2013 ASME Boiler and Pressure Vessel Code

AN INTERNATIONAL CODE

VI

Recommended Rules for the Care and Operation of Heating Boilers

ASME
SETTING THE STANDARD

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AN INTERNATIONAL CODE

2013 ASME Boiler & Pressure Vessel Code

2013 Edition

July 1, 2013

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RECOMMENDED RULES FOR THE CARE AND OPERATION OF HEATING BOILERS

ASME Boiler and Pressure Vessel Committee on Heating Boilers

The American Society of Mechanical Engineers

Two Park Avenue • New York, NY • 10016 USA

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TABLE OF CONTENTS

FIGURES

TABLES

FORMS

(13)

LIST OF SECTIONS

SECTIONS

I Rules for Construction of Power Boilers

II Materials
- Part A — Ferrous Material Specifications
- Part B — Nonferrous Material Specifications
- Part C — Specifications for Welding Rods, Electrodes, and Filler Metals
- Part D — Properties (Customary)
- Part D — Properties (Metric)

III Rules for Construction of Nuclear Facility Components
- Subsection NCA — General Requirements for Division 1 and Division 2
- Appendices
- Division 1
  - Subsection NB — Class 1 Components
  - Subsection NC — Class 2 Components
  - Subsection ND — Class 3 Components
  - Subsection NE — Class MC Components
  - Subsection NF — Supports
  - Subsection NG — Core Support Structures
  - Subsection NH — Class 1 Components in Elevated Temperature Service
- Division 2 — Code for Concrete Containments
- Division 3 — Containments for Transportation and Storage of Spent Nuclear Fuel and High Level Radioactive Material and Waste
- Division 5 — High Temperature Reactors

IV Rules for Construction of Heating Boilers

V Nondestructive Examination

VI Recommended Rules for the Care and Operation of Heating Boilers

VII Recommended Guidelines for the Care of Power Boilers

VIII Rules for Construction of Pressure Vessels
- Division 1
- Division 2 — Alternative Rules
- Division 3 — Alternative Rules for Construction of High Pressure Vessels

IX Welding, Brazing, and Fusing Qualifications

X Fiber-Reinforced Plastic Pressure Vessels

XI Rules for Inservice Inspection of Nuclear Power Plant Components

XII Rules for Construction and Continued Service of Transport Tanks

INTERPRETATIONS

ASME issues written replies to inquiries concerning interpretation of technical aspects of the Code.

Interpretations of the Code are posted in January and July at http://cstools.asme.org/interpretations.cfm. Any Interpretations issued during the previous two calendar years are included with the publication of the applicable Section of the Code. Interpretations of Section III, Divisions 1 and 2 and Section III Appendices are included with Subsection NCA.

CODE CASES

The Boiler and Pressure Vessel Code committees meet regularly to consider proposed additions and revisions to the Code and to formulate Cases to clarify the intent of existing requirements or provide, when the need is urgent, rules for materials or constructions not covered by existing Code rules. Those Cases that have been adopted will appear in the appropriate 2013 Code Cases book: "Boilers and Pressure Vessels" or "Nuclear Components." Supplements will be sent automatically to the purchasers of the Code Cases books up to the publication of the 2015 Code.

(13)

FOREWORD

(This Foreword is provided as an aid to the user and is not part of the rules of this Code.)

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)

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

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

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

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

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design, or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code Cases, and requests for interpretations. Only the Committee has the authority to provide official interpretations of this Code. Requests for revisions, new rules, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action (see Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees). Proposed revisions to the Code resulting from inquiries will be presented to the Committee for appropriate action. The action of the Committee becomes effective only after confirmation by ballot of the Committee and approval by ASME. Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute (ANSI) and published at http://cstools.asme.org/csconnect/public/index.cfm?PublicReview=Revisions 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 an ASME Certification Mark.

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

STATEMENT OF POLICY ON THE USE OF THE 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 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 Certification Mark for the benefit of the users, the enforcement jurisdictions, and the holders of the 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 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 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 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 Certification Mark who may also use the facsimile in advertising to show that clearly specified items will carry the Certification Mark. General usage is permitted only when all of a manufacturer's items are constructed under the rules.

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 official Certification Mark described in the governing Section of the Code.

Markings such as "ASME," "ASME Standard," or any other marking including "ASME" or the 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.

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

1 INTRODUCTION

(a) The following information provides guidance to Code users for submitting technical inquiries to the committees. See Guideline on the Approval of New Materials Under the ASME Boiler and Pressure Vessel Code in Section II, Parts C and D for additional requirements for requests involving adding new materials to the Code. Technical inquiries include requests for revisions or additions to the Code rules, requests for Code Cases, and requests for Code Interpretations, as described below.

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

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

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

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

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

(3) Code Interpretations. Code Interpretations provide clarification of the meaning of existing rules in the Code, and are also presented in question and reply format. Interpretations do not introduce new requirements. In cases where existing Code text does not fully convey the meaning that was intended, and revision of the rules is required to support an interpretation, an Intent Interpretation will be issued and the Code will be revised.

(b) The Code rules, Code Cases, and Code Interpretations established by the committees 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 rules.

(c) Inquiries that do not comply with these provisions or that do not provide sufficient information for a committee's full understanding may result in the request being returned to the inquirer with no action.

2 INQUIRY FORMAT

Submittals to a committee shall include:

(a) Purpose. Specify one of the following:

(1) revision of present Code rules

(2) new or additional Code rules

(3) Code Case

(4) Code Interpretation

(b) Background. Provide the information needed for the committee's understanding of the inquiry, being sure to include reference to the applicable Code Section, Division, Edition, Addenda (if applicable), paragraphs, figures, and tables. Preferably, provide a copy of the specific referenced portions of the Code.

