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Pressure Vessels

The ASME Code Simplified

Robert Chuse
Bryce E. Carson, Sr.



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Seventh Edition

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*Dedicated to
Dr. Michael H. Chuse
1942-1991*

Preface

This seventh edition of *Pressure Vessels: The ASME Code Simplified* has been brought up to date and substantially expanded, containing new sections that outline recent Code changes. The information here represents the authors' more than 60 years combined experience in design, fabrication, and inspection of ASME Code pressure vessels, lending practical experience that couples with up-to-date industry information to make this book a reference tool that is accurate, practical, and easily understood.

The *American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code* has been accepted for many years as the standard for the construction of safe boilers and pressure vessels. This Code is progressive and viable. Important changes and additions are made when required. For example, Code Par. UG-20 contains changes of impact-test requirements and added rules that apply to the design of vessels in regard to expected minimum design metal temperatures during service of the vessel. One major change found in the 1993 ASME Boiler and Pressure Vessel Code was the deletion of most of the stress value tables from these Codes. These tables were replaced by the addition of a new ASME Code Section II, Part D, entitled *Properties*. The Section VIII, Division 1 Code Data Report has been expanded and revised to include the latest Code changes. Code Pars. UCS-66 to 68 were completely rewritten and revised. The National Board Form R-1, Report of Welded Repair or Alteration, has been substantially revised. The joint efficiency requirements were also dramatically revised. Under these new Code rules, the designer must consider each ASME Code Section VIII, Division 1, Table UW-12 joint separately for the value of E which will be utilized in the Code formulas. Radiography is explained, which to use and when to use it to achieve the most cost-effective method: full, spot, or none, whichever is appropriate to the design. Flow charts are given which make understanding these new rules easier.

This book is geared to meet the needs of engineering, manufacturing, repair, and testing companies that have to comply with Code requirements and make Code work better, more efficient, and more profitable. All references are listed here in one simplified manual. This seventh edition pinpoints the industry changes which have taken place over the last few years and helps our readers to become better aware of them, for example, as in the following.

In addition to the specific Code revisions noted above, there are new federal regulations from the U.S. Department of Transportation for cargo tanks. These changes are explained in detail in the newly written Chapter 11 of this seventh edition.

As we approach the year 2000, and as Europe unites economically, the adoption of international standards becomes essential. Just as overseas manufacturers must now conform to ASME standards for vessels to be exported to the United States, the ISO 9000 quality assurance system must be understood and implemented in order to export pressure vessels to Europe in the near future. This quality assurance system is described and clarified in Chapter 12 of this edition.

Welding is one of the most important functions in building pressure vessels. This book is a practical reference and text that can be used in schools and industry. It explains the theory of the weld, welding metallurgy, effects of welding heat, types of welding tests, welding procedures, and qualification of procedures so they can be written as required by the Code and understood clearly. Examples show how tests are prepared, completed, and correctly evaluated.

The various charts, tables, and forms on design, fabrication, and inspection of Code vessels are created to facilitate the reader's application of Code requirements. For example, estimators, engineers, and inspectors will find the thickness tables for cylindrical shells and dished heads for internal pressure useful because they provide information on required thicknesses at a glance. All references to specific parts of the Code—subsections, parts, paragraphs, figures, tables, and appendixes—have been prefixed with the word *Code* (for example, Code Fig. 1-4) in order to distinguish them from references to the various figures, tables, and appendixes in this text.

It is the authors' hope that this book will clarify the reader's understanding of the *ASME Boiler and Pressure Vessel Code* sections and that it will encourage people in the industry to take all the necessary precautions in ordering, designing, fabricating, and inspecting Code vessels.

The data have been selected to answer questions most frequently asked by pressure vessel manufacturers and repair concerns. This information is advisory only, gained from the authors' long experience in

the pressure vessel industry. There is no obligation on the part of anyone to adhere to the recommendations made.

