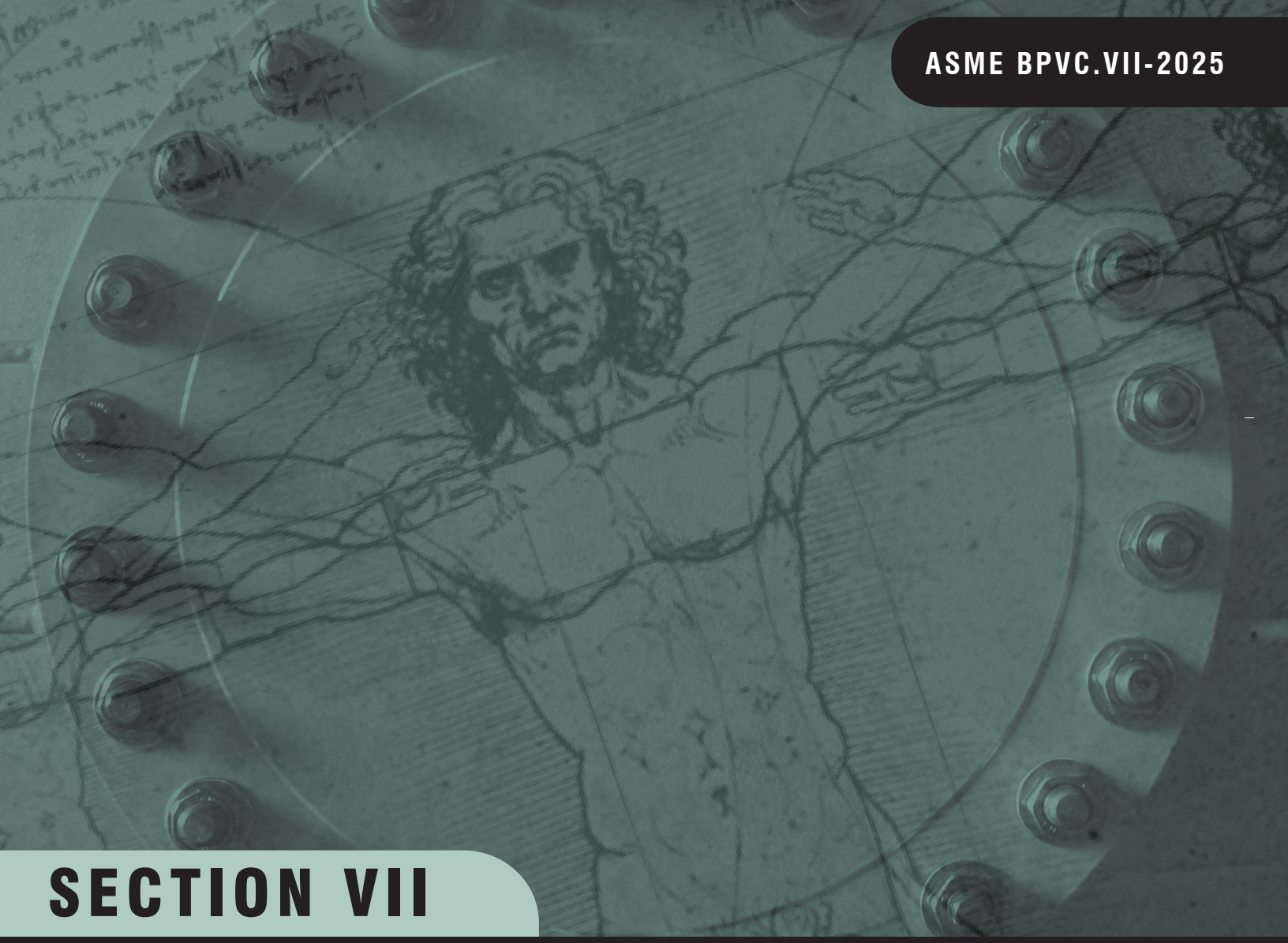
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SECTION VII

2025 ASME Boiler and Pressure Vessel Code

An International Code

Recommended Guidelines for the Care of Power Boilers



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AN INTERNATIONAL CODE

2025 ASME Boiler & Pressure Vessel Code

2025 Edition July 1, 2025

VII

RECOMMENDED GUIDELINES FOR THE CARE OF POWER BOILERS

ASME Boiler and Pressure Vessel Committee
on Power Boilers

The American Society of Mechanical Engineers

Two Park Avenue • New York, NY • 10016 USA

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FOREWORD*

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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 In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees: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. The rules govern the construction** of boilers, pressure vessels, transport tanks, and nuclear components, and the inservice inspection of nuclear components and transport tanks. For nuclear items other than pressure-retaining components, the Committee also establishes rules of safety related to structural integrity. 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. The 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 and, for nuclear items other than pressure-retaining components, structural 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 components addressed by the Code. 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.

The 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

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

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responsible for all technical assumptions inherent in the programs they use and the application of these programs to their design.

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 the Code. Requests for revisions, new rules, Code cases, or interpretations shall be addressed to the staff secretary in writing and shall give full particulars in order to receive consideration and action (see the Correspondence With the Committee page). 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 the Code, the singular shall be interpreted as the plural, and vice versa.

The words "shall," "should," and "may" are used in the Code 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.

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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.

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General

ASME codes and standards are developed and maintained by committees with the intent to represent the consensus of concerned interests. Users of ASME codes and standards may correspond with the committees to propose revisions or cases, report errata, or request interpretations. Correspondence for this Section of the ASME Boiler and Pressure Vessel Code (BPVC) should be sent to the staff secretary noted on the Section's committee web page, accessible at https://go.asme.org/CSCommittees.

NOTE: See ASME BPVC Section II, Part D for guidelines on requesting approval of new materials. See Section II, Part C for guidelines on requesting approval of new welding and brazing materials ("consumables").

Revisions and Errata

The committee processes revisions to this Code on a continuous basis to incorporate changes that appear necessary or desirable as demonstrated by the experience gained from the application of the Code. Approved revisions will be published in the next edition of the Code.

In addition, the committee may post errata and Special Notices at http://go.asme.org/BPVCerrata. Errata and Special Notices become effective on the date posted. Users can register on the committee web page to receive email notifications of posted errata and Special Notices.