(c) Presentations. The inquirer may desire or be asked to attend a meeting of the committee to make a formal presentation or to answer questions from the committee members with regard to the inquiry. Attendance at a committee meeting shall be at the expense of the inquirer. The inquirer's attendance or lack of attendance at a meeting shall not be a basis for acceptance or rejection of the inquiry by the committee.

3 CODE REVISIONS OR ADDITIONS

Requests for Code revisions or additions shall provide the following:

(a) Proposed Revisions or Additions. For revisions, identify the rules of the Code that require revision and submit a copy of the appropriate rules as they appear in the Code, marked up with the proposed revision. For additions, provide the recommended wording referenced to the existing Code rules.

(b) Statement of Need. Provide a brief explanation of the need for the revision or addition.

(c) Background Information. Provide background information to support the revision or addition, including any data or changes in technology that form the basis for the request that will allow the committee to adequately evaluate the proposed revision or addition. Sketches, tables, figures, and graphs should be submitted as appropriate. When applicable, identify any pertinent paragraph in the Code that would be affected by the revision or addition and identify paragraphs in the Code that reference the paragraphs that are to be revised or added.

4 CODE CASES

Requests for Code Cases shall provide a Statement of Need and Background Information similar to that defined in 3(b) and 3(c), respectively, for Code revisions or additions. The urgency of the Code Case (e.g., project underway or imminent, new procedure, etc.) must be defined and it must be confirmed that the request is in connection with equipment that will bear the Certification Mark, with the exception of Section XI applications. The proposed Code Case should identify the Code Section and Division, and be written as a *Question* and a *Reply* in the same format as existing Code Cases. Requests for Code Cases should also indicate the applicable Code Editions and Addenda (if applicable) to which the proposed Code Case applies.

5 CODE INTERPRETATIONS

(a) Requests for Code Interpretations shall provide the following:

(1) Inquiry. Provide a condensed and precise question, omitting superfluous background information and, when possible, composed in such a way that a "yes" or a "no" *Reply,* with brief provisos if needed, is acceptable. The question should be technically and editorially correct.

(2) Reply. Provide a proposed *Reply* that will clearly and concisely answer the *Inquiry* question. Preferably, the *Reply* should be "yes" or "no," with brief provisos if needed.

(3) Background Information. Provide any background information that will assist the committee in understanding the proposed *Inquiry* and *Reply.*

(b) Requests for Code Interpretations must be limited to an interpretation of a particular requirement in the Code or a Code Case. The committee cannot consider consulting type requests such as the following:

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

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

(3) a request seeking the rationale for Code requirements.

6 SUBMITTALS

Submittals to and responses from the committees shall meet the following:

(a) Submittal. Inquiries from Code users shall be in English and preferably be submitted in typewritten form; however, legible handwritten inquiries will also be considered. They shall include the name, address, telephone number, fax number, and e-mail address, if available, of the inquirer and be mailed to the following address:

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

As an alternative, inquiries may be submitted via e-mail to: SecretaryBPV@asme.org.

(b) Response. The Secretary of the appropriate committee shall acknowledge receipt of each properly prepared inquiry and shall provide a written response to the inquirer upon completion of the requested action by the committee.

(13)

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January 1, 2013

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SUMMARY OF CHANGES

The 2013 Edition of this Code contains revisions in addition to the 2010 Edition with 2011 Addenda.

After publication of the 2013 Edition, Errata to the BPV Code may be posted on the ASME Web site to provide corrections to incorrectly published items, or to correct typographical or grammatical errors in the BPV Code. Such Errata shall be used on the date posted.

Information regarding Special Notices and Errata is published on the ASME Web site under the BPVC Resources page at http://www.asme.org/kb/standards/publications/bpvc-resources.

Changes given below are identified on the pages by a margin note, **(13)**, placed next to the affected area.

The Record Numbers listed below are explained in more detail in "List of Changes in Record Number Order" following this Summary of Changes.

Page	*Location*	*Change (Record Number)*
vi	List of Sections	Revised
viii	Foreword	Revised in its entirety ɉτύζϋïτϘ
xi	Submittal of Technical Inquiries to the Boiler and Pressure Vessel Standards Committees	Revised
xiii	Personnel	Updated
xxx	Cross-Referencing and Stylistic Changes in the Boiler and Pressure Vessel Code	Added
85	Mandatory Appendix II	Deleted

LIST OF CHANGES IN RECORD NUMBER ORDER

Record Number	Change
09-760	Added an introductory subtitle clarifying the purpose and limitations of the Foreword. Revised history paragraph to recognize the realignment of the BPV into several BPVs. Deleted the paragraph on tolerances. Made editorial changes to recognize the new committee structure. Deleted words addressing governing code editions. Deleted paragraph concerning materials. Deleted the paragraph dealing with what the committee considers in the formulation of these rules.

(13) # CROSS-REFERENCING AND STYLISTIC CHANGES IN THE BOILER AND PRESSURE VESSEL CODE

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

Subparagraph Breakdowns/Nested Lists Hierarchy

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

Footnotes

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

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

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

Cross-References

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

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

SECTION 1
GENERAL

1.01 SCOPE

This portion of the rules is intended to cover general descriptions, terminology, and basic fundamentals of heating boilers, controls, and automatic fuel burning equipment. Because of the wide variety of makes and types of equipment in use, it is general in scope.

1.02 USE OF ILLUSTRATIONS

The illustrations used in this Section have been selected to show typical examples of the equipment referred to in the text and are not intended to endorse or recommend any one manufacturer's product; nor are the illustrations intended to be used as design criteria or as examples of preferred configurations of equipment.