It must be remembered that there is no alternative to reading and understanding the ASME Code. This book is not meant to replace the reading of the Code, but to clarify it.

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This book reflects an industry-wide effort based on contributions of many persons and companies. Special appreciation goes to the following for assistance in writing this seventh edition.

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Contents

Preface	ix
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Chapter 1. Origin, Development, and Jurisdiction of the ASME Code	1
History of the ASME Code	1
Additions to the Code	3
ASME Boiler and Pressure Vessel Committee	4
Procedure for Obtaining the Code Symbol and Certificate	5
The National Board of Boiler and Pressure Vessel Inspectors	6
Shop Reviews by the National Board	7
National Board Requirements	8
Code Case Interpretations	9
The Uniform Boiler and Pressure Vessel Laws Society	10
Canadian Pressure Vessel Requirements	10
Department of Transportation Regulations	16
Welded Repair or Alteration Procedure	17
Managerial Factors in Handling Code Work	20
Work-Flow Schedules	24
Mill Orders	25
Warehouse Orders	25
Shop Organization	26

Chapter 2. Descriptive Guide to the ASME Code Section VIII, Division 1, Pressure Vessels	27
Requirements for Establishing Design Thickness Based on Degree of Radiography (Code Pars. UW-11 and UW-12)	27
Use of Internal-Pressure Cylindrical Shell Thickness Tables	38
Use of Simplified External-Pressure Cylindrical Shell Thickness Charts	47
Use of Internal-Pressure-Thickness Tables for Ellipsoidal and Torispherical Heads	53

Elements of Joint Design for Heads	67
Use of Pressure–Thickness Charts for Flat Heads and Bolted Flat Cover Plates	69
Various Other Designs for Heads	70
Allowable Pressure, Pitch, and Thickness	75
Simplified Calculations for Reinforcement of Openings	80
Cryogenic and Low-Temperature Vessels	83
Impact-Test Exemptions	85
Service Restrictions and Welded Joint Category	92
Noncircular Cross-Section Type Pressure Vessels	94
Jacketed Vessels	96
Pressure Vessels Stamped with the UM Symbol	97
Stamping Requirements	98
Chapter 3. Design for Safety	101
Basic Causes of Pressure Vessel Accidents	101
Corrosion Failures	101
Stress Failures	101
Other Failures	102
Design Precautions	103
Inspection Openings	106
Quick-Opening Closures	107
Pressure Relief Devices	109
Chapter 4. Guide to Quality Control Systems for ASME Code Vessels: A Practical Guide to Writing and Implementing a Quality Control Manual	113
Chapter 5. Inspection and Quality Control of ASME Code Vessels	139
Shop Inspection	139
Tests	142
ASME Manufacturer's Data Reports	146
Field Assembly Inspection	147
Responsibility for Field Assembly	147
Inspection Procedure	148
Radiography	149
Conditions Requiring Radiography	149
Interpretation of Welding Radiographs	151
Sectioning	157
Hydrostatic Testing	159
Test Gage Requirements	161
Seven Simplified Steps to Efficient Weld Inspection	161
Chapter 6. Welding, Welding Procedure, and Operator Qualification	165
Examination of Procedure and Operator	165

