Pressure Vessels

The ASME Code Simplified

Robert Chuse

Bryce E. Carson, Sr.

Seventh Edition

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During his 43 year career, Mr. Chuse has published more than 45 articles on pressure vessel design, fabrication, and quality control in engineering and industrial journals. His articles and books are widely used by pressure vessel fabricators, designers, and users. He has given lectures on quality control, welding procedure qualification, and pressure vessel design and fabrication for the American Welding Society as well as for utility and manufacturing engineering departments. Mr. Chuse is a member of the American Society of Mechanical Engineers.

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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.

Acknowledgments

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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Chapter

1

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."

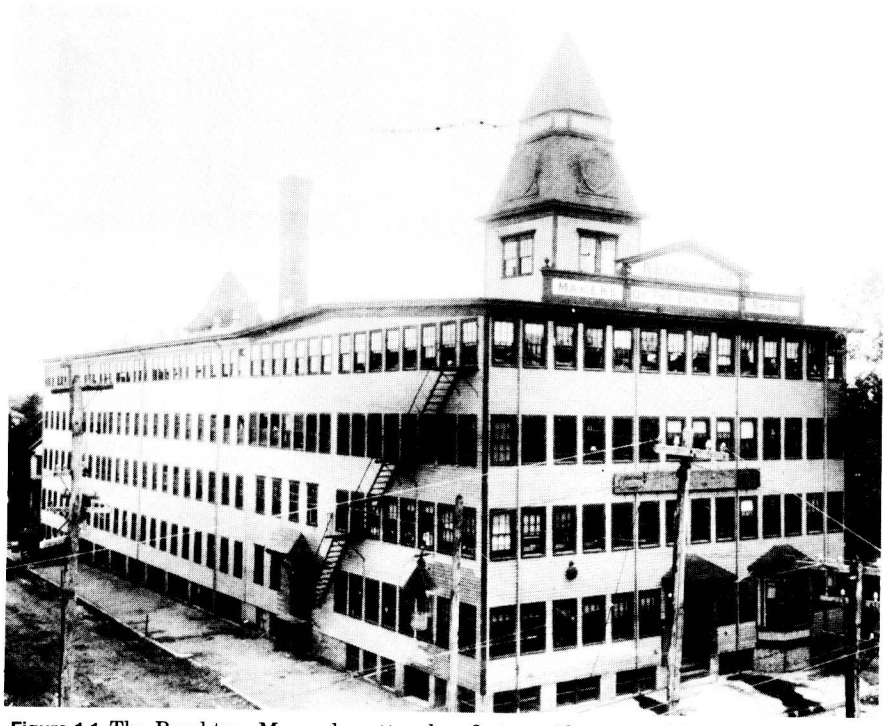

Figure 1.1 The Brockton, Massachusetts, shoe factory. (*Courtesy of The Hartford Steam Boiler Inspection and Insurance Company.*)

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