This Code is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number, the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Code

(4) to permit use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases 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.

(c) The committee will consider proposed cases concerning the following topics only:

(1) equipment to be marked with the ASME Single Certification Mark, or

(2) equipment to be constructed as a repair/replacement activity under the requirements of Section XI

(d) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Code Section and the paragraph, figure, or table number to which the proposed case applies

(4) the editions of the Code to which the proposed case applies

(e) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Cases that have been approved will appear in the next edition or supplement of the Code Cases books, "Boilers and Pressure Vessels" or "Nuclear Components." Each Code Cases book is updated with seven Supplements.

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Supplements will be sent or made available automatically to the purchasers of the Code Cases books until the next edition of the 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. The status of any case is available at http://go.asme.org/BPVCCDatabase. An index of the complete list of Boiler and Pressure Vessel Code Cases and Nuclear Code Cases is available at http://go.asme.org/BPVCC.

Interpretations

(a) Interpretations clarify existing Code requirements and are written as a question and reply. Interpretations do not introduce new requirements. If a revision to resolve conflicting or incorrect wording is required to support the interpretation, the committee will issue an intent interpretation in parallel with a revision to the Code.

(b) Upon request, the committee will render an interpretation of any requirement of the Code. An interpretation can be rendered only in response to a request submitted through the online Inquiry Submittal Form at http://go.asme.org/InterpretationRequest. Upon submitting the form, the inquirer will receive an automatic email confirming receipt.

(c) ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Code requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers may track the status of their requests at http://go.asme.org/Interpretations.

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

(e) Interpretations are published in the ASME Interpretations Database at http://go.asme.org/Interpretations as they are issued.

Committee Meetings

The ASME BPVC committees regularly hold meetings that are open to the public. Persons wishing to attend any meeting should contact the secretary of the applicable committee. Information on future committee meetings can be found at http://go.asme.org/BCW.

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ORGANIZATION OF SECTION VII (25)

1 GENERAL

The purpose of Section VII, Recommended Guidelines for the Care of Power Boilers, is to promote safety in the use of power boilers. These guidelines are intended for use by those directly responsible for operating, maintaining, and examining power boilers.

With respect to the application of these guidelines, a power boiler is a pressure vessel constructed in compliance with Section I in which, due to the application of heat, steam is generated at a pressure exceeding 15 psig (100 kPa) for use external to the boiler. The heat may be derived from the combustion of fuel (solids, liquids, or gases), from the hot waste gases of other chemical reactions, or from the application of electrical energy. The term *power boiler* in this Section includes stationary, locomotive, portable, and traction types, but does not include high-temperature water boilers or miniature boilers (Section I), nuclear power plant boilers (Section III), heating boilers (Section IV), pressure vessels (Section VIII), or marine boilers.

These guidelines apply to the boiler proper, pipe connections and piping up to and including the valve or valves as required by the Code, superheaters, reheaters, economizers, and appurtenances that are directly associated with the boiler.

Guidelines are also provided for operation of auxiliary equipment that affects the safe and reliable operation of power boilers.

Formulating a set of guidelines that is applicable to all sites and types of plants is difficult; therefore, it may be advisable to depart from these guidelines in specific cases. Manufacturer's operating instructions should always be adhered to. Other industry-accepted codes and procedures, such as the National Fire Protection Association's codes covering prevention of furnace explosions, are recommended for additional guidance.

2 SUBSECTIONS AND ARTICLES

Section VII consists of Subsections 1 through 5; Subsections are divided into Articles.

- Subsection 1 — Watertube Drum-Type Industrial Steam Boilers: this Subsection focuses primarily on watertube drum-type industrial steam boilers fired with natural gas or fuel oil at steam conditions up to 600 psig and 750°F (4 MPa and 400°C), because of their extensive use.
  - Article 100, Fundamentals of Watertube Boilers — a general description of boiler fundamentals, including steam generation, boiler assembly types, typically connected pressure parts, combustion, boiler efficiency, and emissions.
  - Article 101, Boiler Operation — guidelines for routine boiler operation, including start-up, normal operation, and shutdown, as well as operator training for safe and reliable operation.
  - Article 102, Boiler Auxiliaries — guidelines for normal and some emergency operations of fuel-burning equipment, air heaters, boiler feed pumps, fans, and other auxiliaries commonly used in the operation of boilers. Emphasis is placed on operating the auxiliaries to avoid an unsafe condition in a boiler.
  - Article 103, Appurtenances — operating guidelines and descriptions for frequently used boiler appurtenances, such as pressure relief valves (safety valves), water columns, gage glasses, drum water-level transmitters, blowdown systems, pressure gages, feedwater regulator valves, and soot blowers.
  - Article 104, Instrumentation, Controls, and Interlocks — brief description and listing of recommended instrumentation for monitoring boiler status and drum water level, controls for boiler operation, and interlocks to prevent unsafe conditions.
  - Article 105, Examinations — guidelines for examination of boilers to ensure that the boiler is capable of safe and reliable operation. These guidelines apply only to those who are responsible for the examination, operation, and maintenance of boiler plants and must not be considered as applying to the state, municipal, or insurance companies' inspectors. Consideration should be given to the importance of continual examination as compared

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with periodic examination. These guidelines are not intended to define or limit the extent of inspection by the Authorized Inspector.
  - Article 106, Repairs, Alterations, and Maintenance — guidelines for boiler repairs and alterations to return the boiler to a safe condition, and for routine maintenance programs to improve boiler availability and keep boilers in a safe operating condition.
- Subsection 2 — Pertaining to All Steam Boilers: this Subsection is intended to apply to boilers described in Subsection 1 and is likely to apply to all Section I steam boilers.
  - Article 200, Protecting Heat Transfer Surfaces — guidelines addressing internal cleaning, laying up, deposits, corrosion, steam contamination, water chemistry, and fire-side conditions
  - Article 201, Preventing Boiler Failures — guidelines for operation of protective equipment, and precautions to prevent causes of boiler failures, such as overpressure, high or low water level, weakening of structure, explosions, and implosions
  - Article 202, Documents, Records, and References — a description of typically required Code documentation and where to obtain copies; information regarding other sources of documents relative to a specific boiler installation, and guidelines for maintaining up-to-date records; and a listing of references cited in this Section
- Subsection 3 — Other Boiler Types: this Subsection contains information regarding other boiler types as they differ from the watertube drum-type industrial steam boilers discussed in Subsections 1 and 2.
  - Article 300, Firetube Boilers
  - Article 301, Electric Steam Boilers
  - Article 302, Utility Boilers
- Subsection 4 — Coal-Fired and Other Solid-Fuel-Fired Boilers: this Subsection includes guidelines unique to boilers fired by coal and other solid fuels.
  - Article 400, Stoker-Fired Boilers
  - Article 401, Pulverized-Coal-Fired Boilers
  - Article 402, Ash Removal
  - Article 403, Maintenance
- Subsection 5 — Glossary. This Subsection is a glossary of words contained in Section VII or likely to be used regarding a boiler.