1.03 MANUFACTURER'S INFORMATION

For detailed information on any specific unit, the Manufacturer's information should be consulted.

1.04 REFERENCE TO SECTION IV

The boilers discussed in this Section will be those limited to the operating ranges of Section IV, Heating Boilers, of the ASME Boiler and Pressure Vessel Code as follows:

(a) steam boilers for operation at pressure not exceeding 15 psi (100 kPa)

(b) hot water heating and hot water supply boilers for operation at pressures not exceeding 160 psi (1 100 kPa) and/or temperatures not to exceed 250°F (120°C)

1.05 GLOSSARY OF TERMS

For terms relating to boiler design, refer to Section IV, Heating Boilers, Appendix E, Terminology. For terms relating to boiler water treatment, refer to 9.12, Glossary of Water Treatment Terms.

A. Boilers and General Terms

absolute pressure: pressure above zero pressure, the sum of the gage and atmospheric pressures.

accumulator (steam): a pressure vessel containing water and steam that is used to store the heat of steam for use at a later period and at some lower pressure.

air purge: the removal of undesired matter by replacement with air.

air vent: a valve opening in the top of the highest drum of a boiler or pressure vessel for venting air. Also a device, manual or automatic, that will effect the removal of air from a steam or hot water heating system. It is usually located at the highest point in the system.

allowable working pressure: the maximum pressure for which the boiler was designed and constructed.

altitude gage: a pressure gage calibrated in feet, indicating the height of the water in the system above the gage; usually found as combination pressure, altitude, and temperature gage.

ambient temperature: the temperature of the air surrounding the equipment.

baffle: a plate or wall for deflecting gases or liquids.

base: support for boiler.

beaded tube end: the rounded exposed end of a rolled tube when the tube metal is formed over against the sheet in which the tube is rolled.

belled tube end: see *flared tube end*.

bellows seal: a seal in the shape of a bellows used to prevent air or gas leakage.

blind nipple: a nipple, or a short piece of piping or tube, closed at one end.

blowdown: the difference between the opening and closing pressures of a safety or safety relief valve.

blowoff valve: a valve or cock in the bottom and/or near the water line of a boiler, that, when opened, permits free passage of scale and sediment during the blowoff operation.

boiler: a pressure vessel that incorporates a fuel input device or mechanism to heat water for space heating or other purposes or to convert water into steam for use in an external distribution system.

watertube: a boiler in which the tubes contain water and steam, the heat being applied to the outside surface.

bent tube: a watertube boiler consisting of two or more drums connected by tubes, practically all of which are bent near the ends to permit attachment to the drum shell on radial lines.

horizontal: a watertube boiler in which the main bank of tubes is straight and on a slope of 5 deg to 15 deg from the horizontal.

sectional header: a horizontal boiler of the longitudinal or cross drum type, with the tube bank composed of multiple parallel sections, each section made up of a front and rear header connected by one or more vertical rows of generating tubes and with the sections or groups of sections having a common steam drum.

box header: a horizontal boiler of the longitudinal or cross drum type consisting of a front and a rear inclined rectangular header connected by tubes.

cross drum: a sectional header or box header boiler in which the axis of the horizontal drum is at right angles to the center lines of the tubes in the main bank.

longitudinal drum: a sectional header or box header boiler in which the axis of the horizontal drum or drums is parallel to the tubes in a vertical plane.

low head: a bent tube boiler having three drums with relatively short tubes in the rear bank.

firetube: a boiler with straight tubes that are surrounded by water and steam and through which the products of combustion pass.

horizontal firebox: a firetube boiler with an internal furnace the rear of which is a tubesheet directly attached to a shell containing tubes. The first-pass bank of tubes is connected between the furnace tubesheet and the rear head. The second-pass bank of tubes, passing over the crown sheet, is connected between the front and rear end closures.

horizontal return tubular: a firetube boiler consisting of a cylindrical shell, with tubes inside the shell attached to both end closures. The products of combustion pass under the bottom half of the shell and return through the tubes.

locomotive: a horizontal firetube boiler with an internal furnace, the rear of which is a tubesheet directly attached to a shell containing tubes through which the products of combustion leave the furnace.

refractory lined firebox: a horizontal firetube boiler, the front portion of which is set over a refractory or water-cooled refractory furnace. The rear of the boiler shell has an integral or separately connected section containing the first-pass tubes through which the products of combustion leave the furnace, then return through the second-pass upper bank of tubes.

vertical: a firetube boiler consisting of a cylindrical shell, with tubes connected between the top head and the tubesheet, that forms the top of the internal furnace. The products of combustion pass from the furnace directly through the vertical tubes.

Submerged vertical: is the same as the plain type above, except that by use of a waterleg construction as a part of the upper tubesheet, it is possible to carry the waterline at a point above the top ends of the tubes.

scotch: in stationary service, a firetube boiler consisting of a cylindrical shell, with one or more cylindrical internal furnaces in the lower portion and a bank of tubes attached to both end closures. The fuel is burned in the furnace, the products of combustion leaving the rear to return through the tubes to an uptake at the front head: known as dry-back type.

