "$4t_p$," respectively
36	RD-1172.1	Definition of *KD* revised
38	Figure RD-1174.2	"$6t_b$" and "$6t_p$" revised to "$4t_b$" and "$4t_p$," respectively
78	Part RR	Requirements moved to Part ROP and Section XIII
79	Part ROP	Added
82	RT-111	Endnote 16 (formerly endnote 17) and subparagraph (a)(7) revised
88	RT-412.2	Title revised
93	RT-622	Last sentence deleted
97	RI-132	Subparagraph (c) revised
103	RS-110	Endnote 22 (formerly endnote 23) revised
104	RS-131	Title revised, and former in-text note relocated to Figure RS-132.1 General Notes
104	Figure RS-132.1	General Notes added
109	Mandatory Appendix 2	Information moved to Section XIII, Mandatory Appendix IV
126	8-100.3	Revised
140	8-700.5.10	Revised in its entirety
174	Nonmandatory Appendix AB	Paragraphs AB-103 through AB-107 revised
215	AH-200	In subpara. (j), 2,000 psi and 14 MPa added to in-text table

Page	*Location*	*Change*
223	Table AJ-1	(1) In first column, designators for Forms CPV-1 and CPV-2 corrected (2) Entry for Form Q-120 updated (3) Note (1) added
235	Form Q-120	(1) Revision line of heading updated (2) On third page, line D1 revised
271	Nonmandatory Appendix AM	Added

LIST OF CHANGES IN RECORD NUMBER ORDER

DELETED

CROSS-REFERENCING AND STYLISTIC CHANGES IN THE BOILER AND PRESSURE VESSEL CODE

There have been structural and stylistic changes to BPVC, starting with the 2011 Addenda, that should be noted to aid navigating the contents. The following is an overview of the changes:

Subparagraph Breakdowns/Nested Lists Hierarchy

- First-level breakdowns are designated as (a), (b), (c), etc., as in the past.
- Second-level breakdowns are designated as (1), (2), (3), etc., as in the past.
- Third-level breakdowns are now designated as (-a), (-b), (-c), etc.
- Fourth-level breakdowns are now designated as (-1), (-2), (-3), etc.
- Fifth-level breakdowns are now designated as (+a), (+b), (+c), etc.
- Sixth-level breakdowns are now designated as (+1), (+2), etc.

Footnotes

With the exception of those included in the front matter (roman-numbered pages), all footnotes are treated as endnotes. The endnotes are referenced in numeric order and appear at the end of each BPVC section/subsection.

Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees

Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees has been moved to the front matter. This information now appears in all Boiler Code Sections (except for Code Case books).

Cross-References

It is our intention to establish cross-reference link functionality in the current edition and moving forward. To facilitate this, cross-reference style has changed. Cross-references within a subsection or subarticle will not include the designator/identifier of that subsection/subarticle. Examples follow:

- *(Sub-)Paragraph Cross-References.* The cross-references to subparagraph breakdowns will follow the hierarchy of the designators under which the breakdown appears.
  - If subparagraph (-a) appears in X.1(c)(1) and is referenced in X.1(c)(1), it will be referenced as (-a).
  - If subparagraph (-a) appears in X.1(c)(1) but is referenced in X.1(c)(2), it will be referenced as (1)(-a).
  - If subparagraph (-a) appears in X.1(c)(1) but is referenced in X.1(e)(1), it will be referenced as (c)(1)(-a).
  - If subparagraph (-a) appears in X.1(c)(1) but is referenced in X.2(c)(2), it will be referenced as X.1(c)(1)(-a).
- *Equation Cross-References.* The cross-references to equations will follow the same logic. For example, if eq. (1) appears in X.1(a)(1) but is referenced in X.1(b), it will be referenced as eq. (a)(1)(1). If eq. (1) appears in X.1(a)(1) but is referenced in a different subsection/subarticle/paragraph, it will be referenced as eq. X.1(a)(1)(1).

PART RG
GENERAL REQUIREMENTS

ARTICLE RG-1
SCOPE AND JURISDICTION

RG-100 SCOPE

(a) Section X establishes the requirements for the fabrication of fiber-reinforced thermosetting plastic pressure vessels for general service, sets limitations on the permissible service conditions, and defines the types of vessels to which these rules are not applicable.

(b) To assure that vessels fabricated according to these rules will be capable of safely withstanding the operating conditions specified by the Design Specification, this Section:

(1) gives minimum requirements for the materials of fabrication;

(2) specifies test procedures for determining laminate mechanical properties;

(3) Defines three methods of design qualification:

(-a) Class I Design — nondestructive qualification test

(-b) Class II Design — mandatory design rules and acceptance testing by nondestructive evaluation (NDE) methods

(-c) Class III Design — qualification of a vessel design through the destructive test of a prototype

(4) suggests nonmandatory design procedures for Class I vessels;

(5) provides mandatory design procedures and acceptance testing for Class II vessels;

(6) defines the general methods of fabrication which may be used;

(7) limits the types of end closures, connections, and attachments which may be employed and the means used to join them to the vessels;

(8) stipulates the procedures to be used in proving that prototype vessels will withstand specified operating and test conditions;

(9) establishes rules under which fabricating procedures used for fabricating Class I and Class III prototype and production vessels are qualified, and defines what deviations from such procedures necessitate requalification;

(10) sets forth requirements to assure that no essential variation in qualified fabrication procedures has occurred;

(11) establishes rules for acceptance testing, inspection, and reporting;

(12) gives requirements for stamping and marking.

(c) For vessels fabricated in accordance with these rules, the provisions of Section X shall apply over any other sections of the Code. When metallic components are part of fiber-reinforced plastic vessels, they shall meet the provisions of Section VIII, Division 1.

(d) The Fabricator shall establish the effective Code edition, addenda and Code Cases for pressure vessels and replacement parts in accordance with Mandatory Appendix 9.

RG-110 APPLICATION LIMITATIONS

RG-111 DESIGN PRESSURE (21)

The internal design pressure of vessels fabricated under this Section shall be limited as follows:

(a) Class I vessels shall not exceed 150 psi (1 MPa) for bag-molded, centrifugally cast, and contact-molded vessels; 2,000 psi (14 MPa) for filament-wound vessels and 3,000 psi (20 MPa) for filament-wound vessels with polar boss openings only.

(b) Class II vessels shall not exceed the limits specified in RD-1120.

(c) Class III vessels shall not exceed 15,000 psi (103.4 MPa) for filament-wound vessels with polar boss openings only.

RG-112 DESIGN TEMPERATURE

The design temperature of vessels fabricated under this Section shall not exceed the lower of (a) or (b).

(a) 250°F (120°C) for Class I and Class II, and 185°F (85°C) for Class III

(b) 35°F (19°C) below the maximum use temperature (see RM-121) of the resin, nor be less than −65°F (−54°C) (see RD-112)