3 APPENDICES

Mandatory Appendix I — Standard Units for Use in Equations

Nonmandatory Appendix A — Checklists for Maintenance Examinations. This Nonmandatory Appendix contains checklists for the maintenance examinations of boilers.

Nonmandatory Appendix B — Guidance for the Use of U.S. Customary and SI Units in the ASME Boiler and Pressure Vessel Code

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SUMMARY OF CHANGES

Changes listed below are identified on the pages by a margin note, **(25)**, placed next to the affected area.

Page	*Location*	*Change*
viii	List of Sections	Title of Section XI, Division 1 revised
ix	Foreword	Third, fourth, seventh, tenth, and eleventh paragraphs editorially revised
xii	Personnel	Updated
xxxvii	Organization of Section VII	Paragraph 1 revised
9	101.1.6.1	Updated
15	101.4.2.4	Revised
46	103.4	Second paragraph revised
95	202.4	Updated

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CROSS-REFERENCING IN THE ASME BPVC

Paragraphs within the ASME BPVC may include subparagraph breakdowns, i.e., nested lists. The following is a guide to the designation and cross-referencing of subparagraph breakdowns:

(a) Hierarchy of Subparagraph Breakdowns

(1) First-level breakdowns are designated as (a), (b), (c), etc.

(2) Second-level breakdowns are designated as (1), (2), (3), etc.

(3) Third-level breakdowns are designated as (-a), (-b), (-c), etc.

(4) Fourth-level breakdowns are designated as (-1), (-2), (-3), etc.

(5) Fifth-level breakdowns are designated as (+a), (+b), (+c), etc.

(6) Sixth-level breakdowns are designated as (+1), (+2), etc.

(b) Cross-References to Subparagraph Breakdowns. Cross-references within an alphanumerically designated paragraph (e.g., PG-1, UIG-56.1, NCD-3223) do not include the alphanumerical designator of that paragraph. The cross-references to subparagraph breakdowns follow the hierarchy of the designators under which the breakdown appears. The following examples show the format:

(1) If X.1(c)(1)(-a) is referenced in X.1(c)(1), it will be referenced as (-a).

(2) If X.1(c)(1)(-a) is referenced in X.1(c)(2), it will be referenced as (1)(-a).

(3) If X.1(c)(1)(-a) is referenced in X.1(e)(1), it will be referenced as (c)(1)(-a).

(4) If X.1(c)(1)(-a) is referenced in X.2(c)(2), it will be referenced as X.1(c)(1)(-a).

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SUBSECTION 1
WATERTUBE DRUM-TYPE INDUSTRIAL STEAM BOILERS

ARTICLE 100
FUNDAMENTALS OF WATERTUBE BOILERS

100.1 STEAM GENERATION

The primary function of a boiler is to generate steam. This is done by applying heat to the water in the boiler. The heat can be generated by electrical means or by combustion, i.e., burning fuel in a furnace.

Electric boilers are discussed in Article 301.

In the fuel-burning method, the heat generated by combustion is conducted through the metal of the boiler or boiler tubes to the water on the other side.

100.2 WATERTUBE BOILERS

100.2.1 Watertube Boilers. In the watertube boiler, the water is inside the tubes and the gases of combustion pass around the outside of the tubes (see Figure 100.2.1-1). The advantages of a watertube boiler versus a firetube boiler (see Article 300) are as follows:

(a) a lower unit weight per pound (kilogram) of steam generated

(b) less time required to raise steam pressure

(c) a greater flexibility for responding to load changes

(d) a greater ability to operate at higher steam pressures and at high rates of steam generation (This is due to the better circulation of water that carries heat away from the heating surfaces.)

The natural circulation of water through a watertube boiler depends solely on the difference in density of the steam and water mixture in the generating tubes, compared to the density of water in the downcomers. As the water is heated in the generating tubes, steam bubbles are formed and the heated mixture of steam and water rises as the weight of the denser water in the downcomers forces the heated mixture up the tubes, establishing circulation. To ensure that this circulation continues unimpaired, it is essential that the required level of water be maintained in the steam drum at all times.

100.2.2 Shop-Assembled (Package) Boilers. Small-size power boilers can be completely assembled in the boiler manufacturer's shop, including burners, fans, controls, soot blowers, etc. These boilers are shipped to the operating site by barge, rail, or over-the-road vehicles. They are called package boilers (see Figure 100.2.2-1) and can be designed to operate at high pressures and capacities. Operating pressures of 1,000 psig (7 MPa) and capacities of 300,000 lb/hr (140 000 kg/hr) and steam temperatures of 950°F (510°C) can be achieved.

100.2.3 Field-Assembled Boilers. Boilers that are too large to ship completely assembled must be field erected. Frequently an economizer and its ductwork are shipped separately from the boiler. The boiler burners may also be separately shipped and installed at the site.