In marine service, this boiler has an internal combustion chamber of waterleg construction covering the rear end of the furnace and tubes, in which the products of combustion turn and enter the tubes: known as wet-back type.

modular: a steam or hot water heating boiler assembly consisting of a grouping of individual boilers called modules, intended to be installed as a unit, with a single inlet and a single outlet. Modules may be under one jacket or individually jacketed.

vacuum: a factory-sealed steam boiler that is operated below atmospheric pressure.

boiler, steam heating: a boiler designed to convert water into steam, that is supplied to an external space heating system.

boiler, hot water heating: a boiler designed to heat water for circulation through an external space heating distribution system.

boiler, hot water supply: a boiler used to heat water for purposes other than space heating.

boiler horsepower: the evaporation of 34.5 lb (15.6 kg) of water per hour from a temperature of 212°F (100°C) into dry saturated steam at the same temperature equivalent to 33,475 Btu/hr (9.8 kW).

boiler inspection: boilers that are fabricated are usually inspected during construction for compliance with Code design requirements. They are also periodically field inspected internally and externally for corrosion or scaling and for the condition of controls, safety devices, etc. Boilers that are cast are given a hydrostatic test only (each section or the complete boiler); a visual inspection by the Authorized Inspector is not required unless local jurisdictions require periodic field inspections.

boiler layup: any extended period of time during which the boiler is not expected to operate and suitable precautions are made to protect it against corrosion, scaling, pitting, etc., on the water and fire sides.

boiler trim: piping on or near the boiler that is used for safety, limit, and operating controls, gages, water column, etc.

bond: a retaining or holding high-temperature cement for making a joint between brick or adjacent courses of brick.

boss: a raised portion of metal of small area and limited thickness on flat or curved metal surfaces.

breeching: a duct for the transport of the products of combustion between the boiler and the stack.

bridgewall: a wall in a furnace over which the products of combustion pass.

buckstay: a structural member placed against a furnace or boiler wall to restrain the motion of the wall.

buckstay spacer: a spacer for separating a pair of channels that are used as a buckstay.

casing: a covering of sheets of metal or other material such as fire-resistant composition board used to enclose all or a portion of a steam generating unit.

cleanout door: a door placed so that accumulated refuse may be removed from a boiler setting.

cock: a plug- or ball-type valve in which a 90 deg turn of the handle will move the valve to full open or closed. Such cocks should be designed so that they are open when the handle is parallel with the line of flow.

column, fluid relief: that piping connected to the top of a hot water heating boiler that is provided for the thermal expansion of the water. It will connect to either an open or closed expansion tank.

combustion chamber: that part of a boiler where combustion of the fuel takes place.

condensate: condensed water resulting from the removal of latent heat from steam.

conductivity: the amount of heat (Btu) transmitted in 1 hr through 1 ft^2 (645 mm^2) of a homogeneous material 1 in. (25 mm) thick for a difference in temperature of 1°F (0.556°C) between the two surfaces of the material.

control: any manual or automatic device for the regulation of a machine to keep it at normal operation. If automatic, the device is motivated by variations in temperature, pressure, water level, time, light, or other influences.

convection: the transmission of heat by the circulation of a liquid or a gas such as air. Convection may be natural or forced.

core: a rod or closed tube inserted in a tube to reduce the flow area.

cross box: a boxlike structure attached to the longitudinal drum of a sectional header boiler for the connection of circulating tubes.

crown sheet: in a firebox boiler, the plate forming the top of the furnace.

damper: a device for introducing a variable resistance for regulating the volumetric flow of gas or air.

butterfly type: a blade damper pivoted about its center.

curtain type: a damper, composed of flexible material, moving in a vertical plane as it is rolled.

flap type: a damper consisting of one or more blades each pivoted about one edge.

louver type: a damper consisting of several blades each pivoted about its center and linked together for simultaneous operation.

slide type: a damper consisting of a single blade that moves substantially normal to the flow.

design load: the load for which a steam generating unit is designed, usually considered the maximum load to be carried.

design pressure: the maximum allowable working pressure permitted under the rules of Section IV of the Code.

developed boiler horsepower: the boiler horsepower generated by a steam generating unit.

diagonal stay: a brace used in firetube boilers between a flat head or tubesheet and the shell.

diaphragm: a partition of metal or other material placed in a header, duct, or pipe to separate portions thereof.

discharge tube: a tube through which steam and water are discharged into a drum; also a riser or releaser.

downcomer: a tube in a boiler or waterwall system through which fluid flows downward.

drain: a valved connection at the lowest point for the removal of all water from the pressure parts.

drip: a pipe, or a steam trap and a pipe, considered as a unit, that conducts condensate from the steam side of a piping system to the return side.

drum: a cylindrical shell closed at both ends designed to withstand internal pressure.

drum baffle: a plate or series of plates or screens placed within a drum to divert or change the direction of the flow of water or water and steam.

drum head: a plate closing the end of a boiler drum or shell.

dry pipe: a perforated or slotted pipe or box inside the drum and connected to the steam outlet.

dry return: a return pipe in a steam heating system that carries condensate and air and is above the water level of the boiler.

dry steam drum: a pressure chamber, usually serving as the steam offtake drum, located above and in communication with the steam space of a boiler steam-and-water drum.

dutch oven: a furnace that extends forward of the wall of a boiler setting. It usually is of all refractory construction with a low roof, although in some cases the roof and side walls are water cooled.

earthquake bracing: diagonal bracing between columns designed to withstand violent lateral motion of the structure.

efficiency: the ratio of output to the input. The efficiency of a steam generating unit is the ratio of the heat absorbed by water and steam to the heat in the fuel fired.

ejector: a device that utilizes the kinetic energy in a jet of water or other fluid to remove a fluid or fluent material from tanks or hoppers.

electric boiler: a boiler in which the electric heating means serve as the source of heat.

equalizer: connections between parts of a boiler to equalize pressures.