Record of Qualifications	166
Welding Procedures and Qualification Simplified	166
Welding Procedure Specification Forms	168
Variables [Code Pars. QW-400, QW-250, and QW-350 and Tables QW-415 (WPS) and QW-416 (WPQ)]	170
Welder Qualifications	173
Welding Details and Symbols	180
Joint Preparation and Fit-Up	185
Effects of Welding Heat	187
Preheating	192
Postweld Heat Treatment	193
Conditions Requiring Postweld Heat Treatment	194
 Chapter 7. Nondestructive Examination	 197
Leak Testing	206
Acoustic Emission Testing	207
 Chapter 8. ASME Code Section VIII, Division 2, Alternative Rules	 209
 Chapter 9. Power Boilers: Guide to the ASME Code Section I, Power Boilers	 215
 Chapter 10. Nuclear Vessels and Required Quality Assurance Systems	 223
Power Plant Cycles	223
Pressurized Water Reactor Plants	224
Boiling Water Reactor Plants	225
Quality Assurance	229
 Chapter 11. Department of Transportation Requirements for Cargo Tanks	 239
History and Overview of 49 CFR§107 to §180	239
Specification Cargo Tanks—General Design Information (§178.340)	240
Specification Cargo Tank MC-306 (§178.341)	241
Specification Cargo Tank MC-307 (§178.342)	243
Specification Cargo Tank MC-312 (§178.343)	244
Specification Cargo Tank MC-331 (§178.337[])	246
Certification of Cargo Tanks (§178.340-10)	249
Maintenance of Specification Cargo Tanks—General Information (§180)	252
Glossary of Terms	253
Qualification and Maintenance of Specification Cargo Tanks §180 to §180.417)	255
Purpose, Applicability, and General Requirements (§180.1 to §180.3)	255
Definitions (§180.403)	255
Qualification of Cargo Tanks (§180.405)	256

Upgrading Existing Specification MC-306, MC-307, and MC-312 Cargo Tanks [§180.405(c) to (g)]	257
Requirements for Tests and Inspections of Specification Cargo Tanks (§180.407)	258
Minimum Qualifications for Inspectors and Testers (§180.409)	267
Acceptable Results of Tests and Inspections (§180.411)	269
Repair, Modification, Stretching, or Rebarreling of a Cargo Tank (§180.413)	270
Test and Inspection Markings (§180.415)	271
Reporting and Record Retention Requirements (§180.417)	273
 Chapter 12. ISO 9000 Quality Assurance Systems	 275
Introduction to ISO 9000 Standards	275
Assessment of the Quality Assurance Program	278
Notified Bodies and the CE Mark	281
 Appendix A. Cylinder Volume Tables and Diagrams	 283
 Appendix B. Circumferences of Cylinders	 289
 Appendix C. Decimal Equivalents and Theoretical Weights of Steel Plates	 301
 Appendix D. Pipe Wall Thicknesses	 303
 Appendix E. Dry Saturated Steam Temperatures	 305
 Appendix F. Metric (SI) Units; English and Metric Conversions	 309
 Bibliography	315
Index	317

Origin, Development, and Jurisdiction of the ASME Code

History of the ASME Code

On March 20, 1905, a disastrous boiler explosion occurred in a shoe factory in Brockton, Massachusetts, killing 58 persons, injuring 117 others, and causing a quarter of a million dollars in property damage. For years prior to 1905, boiler explosions had been regarded as either an inevitable evil or “an act of God” (see Figs. 1.1 and 1.2). But this catastrophic accident had the effect of making the people of Massachusetts see the necessity and desirability of legislating rules and regulations for the construction of steam boilers in order to secure their maximum safety. After much debate and discussion, the state enacted the first legal code of rules for the construction of steam boilers in 1907. In 1908, the state of Ohio passed similar legislation, the Ohio Board of Boiler Rules adopting, with a few changes, the rules of the Massachusetts Board.

Therefore, other states and cities in which explosions had taken place began to realize that accidents could be prevented by the proper design, construction, and inspection of boilers and pressure vessels and began to formulate rules and regulations for this purpose. As regulations differed from state to state and often conflicted with one another, manufacturers began to find it difficult to construct vessels for use in one state that would be accepted in another. Because of this lack of uniformity, both manufacturers and users made an appeal in 1911 to the Council of the American Society of Mechanical Engineers to correct the situation. The Council answered the appeal by appointing a committee “to formulate standard specifications for the construction of steam boilers and other pressure vessels and for their care in service.”