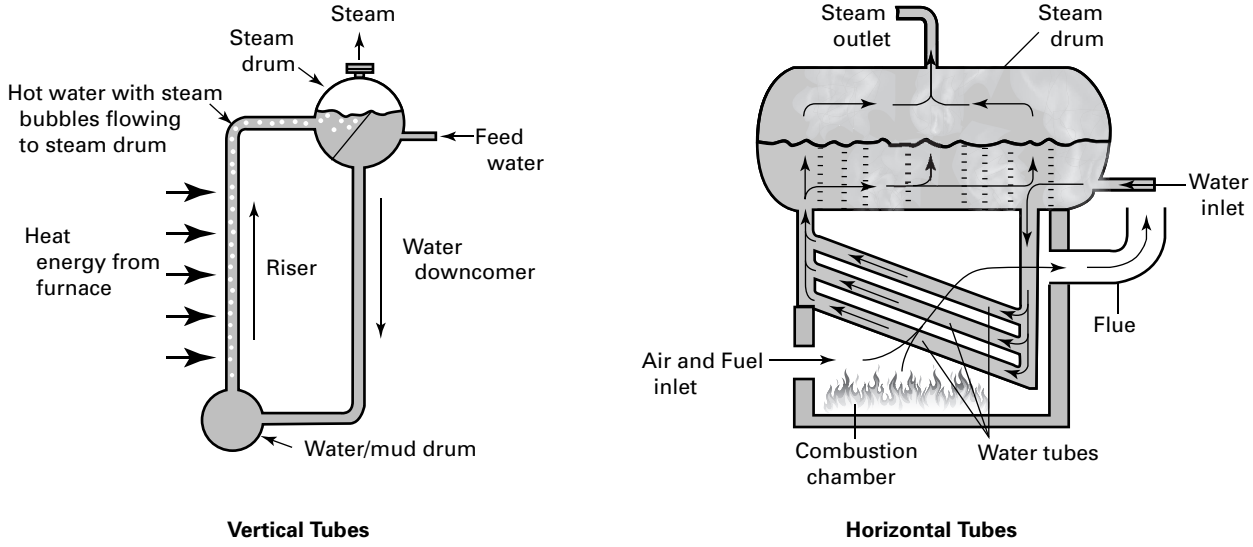
100.3 STEAM DRUMS

Features that make up a simple steam drum include a connection to introduce feedwater, downcomers to allow the distribution of water from the drum to downstream components, a system of risers to allow steam to re-enter the drum from saturated and/or superheated steam circuits (outlet headers) and a steam outlet connection (to the turbine, economizer recirculating system, etc., depending on boiler type) (see Figure 100.3-1). In operation, the function of the steam

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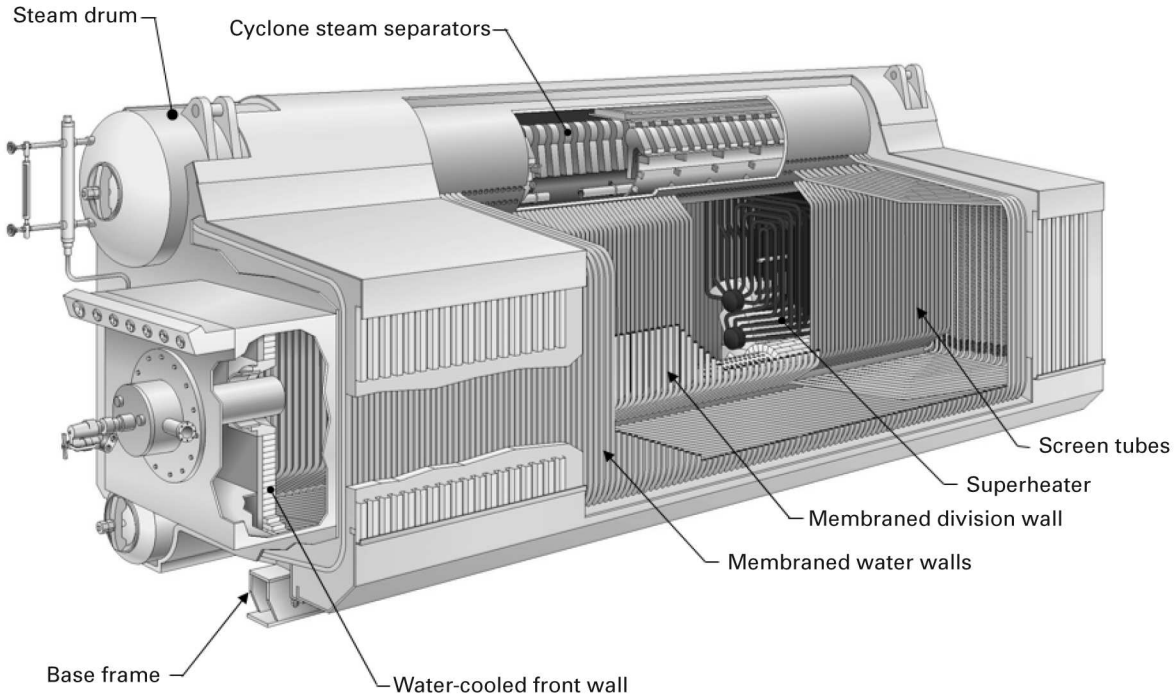
Figure 100.2.1-1
Watertube Boiler



Vertical Tubes **Horizontal Tubes**

GENERAL NOTE: Courtesy of Babcock & Wilcox.