equivalent direct radiation (EDR): the amount of heating surface that will give off 240 Btu/hr (0.070 kW) for steam and 150 Btu/hr (0.044 kW) for hot water. EDR may have no direct relation to actual surface area.

equivalent evaporation: evaporation expressed in pounds of water evaporated from a temperature of 212°F (100°C) to dry saturated steam at 212°F (100°C).

evaporation rate: the number of pounds of water evaporated in a unit of time.

expanded joint: the pressure of a tight joint formed by enlarging a tube seat.

expander: the tool used to expand tubes.

expansion joint: the joint to permit movement due to expansion without undue stress.

explosion door: a door in a furnace or boiler setting designed to be opened by a predetermined gas pressure.

extended surface: metallic heat absorbing surface protruding beyond the tube wall.

extension furnace: see *dutch oven*.

external header: connection between sections of a cast iron boiler to effect circulation of the steam or heated water.

externally fired boiler: a boiler in which the furnace is essentially surrounded by refractory or water-cooled tubes.

feed pipe: a pipe through which water is conducted into a boiler.

feed trough: a trough or pan from which feed water overflows in the drum.

feedwater: water introduced into a boiler during operation. Includes makeup and return condensate or return water.

ferrule: a short metallic ring rolled into a tube hole to decrease its diameter; also, a short metallic ring rolled inside of a rolled tube end; also, a short metallic ring for making up handhole joints.

fin: a strip of steel welded longitudinally to a tube.

fin tube: a tube with one or more fins.

firebox: the equivalent of a furnace; a term usually used for the furnaces of locomotive and similar types of boilers.

fire crack: a crack starting on the heated side of a tube, shell, or header resulting from excessive temperature stresses.

fired pressure vessel: a vessel containing a fluid under pressure exposed to heat from the combustion of fuel.

firetube: a tube in a boiler having water on the outside and carrying the products of combustion on the inside.

flame plate: a baffle of metal or other material for directing gases of combustion.

flared tube end: the projecting end of a rolled tube that is expanded or rolled to a conical shape.

float switch: a float operated switch that makes and breaks an electric circuit in accordance with a change in a predetermined water level.

flow sensing fuel cutoff: a device that will cut off the fuel supply when circulating water flow is interrupted in coil-type boilers or watertube boilers requiring forced circulation to prevent overheating of the coils or tubes.

french coupling: a coupling with a right- and left-hand thread.

furnace: an enclosed space provided for the combustion of fuel.

furnace volume: the cubical contents of the furnace or combustion chamber.

fusible plug: a hollowed threaded plug having the hollowed portion filled with a low melting point material, usually located at the lowest permissible water level.

gage cock: a valve attached to a water column or drum for checking the water level.

gage glass: the transparent part of a water gage assembly connected directly or through a water column to the boiler, below and above the waterline, to indicate the water level in the boiler.

gage pressure: the pressure above atmospheric pressure.

generating tube: a tube in which steam is generated.

grooved tube seat: a tube seat having one or more shallow grooves into which the tube may be forced by the expander.

hairpin tube: a tube bent to the shape of a hairpin.

handhole: an opening in a pressure part for access, usually not exceeding 6 in. (150 mm) in longest dimension.

handhole cover: a handhole closure.

header: piping that connects two or more boilers together. It may be either supply or return piping.

heat balance: an accounting of the distribution of the heat input and output.

heat exchanger: a vessel in which heat is transferred from one medium to another.

heating surface: that surface which is exposed to the heating medium for absorption and transfer of heat to the heated medium.

horizontal return tubular boiler (HRT): see *boiler*.

hydrostatic test: a strength and tightness test of a closed pressure vessel by water pressure.

impingement: the striking of moving matter, such as the flow of steam, water, gas, or solids, against similar or other matter.

inspection door: a small door located in the outer enclosure so that certain parts of the interior of the apparatus may be observed.

Inspector, Authorized: a boiler inspector who, according to the local requirements, is authorized to inspect boilers. He may be a city, state, province, or insurance company employee.

insulation: a material of low thermal conductivity used to reduce heat losses.

internal furnace: a furnace within a boiler consisting of a straight or corrugated flue, or a firebox substantially surrounded, except on the bottom, with water-cooled heating surface.

internally fired boiler: a firetube boiler having an internal furnace such as a scotch, locomotive firebox, vertical tubular, or other type having a water-cooled plate type furnace.

joint: a separable or inseparable juncture between two or more materials.

joints, swing: threaded, flanged, welded, or brazed pipe and fittings so arranged that the piping system that they comprise, when connected to a boiler, can expand and contract without imposing excessive force on it.

jumper tube: a short tube connection for bypassing, routing, or directing the flow of fluid as desired.

lagging: a covering, usually of insulating material, on pipe or ducts.

lance door: a door through which a hand lance may be inserted for cleaning heating surfaces.

lever valve: a quick-operating valve operated by a lever that travels through an arc not greater than 180 deg.

lift: the movement of the disk off the seat of a safety or safety relief valve when the valve is opened. Lift normally refers to the amount of movement of the disk off the seat when the valve is discharging at rated pressure.

ligament: the minimum cross section of solid metal in a header, shell, or tubesheet between two adjacent holes.

limit control: any device that shuts down the burner when operating limits are reached.

load: the rate of output; also, the weight carried.

load factor: the ratio of the average load in a given period to the maximum load carried during that period.

longitudinal drum boiler: see *boiler*.

low-water fuel cutoff: a device that will automatically cut off the fuel supply before the surface of the water falls below the lowest visible part of the water gage glass in steam heating boilers or below any location above the lowest safe permissible water level established by the manufacturer in hot water heating and supply boilers.

