

# **POWER BOILERS**

**A GUIDE TO SECTION I OF  
THE ASME BOILER AND  
PRESSURE VESSEL CODE**

**Second Edition**

by

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# DEDICATION TO THE SECOND EDITION

*The authors of the Second Edition dedicate this book to their esteemed colleague on Section I, the late Martin D. Bernstein. Martin (Marty to most of his good friends) served with passion and dedication from the early 1970s until his untimely passing in 2002, at which time he was Vice-chairman of the Committee. In addition to his duties on Section I, Marty was an active member of the ASME Committee on Safety Valve Requirements, serving as Vice-Chairman from 1990 and Chairman in 2000. We were fortunate to know Marty and to have had the pleasure of his company during the frequent Boiler Code weeks over the years.*

# DEDICATION TO THE FIRST EDITION

*The authors dedicate this book to their distinguished colleague on Subcommittee I, the late Walter Harding of Combustion Engineering. From the 1950s until his retirement in the 1980s, Walter Harding served with distinction on the ASME Boiler and Pressure Vessel Committee in many capacities, including Chairman of the Main Committee. An engineer of the greatest integrity, Harding was an inspiring role model for younger committee members, extremely knowledgeable, ever helpful, cheerful, and the possessor of a fine sense of humor. We were fortunate to have had the privilege of serving with him.*



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# FOREWORD

In 1986, the ASME Professional Development Department approached original author Martin Bernstein and asked him to develop and teach a 2-day professional development course on Section I of the ASME Boiler and Pressure Vessel Code, whose title is now Rules for Construction of Power Boilers. The task of developing course notes and the prospect of teaching all day for 2 days with no relief were somewhat daunting, so Bernstein enlisted the help of Lloyd Yoder, his long-time friend and colleague on BPV Committee on Power Boilers I (BPV I), the ASME committee that governs Section I. The two then collaborated on the preparation of appropriate notes and from 1986 to just prior to Martin's death in March, 2002, taught a 2-day course for the ASME at various locations within the United States and overseas. During that time, they expanded and refined the course notes, covering material of interest to those who have been taking the course — design engineers; project managers; architect engineers; engineers from boiler manufacturers, boiler operators, and insurance and inspection agencies; and others involved with power boilers and the ASME Code governing their construction.

The introduction in the brochure for that 2-day professional development course on Section I explained that Section I contains the rules for the construction of power boilers, but that those rules are accompanied by very little explanation. Thus, the course was intended to provide a basic understanding of those rules, their intent, and how they are applied, interpreted, and revised. This book is a greatly expanded version of those course notes, with broader and more detailed coverage on various topics of interest to those involved with power boilers.

Author John MacKay was asked to take on the task of updating this book. He recruited Jim Pillow, friend and BPV I colleague, to assist with the effort. John and Jim accepted the challenge as a way to honor the accomplishments of Martin and Lloyd and to carry on their work. Both Martin and Lloyd spent their careers working for major boiler manufacturers and decades serving in various capacities on the ASME Boiler and Pressure Vessel Committees. Likewise, John and Jim have spent their careers involved in the design, manufacture, and installation of power boilers and continue their decades of service as members of the ASME Boiler and Pressure Vessel Committees. This book is a compendium of the authors' knowledge and experience.

The design and construction of power boilers involves the use of other sections of the ASME Code besides Section I, and the use of those other sections is explained in this book when appropriate. Section II, Materials, provides detailed specifications for materials and welding consumables, as well as tabulations of design stresses and material properties, such as yield strength and tensile strength as a function of temperature. Section V, Nondestructive Examination, contains a series of standards that provide the methodology for conducting the various nondestructive examinations used in Section I construction. Section IX, Welding and Brazing Qualifications, provides the information necessary to qualify the weld procedures and the welders required for Section I construction. In a rather unusual arrangement, the construction rules for boiler piping are found partly in Section I and partly in the B31.1 Power Piping Code. This has led to considerable misunderstanding and confusion, and the authors have endeavored to provide a clear explanation of these rules and the potential pitfalls to be avoided.

Both authors of this edition are long-time members of the ASME committee that governs Section I, BPV I. In the course of its duties, that committee answers a steady flow of questions from all over the world on the application and interpretation of Section I. The authors have thus participated in or are familiar with

Section I interpretations and Code changes going back more than three decades. Since 1978 the ASME has been publishing those interpretations, but they are not widely or readily available, nor is their background known by most people. A useful feature of this book is that as a particular subject is covered, many important interpretations dealing with that subject are cited and discussed. These interpretations form a very useful body of reference information, since they explain or clarify rules that have led to inquiries from the public and provide insight into the views of BPV I.