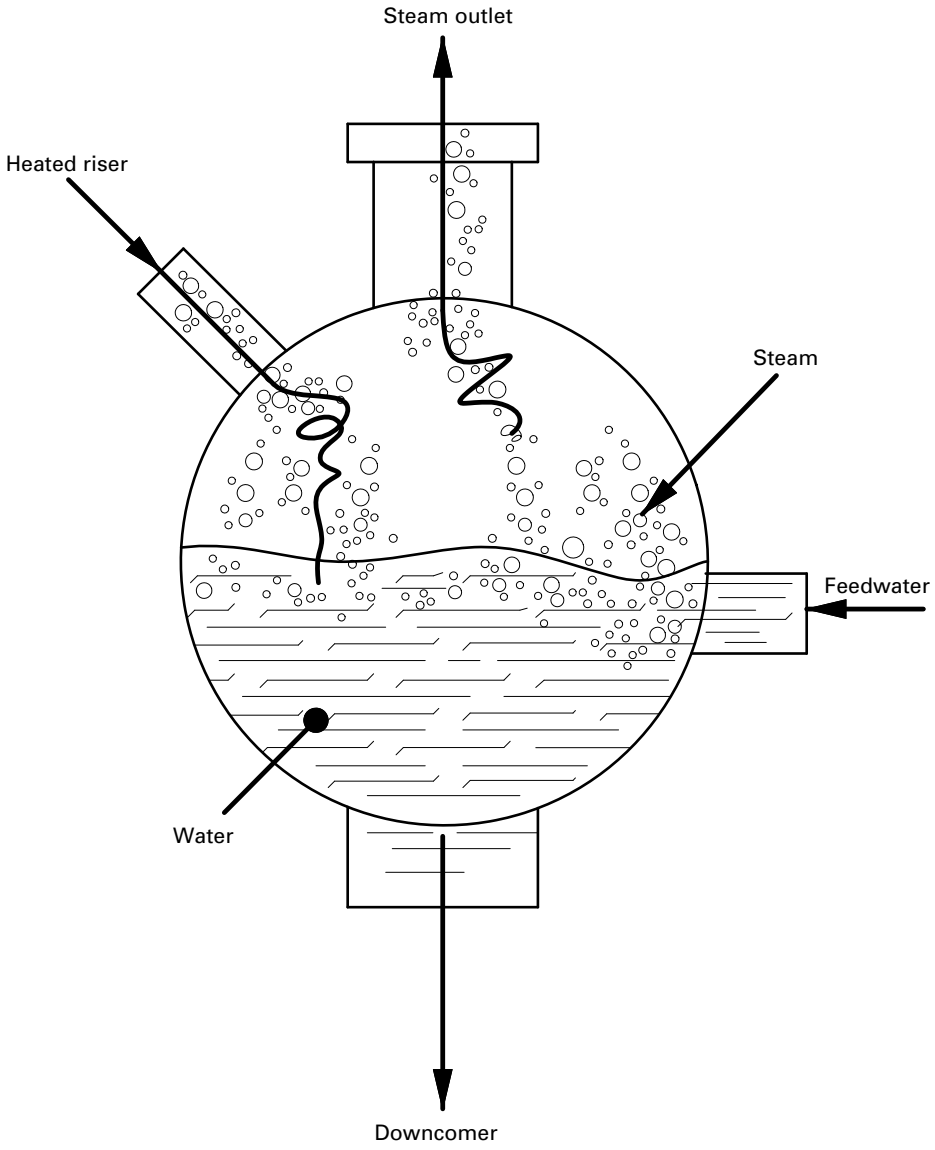
Figure 100.2.2-1
Package Boiler



GENERAL NOTE: Courtesy of Babcock & Wilcox.

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Figure 100.3-1
Simple Steam Drum



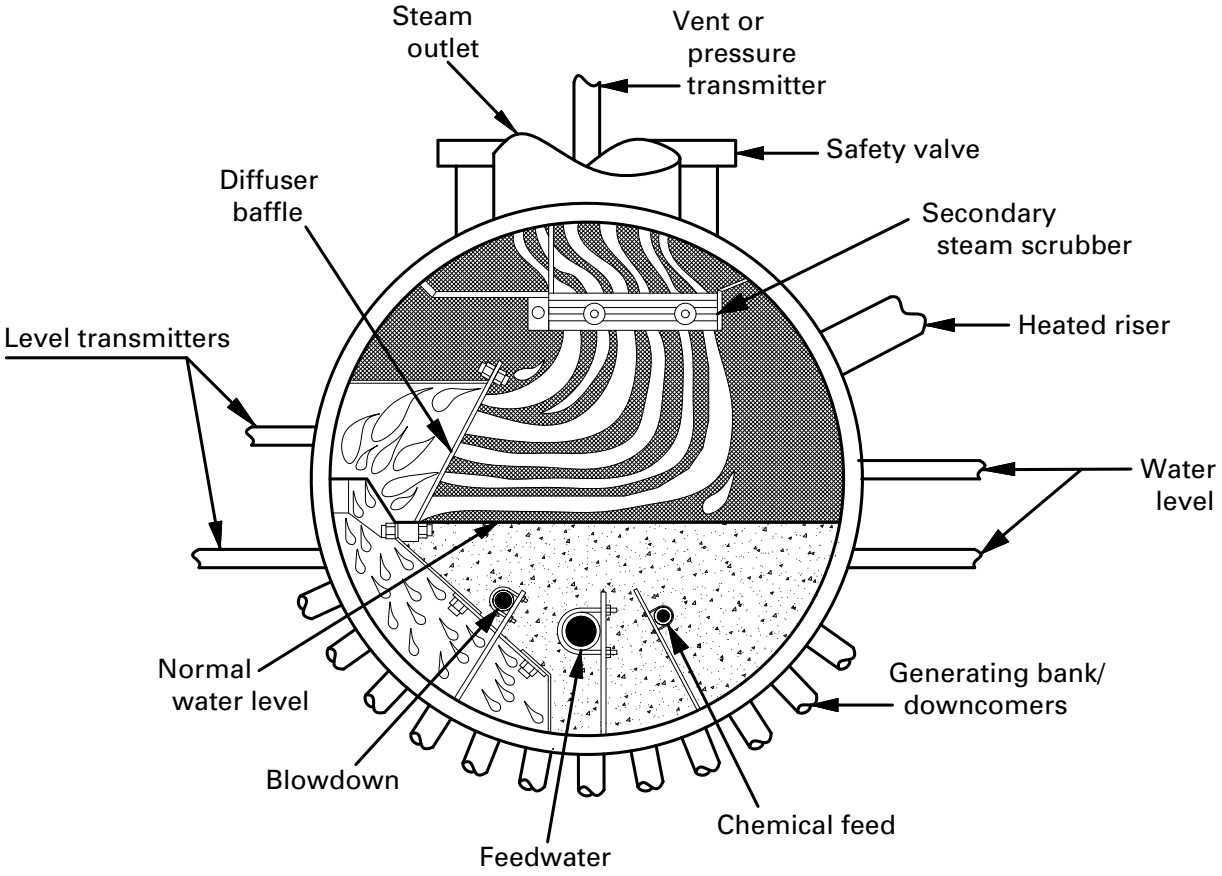
GENERAL NOTE: Courtesy of Babcock & Wilcox.

drum is to separate the steam from the mixture of water and steam. A considerable variety of drum internals (baffles, moisture separators, screens, dryers) may be used to aid this separation.