low-water fuel cutoff, manual reset: a device that will automatically cut off the fuel supply and cause a safety shutdown requiring manual reset.

lowest safe waterline: that water level in the boiler below which the burner is not allowed to operate.

lug: any projection, such as an ear, used for supporting or grasping.

makeup water: water introduced into the boiler to replace that lost or removed from the system.

manhead: the head of a boiler drum or other pressure vessel having a manhole.

manhole: the opening in a pressure vessel of sufficient size to permit a man to enter.

manifold: a pipe or header for collecting a fluid from, or the distributing of a fluid to, a number of pipes or tubes.

maximum continuous load: the maximum load that can be maintained for a special period.

miniature boiler: fired pressure vessels that do not exceed the following limits: 16 in. (400 mm) inside diameter of shell; 42 in. (1 075 mm) overall length to outside of heads at center; 20 ft^2 (1.9 m^2) water heating surface; or 100 psi (700 kPa) maximum allowable working pressure.

mud leg: see *waterleg*.

nipple, push: a short length of pipe tapered at both ends, used to hold sections of cast boilers together.

nipple, threaded: a short length of threaded pipe.

operating control: any device that controls the operation of a fuel burner to maintain the desired condition.

operating water level: in a steam boiler, the maintained water level that is above the lowest safe water level.

packaged steam generator: a boiler equipped and shipped complete with fuel burning equipment, mechanical draft equipment, automatic controls, and accessories.

pad: see *boss*. A pad is larger than a boss and is attached to a pressure vessel to reinforce an opening.

pass: a confined passageway, containing heating surface, through which a fluid flows in essentially one direction.

peak load: the maximum load carried for a stated short period of time.

peepdoor: a small door usually provided with a shielded glass opening through which combustion may be observed.

peephole: a small hole in a door covered by a movable cover.

pitch: the distance between center lines of tubes, rivets, staybolts, or braces.

plate baffle: a metal baffle.

platen: a plane surface receiving heat from both sides and constructed with a width of one tube and a depth of two or more tubes, bare or with extended surfaces.

pneumatic control: any control that uses compressed air as the actuating means.

popping pressure: the pressure at which a safety valve opens.

porcupine boiler: a boiler consisting of a vertical shell from which project a number of dead end tubes.

port: an opening through which fluid passes.

power control valve: a safety valve opened by a power driven mechanism.

pressure: force per unit of area.

pressure, accumulation test: that steam pressure at which the capacity of a safety, safety relief, or relief valve is determined.

pressure drop: the difference in pressure between two points in a system, at least one of which is above atmospheric pressure, and caused by resistance to flow.

pressure-expanded joint: a tube joint in a drum, header, or tubesheet expanded by a tool that forces the tube wall outward by driving a tapered pin into the center of a sectional die.

pressure vessel: a closed vessel or container designed to confine a fluid at a pressure above atmospheric.

pulsation: rapid fluctuations in furnace pressure.

rated capacity: the Manufacturer's stated capacity rating for mechanical equipment; for example, the maximum continuous capacity in pounds of steam per hour for which a boiler is designed.

rating: see *load*.

receiver: the tank portion of a condensate or vacuum return pump where condensate accumulates.

recessed tube wall: a refractory furnace wall with slots in which waterwall tubes are placed so that the tubes are partially exposed to the furnace.

recirculation: the reintroduction of part of the flowing fluid to repeat the cycle of circulation.

refractory baffle: a baffle of refractory material.

relief valve: see *safety relief valve*.

retarder: a straight or helical strip inserted in a firetube primarily to increase the turbulence.

rifled tube: a tube that is helically grooved on the inner wall.

rolled joint: a joint made by expanding a tube into a hole by a roller expander.

saddle: a casting, fabricated chair, or member used for the purpose of support.

safe working pressure: see *design pressure*.

safety relief valve: an automatic pressure relieving device actuated by the pressure upstream of the valve and characterized by opening pop action with further increase in lift with an increase in pressure over popping pressure.

safety valve: an automatic pressure relieving device actuated by the static pressure upstream of the valve and characterized by full-opening pop action. It is used for gas or vapor service.

sampling: the removal of a portion of material for examination or analysis.

scotch boiler: see *boiler*.

screen: a perforated plate, cylinder, or meshed fabric, usually mounted on a frame for separating coarser from finer parts.

screen tube: a tube in a water screen.

seal: a device to close openings between structures to prevent leakage.

seal weld: a weld used primarily to obtain tightness and prevent leakage.

seam: the joint between two plates riveted together.

sectional-header boiler: see *boiler*.

separator: a device for sorting and dividing one substance from another.

shell: the cylindrical portion of a pressure vessel.

shutoff valve: see *stop valve*.

slip seal: a seal between members designed to permit movement of either member by slipping or sliding.

smokebox: an external compartment on a boiler to catch unburned products of combustion.

spalling: the breaking off of the surface of refractory material as a result of internal stresses.

spun ends: the ends of hollow members closed by rolling while heated.

stay: a tensile stress member to hold material or other members rigidly in position.

staybolt: a bolt threaded through or welded at each end, into two spaced sheets of a firebox or box header to support flat surfaces against internal pressure.

steam dome: a receptacle riveted or welded to the top sheet of a firetube boiler through and from which the steam is taken from the boiler.

steam gage: a gage for indicating the pressure of steam.

stop valve: valve (usually gage type) that is used to isolate a part of a heating system or a boiler from the other parts.

strainer, condensate: mechanical means (screen) of removing solid material from the condensate before it reaches the pump.

strength weld: a weld capable of withstanding a design stress.

stub tube: a short tube welded to a pressure part for field extension.