Although Section I nominally covers only the new construction of power boilers, this book goes further and contains a chapter on rules covering boilers in service, such as those found in the National Board Inspection Code. The original authors also found that participants in their course on Section I were interested in the subject of creep and fatigue damage during boiler life and the related subject of boiler life extension. Accordingly, a chapter providing an overview of those subjects has been included.

When the ASME in 1911 began the development of a boiler code, it addressed a serious safety problem of that time by formulating a uniform set of rules for the construction of steam boilers, rules that could be adopted by all the states. That set of rules eventually became Section I. The interesting history of steam power in the nineteenth century provides the background for the development of Section I and is described in Appendix I.

The organization and operation of the ASME Boiler and Pressure Vessel Committees is a subject not likely to be found on a best-seller list. Nevertheless, some knowledge of the workings of the committees may prove useful for those submitting inquiries or requests for Code changes, or for Code Cases. Appendix II provides a description of how the committees operate.

Those unfamiliar with the ASME Code may at first be confused by a number of terms commonly used in it. Examples include third party inspection, Authorized Inspector, Authorized Inspection Agency, Certified Individual, jurisdiction, Maximum Allowable Working Pressure (MAWP), boiler proper, boiler proper piping, boiler external piping, interpretation, Code Case, certification, and Certificate of Authorization (to use a Code symbol stamp). The authors explain these terms in the text wherever appropriate.

Although the ASME Boiler and Pressure Vessel Code changes relatively slowly, it does change continuously and, at times, profoundly. The rate of change in recent years seems to have increased, perhaps due to technological innovation and international competition. Thus, while it provides a substantial body of information and an explanation of the rules as they now exist, this book can never provide the last word. The Code Edition covered in the original issue of this book was the 1998 Edition of Section I, which was comprised of the 1995 Edition with Addenda through 1997. In a departure from previous practice, the 1998 Edition included the first Addenda to that Edition, the 1998 Addenda, as explained further in Chapter 2. This edition of this book covers the 2010 Edition with the 2010 Addenda. The authors are confident that the book will provide the industry with a very useful reference and guide to Section I.

# INTRODUCTION

It is helpful to begin the study of Power Boilers, Section I of the ASME Boiler and Pressure Vessel Code, with some discussion of its character and philosophy. According to the dictionary, the term **code** has several meanings: a system of principles or rules; a body of laws arranged systematically for easy reference. Section I is primarily a system of rules. When, in 1911, the ASME decided that the country needed a boiler code, it assigned a committee and gave it a mandate to formulate standard rules for the construction of steam boilers and other pressure vessels. The first edition of what is now known as Section I was finally approved by the ASME in 1915 and incorporated what was considered the best current practice in boiler construction. However, the guiding principle then, as now, was that these be safety rules.

Part of the Foreword of Section I explains the guiding principles and philosophy of Section I, and also of the Boiler and Pressure Vessel Committees, which continues to administer the Code:

*The American Society of Mechanical Engineers set up a committee in 1911 for the purpose of formulating standard rules for the construction of steam boilers and other pressure vessels. This committee is now called the Boiler and Pressure Vessel Committee.*

*The Committee's function is to establish rules of safety, relating only to pressure integrity, governing the construction of boilers, pressure vessels, transport tanks and nuclear components, and inservice inspection for pressure integrity of nuclear components and transport tanks, and to interpret these rules when questions arise regarding their intent. This code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks and nuclear components, and the inservice inspection of nuclear components and transport tanks. The user of the Code should refer to other pertinent codes, standards, laws, regulations, or other relevant documents. With few 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. Recognizing this, the Committee has approved a wide variety of construction rules in this Section to allow the user or his designee to select those which will provide a pressure vessel having a margin for deterioration in service so as to give a reasonably long, safe period of usefulness. Accordingly, it is not intended that this Section be used as a design handbook; rather, engineering judgment must be employed in the selection of those sets of Code rules suitable to any specific service or need.*

*This Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities. The Code does not address all aspects of these activities, and those aspects which 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 designers 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 Boiler and Pressure Vessel Committee deals with the care and inspection of boilers and pressure vessels in service only to the extent of providing suggested rules of good practice as an aid to owners and their inspectors.*

*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.*

Certain points in these paragraphs should be stressed. Section I covers the construction, i.e., materials, design, fabrication, examination, inspection, testing, certification, and pressure relief of boilers. That is, it covers new construction only. (Rules covering boilers in service will be discussed later, in Chapter 16.) Although there is general agreement that Section I should apply to new replacement parts, and such parts are usually specified that way, until the appearance of the 1996 Addenda, Section I had no clear provisions dealing with replacement parts other than how they should be documented. Those Addenda included changes to PG-106.8 and PG-112.2.4, which require the manufacturer of replacement parts to state on the data report form (the documentation that accompanies the part; see Chapter 9) the extent to which the company is assuming design responsibility for a replacement pressure part.