In a baffle-type drum (see Figure 100.3-2), the deflection baffle directs the water to the downcomers as free from steam bubbles as possible. Screens separate the moisture from the steam before the steam leaves the drum. Incoming feedwater, which is usually below boiling temperature and consequently denser than the water already in the drum, is directed to the downcomers to prevent carrying any steam bubbles into the downcomers, which would reduce the head available to maintain natural circulation. Even though boiler feedwater is very pure, it still contains small amounts of solids. As water evaporates, most of these solids are left behind in the liquid phase, resulting in concentration. High concentrations of dissolved solids are objectionable because they cause foaming. Also, at higher concentrations more of the solids can be mechanically "carried over" with the steam exiting the drum, reducing the purity of the steam perhaps to intolerable levels for the downstream equipment. Suspended solids can create deposits on the boiler tube surfaces that insulate the tube metal from the cooling effect of the circulating water, leading to overheating. Deposits in tubes can build up to the extent

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Figure 100.3-2
Steam Drum With Internals — Baffle Type



GENERAL NOTE: Courtesy of Babcock & Wilcox.

that they impede circulation. The term total solids is used to describe the sum of dissolved and suspended solids. To reduce the total solids in the water, the steam drum contains a continuous blowdown pipe, through which a portion of the drum water can be removed to waste. To maintain level in the drum, the blowdown is replaced by makeup containing fewer impurities. This makeup is just additional feedwater beyond the amount of evaporation (the steam leaving the drum) to compensate for the blowdown flow. Steam drums may contain mechanical separators, such as the cyclone separators shown in Figure 100.3-3. In this design, the cyclone separators provide the first stage of steam–water separation with additional separation achieved by scrubbers (screens) before the steam leaves the drum. Steam leaving the drum is at the saturation temperature associated with the steam pressure at the drum exit.

100.4 ECONOMIZERS

Economizers are typically tubular heat transfer surfaces used to preheat boiler feedwater before it enters the drum of a watertube boiler. A typical economizer is shown in Figure 100.4-1.

Water is inside the tubes, and the boiler exit gases of combustion pass over the heat transfer surface, which is typically tubular. Tubular economizers may have bare tubes or may use “extended surface” tubes. In the latter case, heat transfer surface is added by attaching plates, fins, or studs to the outside of the tubes.

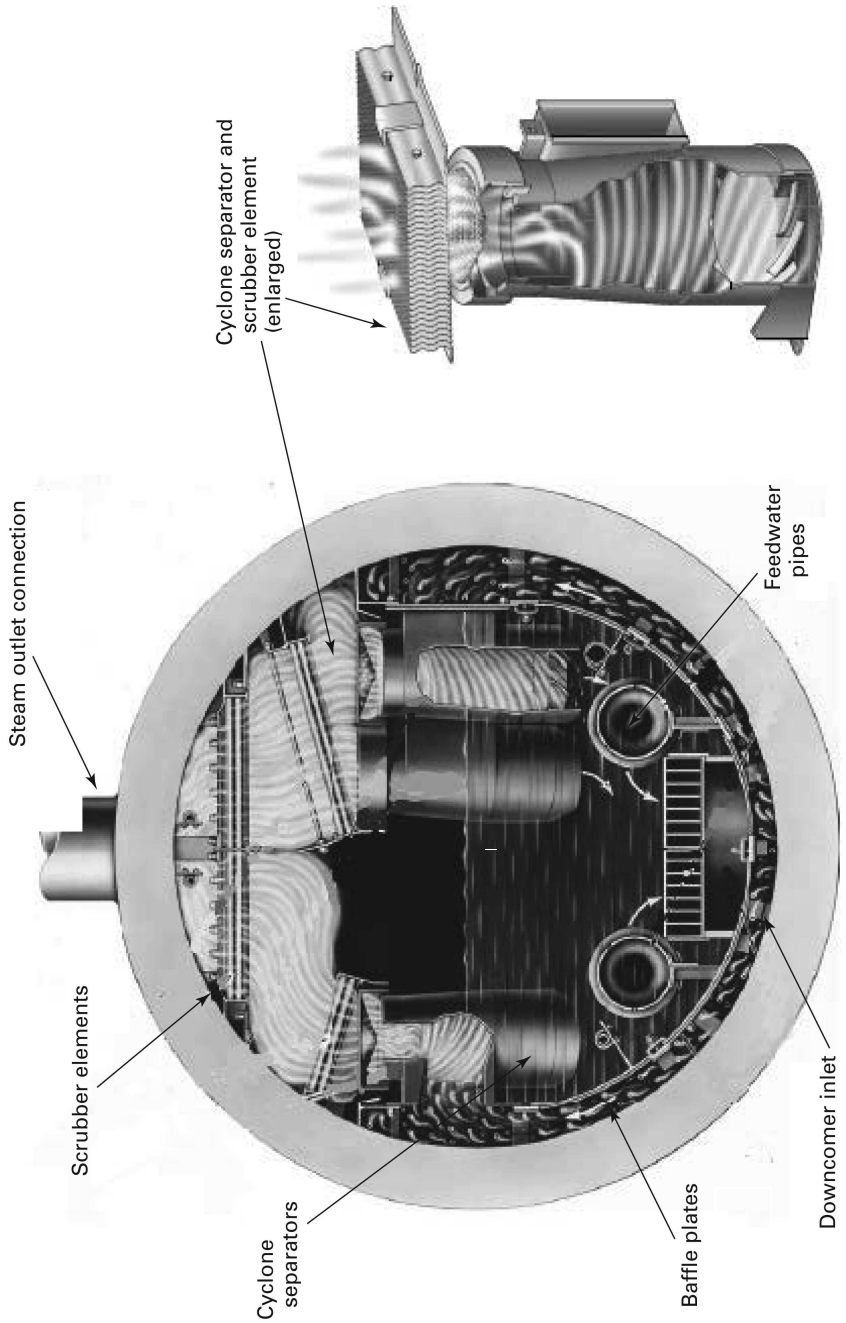
An economizer warms the feedwater, preventing thermal shock of the drum, and recovers heat that would otherwise be exhausted and lost.