stud: a projecting pin serving as a support or means of attachment.

stud tube: a tube having short studs welded to it.

swinging load: a load that changes at relatively short intervals.

thermal probe: a liquid-cooled tube used as a calorimeter in a furnace to measure heat absorption rates.

thimble: a short piece of pipe or tube.

throat: the neck portion of a passageway.

through-stay: a brace used in firetube boilers between the heads or tubesheets.

tie plate: a plate, through which a bolt or tie rod is passed, to hold brick in place.

tie rod: a tension member between buckstays, tie plates, or cast boiler sections.

tile: a preformed, burned refractory, usually applied to shapes other than standard brick.

tile baffle: a baffle formed of preformed, burned refractory shapes.

trap: a device installed in steam piping that is designed to prohibit the passage of steam but allow the passage of condensate and air.

try cock: see *gage cock*.

tube: a hollow cylinder for conveying fluids.

tube cleaner: a device for cleaning tubes by brushing, hammering, or by rotating cutters.

tube door: a door in a boiler or furnace wall through which tubes may be removed or new tubes passed.

tube hole: a hole in a drum, header, or tubesheet to accommodate a tube.

tube plug: a solid plug driven into the end of a tube.

tube seat: that part of a tube hole with which a tube makes contact.

tubesheet: the plate containing the tube holes.

tube turbining: the act of cleaning a tube by means of a power driven rotary device that passes through the tube.

unfired pressure vessel: a vessel designed to withstand internal pressure, neither subjected to heat from products of combustion nor an integral part of a fired pressure vessel system.

uptake: vertical smoke outlet from a boiler before it connects to the breeching.

use factor: the ratio of hours in operation to the total hours in that period.

valve, safety: for use on steam heating boilers not exceeding 15 psi (100 kPa) MAWP, a direct spring-loaded pressure relief valve designed to actuate on inlet static pressure and characterized by pop action.

valve, safety relief: for use on hot water heating and supply boilers not exceeding 160 psi (1 100 kPa) MAWP, a direct spring-loaded pressure relief valve designed to actuate on inlet static pressure and characterized by rapid opening followed by further increase in disk lift with increasing overpressure.

vent: an opening in a vessel or other enclosed space for the removal of gas or vapor.

waste heat: sensible heat in noncombustible gases, such as gases leaving furnaces used for processing metals, ores, or other materials.

water column: a vertical tubular member connected at its top and bottom to the steam and water space respectively of a boiler, to which the water gage, gage cocks, and high- and low-level alarms may be connected.

water gage: the gage glass and its fittings for attachment.

waterleg: water-cooled sides of a firebox type boiler; sometimes called *mud leg* because solids that accumulate have a tendency to settle there.

water level: the elevation of the surface of the water in a boiler.

water tube: a tube in a boiler having the water and steam on the inside and heat applied to the outside.

wrapper sheet: the outside plate enclosing the firebox in a firebox or locomotive boiler; also, the thinner sheet in the shell of a two-thickness boiler drum.

B. Fuels, Fuel Burning Equipment, and Combustion

air: the mixture of oxygen, nitrogen, and other gases that, with varying amounts of water vapor, forms the atmosphere of the earth.

air atomizing oil burner: a burner for firing oil in which the oil is atomized by compressed air that is forced into and through one or more streams of oil, breaking the oil into a fine spray.

air deficiency: insufficient air, in an air–fuel mixture, to supply the oxygen theoretically required for complete oxidation of the fuel.

air–fuel ratio: the ratio of the weight, or volume, of air to fuel.

air infiltration: the leakage of air into a setting or duct.

air moisture: the water vapor suspended in the air.

air purge: the removal of undesired matter by replacement with air.

air resistance: the opposition offered to the passage of air through any flow path.

air, saturated: air that contains the maximum amount of water vapor that it can hold at its temperature and pressure.

ambient air: the air that surrounds the equipment. The standard ambient air for performance calculations is air at 80°F (27°C), 60% relative humidity, and a barometric pressure of 29.92 in. Hg (760 mm Hg).

aspirating burner: a burner in which the fuel in a gaseous or finely divided form is burned in suspension, the air for combustion being supplied by bringing it into contact with the fuel. Air is drawn through one or more openings by the lower static pressure created by the velocity of the fuel stream.

atmospheric air: air under the prevailing atmospheric conditions.

atmospheric pressure: the barometric reading of pressure exerted by the atmosphere: at sea level, 14.7 lb/in.^{2} (101 kPa) or 29.92 in. Hg (101 kPa).

atomizer: a device by means of which a liquid is reduced to a very fine spray.

automatic lighter: a means for starting ignition of fuel without manual intervention; usually applied to liquid, gaseous, or pulverized fuel.

auxiliary air: additional air, either hot or cold, that may be introduced into the exhauster inlet or burner lines to increase the primary air at the burners.

available draft: the draft that may be utilized to cause the flow of air for combustion or the flow of products of combustion.

axial fan: consists of a propeller or disk type of wheel within a cylinder that discharges the air parallel to the axis of the wheel.

balanced draft: the maintenance of a fixed value of draft in a furnace at all combustion rates by control of incoming air and outgoing products of combustion.

barometric pressure: atmospheric pressure as determined by a barometer, usually expressed in inches of mercury.

blower: a fan used to force air under pressure.

booster fan: a device for increasing the pressure or flow of a gas.

breeching: a duct for the transport of the products of combustion between parts of a steam generating unit or to the stack.

British thermal unit: the mean British thermal unit is $^1/_{180}$ of the heat required to raise the temperature of 1 lb of water from 32°F to 212°F at a constant atmospheric pressure. It is about equal to the quantity of heat required to raise 1 lb of water 1°F.