Also mentioned in the Foreword is the impracticality of establishing rules addressing in-service deterioration due to operating environments; however, a wide variety of construction rules have been approved from which the manufacturer may select to provide a boiler having a margin for deterioration in service so as to give a reasonably long, safe period of usefulness. This is an acknowledgment of the fact that no equipment lasts forever and that boilers do have a finite life. The mechanisms by which a boiler wears out and the means by which remaining life may be estimated are discussed in Chapter 14.

The Section I rules were based on the best design practice known when they were written and have continued to evolve on the same basis. They have worked well over many years. Rule changes have been made that recognize advances in design and materials, as well as evidence of satisfactory experience. The needs of the users, manufacturers, and inspectors are considered, but safety relating to pressure integrity is always the primary concern.

Another basis for the success of Section I is its committee's insistence that the rules be general and not be interpreted as approving, recommending, or endorsing any proprietary or specific design or limiting a manufacturer's freedom to choose any design or construction that conforms to the Code rules. The committee considers that a manufacturer is ultimately responsible for the boiler design and leaves certain aspects not explicitly covered by Section I to the manufacturer. Traditionally, the manufacturer has recognized and borne the responsibility for such things as functional performance, providing for thermal expansion and support of the boiler and its associated piping and for consideration of thermal stress, wind, and seismic loading.

The useful advice that Section I is not a handbook and cannot replace education, experience, and the use of engineering judgment was added to the Foreword of all sections of the Code in the 1992 Addenda. This overdue advice was added in an attempt to limit the ASME's entanglement in certain disputes among manufacturers, owners, and regulatory authorities regarding the application of the Code.

Further evidence of the flexibility and reasonableness of Section I and another key to its success as a living document is found in the second paragraph of the Preamble:

*The Code does not contain rules to cover all details of design and construction. Where complete details are not given, it is intended that the manufacturer, subject to the acceptance of the Authorized Inspector, shall provide details of design and construction which will be as safe as otherwise provided by the rules in the Code.*

This important paragraph provides a way to accept new or special designs for which no rules are given, by allowing the designer to prove to the satisfaction of an Authorized Inspector that the safety of the new design is equivalent to that usually supplied.



According to one of the definitions cited above, a code is a body of laws arranged systematically for easy reference. Although this may be true of Section I, it is not at first easy to use or understand because it is neither a textbook nor an engineering design manual. It is rather a collection of rules that have been revised and expanded over the years with very little accompanying explanation. These rules mandate the fundamental construction features considered necessary for a safe boiler (one that is a safe pressure container), but typically do not provide any advice on how to design a boiler from the standpoint of what size or arrangement of components should be used. There are no provisions dealing with the thermal performance and efficiency of the boiler or how much steam it will produce (other than for some approximate guidelines for judging the adequacy of the pressure relief valve discharge capacity). It is assumed that the boiler manufacturer or designer already has this knowledge, presumably from experience or available technical literature. Many rules seem, and indeed are, arbitrary; but as explained before, they were originally written to incorporate what was considered good practice in the industry.

Section I's method of achieving safe boiler design is a relatively simple one. It requires all those features considered necessary for safety (e.g., water gauge glass, pressure relief valve, pressure gauge, check valve, drain) and then provides detailed rules governing the construction of the various components comprising the boiler, such as tubes, piping, headers, shells, and heads. This approach is analogous to the old saying that a chain is no stronger than its weakest link. For a boiler, the links of the figurative chain can be considered to be the material, the design (formulas, loads, allowable stresses, construction details), fabrication techniques including welding, examination, inspection, testing, overpressure protection and certification by stamping and data reports. If each of these elements meets the appropriate Section I rules, a safe boiler results. The boiler can then be described as a Section I boiler, meaning one constructed to meet all the requirements of Section I of the ASME Boiler and Pressure Vessel Code. An important element of this construction process is a quality control program, intended to assure that the Code has been followed. Each aspect of the process is discussed in this book.

Code construction under the rules of Section I takes place as follows: The ASME certifies a manufacturer (i.e., after appropriate review and acceptance of the manufacturer's facilities, organization, and quality control system, authorizes the manufacturer to engage in Code construction). The manufacturer then constructs, documents, certifies, and stamps the boiler in compliance with the rules of Section I. The manufacturer's activities are monitored and inspected by a third party (the Authorized Inspector, see Chapter 8). The boiler is then acceptable to jurisdictions with laws stipulating ASME construction of boilers. Section IV construction (of heating boilers), Section VIII construction (of pressure vessels), Section X construction (of fiber-reinforced plastic pressure vessels) and Section XII construction (of transport tanks) is carried out in similar fashion.



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