During normal boiler operation, steam is not produced within the economizer.

Economizers are almost always drainable.

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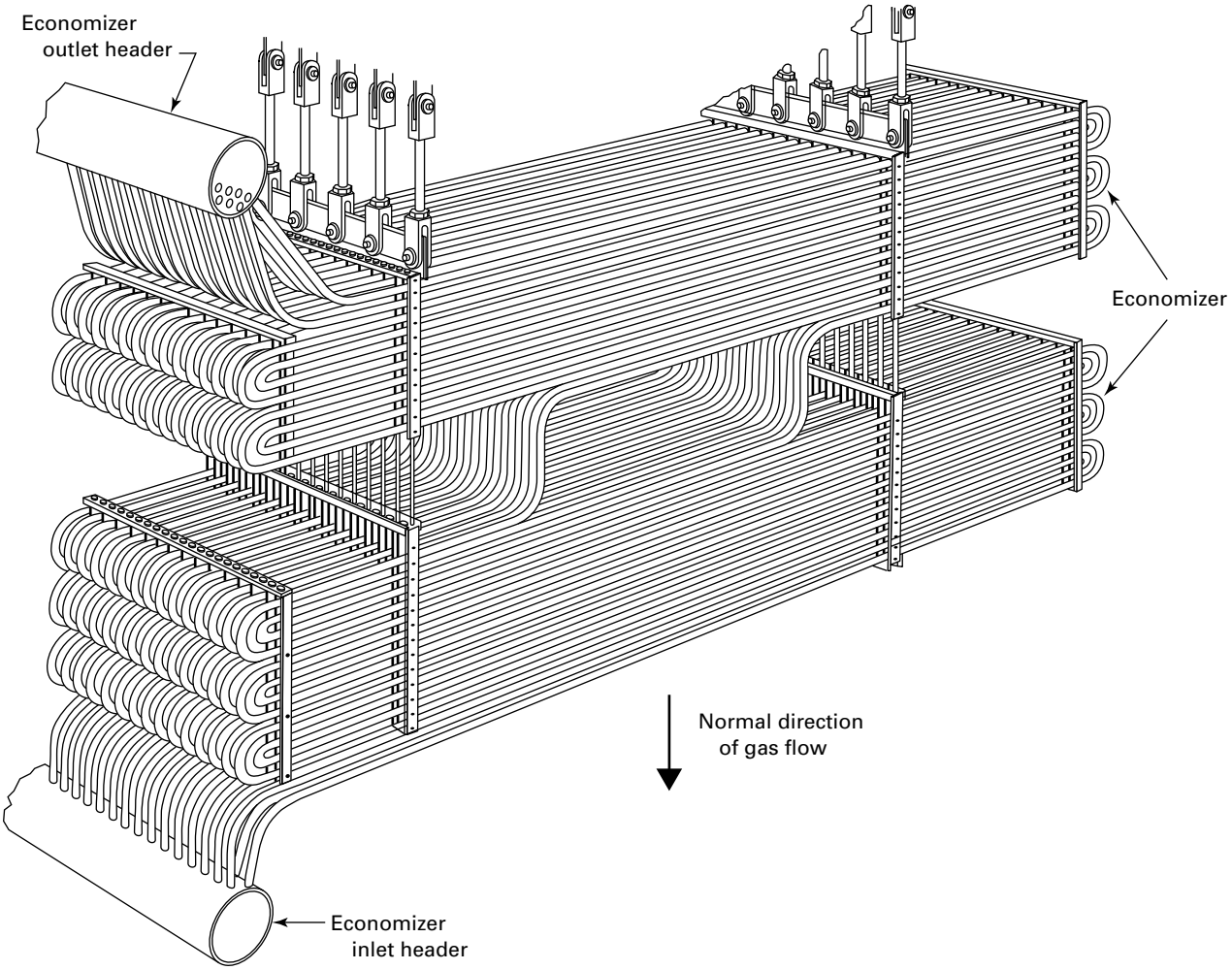
Figure 100.3-3
Steam Drum With Internals — Cyclone Separator Type



GENERAL NOTE: Courtesy of Babcock & Wilcox.

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Figure 100.4-1
Typical Economizer



GENERAL NOTE: Courtesy of Babcock & Wilcox.

100.5 SUPERHEATERS

Superheaters are tubular heat transfer surfaces used to increase the steam temperature after the steam has exited the drum of a watertube boiler. Steam inside the tubes is heated as the combustion gas passes over the outside of the bare or extended surface tubes.

The final-pass superheater is located at the boiler furnace exit where the gases of combustion are hot enough to achieve the final steam temperature desired.

Superheaters may be drainable, but many are “pendent” configuration and not drainable.

100.6 COMBUSTION

The three requirements for combustion are fuel, oxygen, and heat. The most common fuels used in boilers are coal, oil, and gas. The basic combustible elements in these fuels are hydrogen and carbon.

Coal and other solid fuels are further discussed in Subsection 4.

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Oxygen is needed to support combustion. In the combustion process, a chemical reaction takes place between the oxygen in the air and the fuel. Nitrogen and other gases in air are not needed to sustain the reaction but do carry away the heat of combustion. In some cases, the nitrogen in the air (as well as nitrogen in the fuel) may react with oxygen to form nitrogen oxide (NOx) compounds, which are often limited by environmental regulations.

A source of ignition is required to ignite the fuel. There is a specific ignition temperature for every combustible substance. Once ignited, a fuel will not continue to burn unless this temperature is maintained. The fuel will continue to burn as it supplies its own heat, provided enough oxygen is available to continue the reaction.

The greater the surface area of oil that is exposed to air, the faster the burn. The combustion process can be improved by atomizing the oil into a very fine mist and by creating turbulence with the air supplied for combustion. Heavy fuel oil has a high viscosity at ambient temperatures and must be heated to reduce the viscosity for efficient atomization. Fuel can be atomized mechanically, with the high-pressure drop across the oil gun tip, or by shearing action using steam or air.

Each component in natural gas has its own ignition temperature, but the ignition temperature of the mixture is about 1,200°F (650°C). The temperature produced during normal combustion of natural gas is between 2,500°F (1 400°C) and 3,000°F (1 600°C). Air must come in contact with the gas for combustion to proceed. Certain mixtures of gas and air are very explosive. Mixtures of natural gas and air containing less than 4% or more than 15% of gas by volume will not explode.