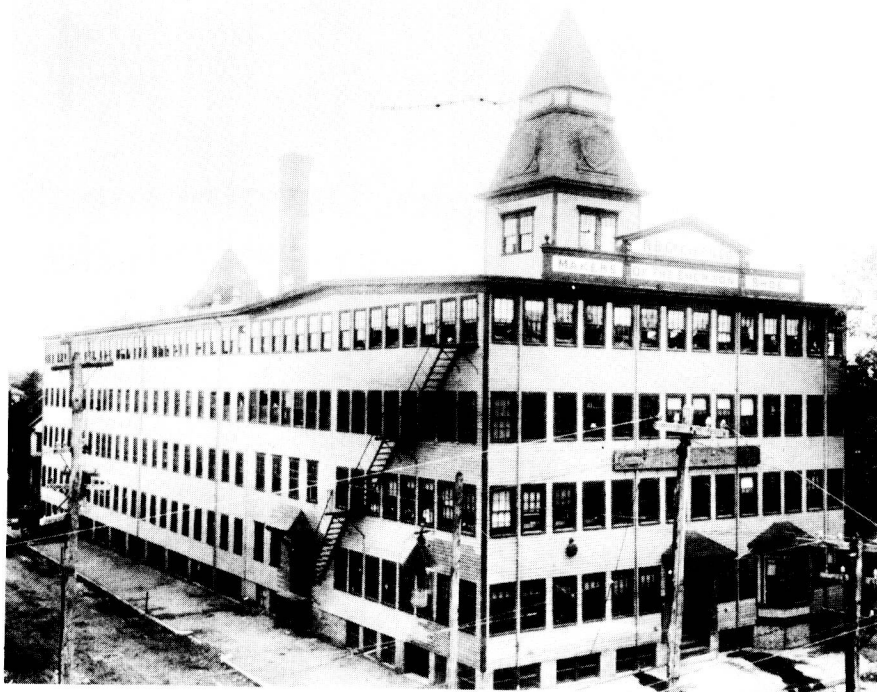


Figure 1.1 The Brockton, Massachusetts, shoe factory. (Courtesy of The Hartford Steam Boiler Inspection and Insurance Company.)

The first committee consisted of seven members, all experts in their respective fields: one boiler insurance engineer, one material manufacturer, two boiler manufacturers, two professors of engineering, and one consulting engineer. The committee was assisted by an advisory committee of 18 engineers representing various phases of design, construction, installation, and operation of boilers.

Following a thorough study of the Massachusetts and Ohio rules and other useful data, the committee made its preliminary report in 1913 and sent 2000 copies of it to professors of mechanical engineering, engineering departments of boiler insurance companies, chief inspectors of boiler inspection departments of states and cities, manufacturers of steam boilers, editors of engineering journals, and others interested in the construction and operation of steam boilers, with a request for suggestions of changes or additions to the proposed regulations.

After three years of countless meetings and public hearings, a final draft of the first *ASME Rules for Construction of Stationary Boilers and For Allowable Working Pressures*, known as the 1914 edition, was adopted in the spring of 1915.



Figure 1.2 Shoe factory after the boiler explosion of March 20, 1905, which led to the adoption of many state boiler codes and the *ASME Boiler and Pressure Vessel Code*. (Courtesy of *The Hartford Steam Boiler Inspection and Insurance Company*.)

Additions to the Code

Since 1914, many changes have been made and new sections added to the Code as the need arose. The present sections are listed in the following order:

Section I. Power Boilers

Section II. Material Specifications

Ferrous Materials, Part A

Nonferrous Materials, Part B

Welding Rods, Electrodes, and Filler Metals, Part C

Properties, Part D

Section III, Division 1. Nuclear Power Plant Components

Subsection NCA: General Requirements

Subsection NB: Class 1 Components

Subsection NC: Class 2 Components

Subsection ND: Class 3 Components

Subsection NE: Class MC Components

Subsection NF: Component Supports

Subsection NG: Core Support Structures

Section III, Division 2. Concrete Reactor Vessel Containments

Section IV. Heating Boilers

Section V. Nondestructive Examinations

Section VI. Recommended Rules for Care and Operation of Heating Boilers

Section VII. Recommended Rules for Care of Power Boilers

Section VIII, Division 1. Pressure Vessels

Section VIII, Division 2. Pressure Vessels—Alternative Rules

Section IX. Welding and Brazing Qualifications

Section X. Fiberglass-Reinforced Plastic Pressure Vessels

Section XI. Rules for Inservice Inspection of Nuclear Power Plant Components

ASME Boiler and Pressure Vessel Committee

The increase in the size of the Code reflects the progress of industry in this country. To keep up with this spontaneous growth, constant revisions have been required. The ASME Code has been kept up to date by the Boiler and Pressure Vessel Committee (currently consisting of more than 800 volunteer engineers and other technical professionals) which considers the needs of the users, manufacturers, and inspectors of boilers and pressure vessels. In the formulation of its rules for the establishment of design and operating pressures, the Committee considers materials, construction, methods of fabrication, inspection, certification, and safety devices. The ASME works closely with the American National Standards Institute (ANSI) to assure that the resulting documents meet the ANSI criteria for publication as American National Standards.

The members of the Committee do not represent particular organizations or companies but have recognized background and experience by which they are placed in categories, which include manufacturers, users of the products for which the codes are written, insurance inspection, regulatory, and general. The Committee meets on a regular basis to consider requests for interpretations and revisions and additions to Code rules as dictated by advances in technology. Approved revisions and additions are published semiannually as addenda to the Code.

To illustrate, boilers were operating in 1914 at a maximum pressure of 275 psi and temperature of 600°F. Today, boilers are designed for pressures as high as 5000 psi and temperatures of 1100°F, and pressure vessels for pressures of 3000 psi and over and for temperatures ranging from -350°F to more than 1000°F.

Each new material, design, fabrication method, and protective device brought new problems to the Boiler Code Committee, requiring the expert technical advice of many subcommittees in order to expedite proper additions to and revisions of the Code. As a result of the splendid work done by these committees, the *ASME Boiler and Pressure Vessel Code* has been developed; it is a set of standards that assures every state of the safe design and construction of all boiler and pressure vessels used within its borders and is used around the world as a basis for enhancing public health, safety, and welfare. Many foreign manufacturers are accredited under the provisions of the *ASME Boiler and Pressure Vessel Code*.

Procedure for Obtaining the Code Symbol and Certificate

Users of pressure vessels prefer to order ASME Code vessels because they know that such vessels will be designed, fabricated, and inspected to an approved quality control system in compliance with a safe standard. Pressure vessel manufacturers want the Code symbol and Certificate of Authorization so that they will be able to bid for Code work, thereby broadening their business opportunities. They also believe that authorization to build Code vessels will enhance the reputation of their shop.

If a company is interested in building Code vessels according to the ASME Section VIII, Division 1, Pressure Vessels Code, it should acquaint itself with Code Par. U-2, which requires the manufacturer to have a contract or agreement with a qualified inspection agency employing Authorized Inspectors. This third party in the manufacturer's plant, by virtue of being authorized by the state to do Code inspection, is the legal representation which permits the manufacturer to fabricate under state laws (the ASME Code).

Manufacturers who want to construct Code vessels covered by Section VIII, Division 1, obligate themselves with respect to quality and documentation (see Code Appendix 10, Quality Control Systems). A survey will be required for the initial issuance of an ASME Certificate of Authorization and for each renewal. The evaluation is performed jointly by the Authorized Inspection Agency and the jurisdictional authority concerned which has adopted, and also administers, the applicable boiler and pressure vessel legislation. When the jurisdictional authority does not make the survey, or the jurisdiction is the inspection agency, the National Board of Boiler and Pressure Vessel Inspectors will be asked to participate in the survey.

After the survey has been jointly made to establish that a quality