100.7 BOILER EFFICIENCY AND AIR EMISSIONS

The efficiency of a boiler is dependent on how much of the heating value of the fuel is lost, either as sensible heat or as a result of incomplete combustion. Sensible heat loss in the dry stack gases is by far the largest loss. An oversupply of excess air (over and above that required to safely complete combustion of the fuel) will increase heat loss, reducing boiler efficiency. The amount of excess air can be determined by measuring the amount of oxygen in the stack gases. This loss should be minimized by not supplying more excess air than required.

Moisture is the next largest cause of heat loss. Moisture in the fuel becomes superheated steam when the fuel burns, and the latent heat of this steam is lost up the stack. The hydrogen content of the fuel combines with oxygen, forming additional water as superheated steam. The humidity of the air is another source of moisture in the furnace and causes a loss in efficiency.

An oversupply of excess air and high moisture in the fuel or in the combustion air will lower the peak flue gas temperature, leading directly to lower temperature of the output steam.

Incomplete combustion can be caused by poor mixing of fuel and air or lack of sufficient air supply to the fuel as it is being burned. When carbon is only partially oxidized, carbon monoxide gas is formed. Incomplete combustion therefore can be detected by the measurement of carbon monoxide in the stack gas. Incomplete combustion of fuel is a safety hazard and represents a serious efficiency loss that can be minimized by using sufficient air and a suitable means of mixing the fuel and air.

The heat loss in the combustion gas is also directly related to the exit gas temperature. Maintenance of clean water-side and gas-side surfaces maximizes heat transfer to the fluid and results in higher efficiency.

Combustion of oil or natural gas produces oxides of nitrogen, and some oils contain low levels of ash and/or sulfur. Control of the emission of all of these may be required.

Low-NOx burners mix air and fuel in steps to minimize peak flame temperature and limit the production of nitrogen oxides. Improper adjustment of such burners can lead to incomplete combustion as well as the loss of boiler tube material due to hot reducing gases at the surface of the tubes.

Noncatalytic conversion of nitrogen oxides to nitrogen gas (N_2) utilizes ammonia or urea injected into the upper furnace. Catalytic conversion of nitrogen oxides to N_2 requires the injection of ammonia into the boiler furnace convection pass ahead of catalyst grids installed where a specific gas temperature range exists within the boiler convection passes.

Other control devices, such as scrubbers, may be required following the boiler exit for control of sulfur oxides emission.

Oil-containing ash will deposit soot on the boiler tubes. This soot needs to be periodically removed to maintain performance and avoid furnace explosions.

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ARTICLE 101
BOILER OPERATION

101.1 GENERAL GUIDELINES

101.1.1 Personnel Training. Safe and reliable operation is dependent to a large extent upon the skill and attentiveness of the operator and the maintenance personnel. Operating skill implies a knowledge of fundamentals, familiarity with equipment, and a suitable background of technical and safety training and experience.

Full and effective use should be made of the Manufacturer's instruction books on operation and maintenance. Of special importance are written procedures prepared expressly for each installation by the Manufacturer's service engineers and qualified personnel from the operating organization before and during the commissioning period. These procedures are based on actual experience and often include invaluable information on what the equipment is expected to do. Limitations critical to safe and reliable operation are also given.

Control systems vary in complexity from computer control to manual operation. Regardless of the type of system used, the operators should be thoroughly trained so that they can maintain safe and continuous operation during changeover from automatic to manual control as well as continue operation by manual control if the automatic systems are out of service. The operator should have instrumentation at the point of manual operation to allow monitoring of operating conditions at all times. Regularly scheduled auto–manual changeover, manual operation, and emergency drills to prevent loss of these skills are recommended.

Personnel training should also include training on how to perform their duties safely. Employers have the obligation to provide their employees with a safe workplace. This generally entails in the following order:

(a) Identify and assess hazards and potential hazards present, or likely to be present.

(b) Eliminate those hazards through engineered controls (e.g., providing fixed ladders to frequently accessed equipment rather than using a portable ladder) or material substitution (e.g., substituting nonhazardous materials for hazardous materials).

(c) Reduce employee exposure to known hazards through administrative actions (e.g., preventing employees from entering high hazard areas unless specified precautions are taken), or provide personal protection equipment (PPE) (e.g., providing properly fitted hearing protection in high-noise areas). Reliance solely on the use of PPE is not usually accepted as satisfactorily meeting the obligation.

101.1.2 Preventing Explosions. Interlocks should be established that ensure operation is within safe limits as described in ASME CSD-1 or NFPA 85 (see reference lists in 101.1.6 and 202.4.1). Start-up and shutdown events should be performed to satisfy the interlock system. This will prevent potentially dangerous moves during mental lapses or moments of crisis.

One of the most common causes of furnace explosions is failure to purge the boiler furnace prior to start-up. The boiler furnace, generating bank, economizer, air heater, and ducts should be adequately purged before any source of ignition (ignitor, pilot flame) is introduced into the furnace to ensure that no fuel gas or oil vapors have accumulated in the unit. The purge, usually air, should be at a sufficient rate to provide adequate velocity to clear dead spots in the entire unit. This precaution should always be observed after an accidental loss of ignition. Purge interlock systems equipped with timers, when properly installed and adjusted, ensure that purging will be adequate and effective. Such interlocks should not be bypassed or defeated. Purge times and flows should be observed by the operator to verify the purge sequence is complete. Airflow rates may be read directly on an airflow recorder or determined by comparing draft-loss differentials across parts of the boiler system with values known to represent acceptable airflows. For boilers that use a manual torch as an ignition source, in particular stationary boilers that fire oil or gas, it is recommended that the manual ignition system be replaced with an automated ignition system in accordance with ASME CSD-1, NFPA 85, or other nationally recognized standard.

See 201.6 and 201.7 for additional information.

101.1.3 Maintaining Proper Water Level. Boiler water level control and furnace pressure control, where required, are subsystems of combustion control. Every effort should be made to place these on automatic operation as soon as possible during start-up because otherwise, they require constant operator attention.

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