Bunker C oil: residual fuel oil of high viscosity commonly used in marine and stationary steam power plants (No. 6 fuel oil).

burner: a device for the introduction of fuel and air into a furnace at the desired velocities, turbulence, and concentration to establish and maintain proper ignition and combustion of the fuel.

burner windbox: a plenum chamber around a burner in which an air pressure is maintained to insure proper distribution and discharge of secondary air.

burner windbox pressure: the air pressure maintained in the windbox or plenum chamber measured above atmospheric pressure.

calorific value: the number of heat units liberated per unit of quantity of a fuel burned in a calorimeter under prescribed conditions.

calorimeter: apparatus for determining the calorific value of a fuel.

carbon: the element that is the principal combustible constituent of all fuels.

carbonization: the process of converting coal to carbon by removing other ingredients.

centrifugal fan: consists of a fan rotor or wheel within a scroll type of housing that discharges the air at right angle to the axis of the wheel.

chimney: a brick, metal, or concrete stack.

chimney core: the inner cylindrical section of a double-wall chimney, that is separated from the outer section by an air space.

chimney lining: the material that forms the inner surface of the chimney.

circular burner: a liquid, gaseous, or pulverized fuel burner having a circular opening through the furnace wall.

closed fireroom system: a forced draft system in which combustion air is supplied by elevating the air pressure in the fireroom.

coal: solid hydrocarbon fuel formed by ancient decomposition of woody substance under conditions of heat and pressure.

coal burner: a burner for use with pulverized coal.

coal gas: gas formed by the destructive distillation of coal.

coal tar: black viscous liquid, one of the byproducts formed by distillation of coal.

coke: fuel consisting largely of the fixed carbon and ash in coal obtained by the destructive distillation of bituminous coal.

coke breeze: fine coke screenings usually passing a $^1/_2$ in. (13 mm) or $^3/_4$ in. (19 mm) screen opening.

coke oven gas: gas produced by destructive distillation of bituminous coal in closed chambers. The heating value is 500 Btu/ft^3 (4 450 kCal/m^3) to 550 Btu/ft^3 (4 395 kCal/m^3).

coke oven tar: see *coal tar*.

coking: the conversion by heating in the absence or near absence of air of a carbonaceous fuel, particularly certain bituminous coals, to a coherent, firm, cellular carbon product known as coke.

colloidal fuel: mixture of fuel oil and powdered solid fuel.

combustible: the heat producing constituents of a fuel.

combustible loss: the loss representing the unliberated thermal energy occasioned by failure to oxidize completely some of the combustible matter in the fuel.

combustion: the rapid chemical combination of oxygen with the combustible elements of a fuel resulting in the production of heat.

combustion rate: the quantity of fuel fired per unit of time, as pounds of coal per hour, or cubic feet of gas per minute.

complete combustion: the complete oxidation of all the combustible constituents of a fuel.

conductor, electric:

ground: wire or other means of returning the electric current to the earth.

load (hot): current-carrying wire or other means of connection between the electric source of power and the load in the circuit.

neutral: current-carrying wire or other means of connection between the load in the circuit and ground.

control valve: a valve used to control the flow of air or gas.

cracked residue: the fuel residue obtained by cracking crude oils.

cracking: the thermal decomposition of complex hydrocarbons into simpler compounds of elements.

crude oil: unrefined petroleum.

damper: a device for introducing a variable resistance for regulating the volumetric flow of gas or air.

butterfly type: a single blade damper pivoted about its center.

curtain type: a damper, composed of flexible material, moving in a vertical plane as it is rolled.

flap type: a damper consisting of one or more blades each pivoted about one edge.

louver type: a damper consisting of several blades each pivoted about its center and linked together for simultaneous operation.

slide type: a damper consisting of a single blade that moves substantially normal to the flow.

damper loss: the reduction in the static pressure of a gas flowing across a damper.

delayed combustion: a continuation of combustion beyond the furnace (see also *secondary combustion*).

dew point: the temperature at which condensation starts.

distillate fuels: liquid fuels distilled usually from crude petroleum, except residuals such as No. 5 and No. 6 fuel oil.

distillation: vaporization of a substance with subsequent recovery of the vapor by condensation often used in a less precise sense to refer to vaporization of volatile constituents of a fuel without subsequent condensation.

draft: the difference between atmospheric pressure and some lower pressure existing in the furnace or gas passages of a steam generating unit.

draft differential: the difference in static pressure between two points in a system.

draft gage: a device for measuring draft, usually in inches of water.

draft loss: the drop in the static pressure of a gas between two points in a system, both of which are below atmospheric pressure, and caused by resistances to flow.

dual flow oil burner: a burner having an atomizer, usually mechanical, having two sets of tangential slots, one set being used for low capacities and the other set for high capacities.

duct: a passage for air or gas flow.

electric ignition: ignition of a pilot or main flame by the use of an electric arc or glow plug.

evase stack: an expanding connection on the outlet of a fan or in an air flow passage for the purpose of converting kinetic energy to potential energy, i.e., velocity pressure into static pressure.

excess air: air supplied for combustion in excess of that theoretically required for complete oxidation.

exhauster: a fan used to withdraw air or gases under suction.

explosion: combustion that proceeds so rapidly that high pressure is generated suddenly.

external-mix oil burner: a burner having an atomizer in which the liquid fuel is struck, after it has left an orifice, by a jet of high velocity steam or air.

fan: a machine consisting of a rotor and housing for moving air or gases at relatively low pressure differentials.

fan inlet area: the inside area of the fan inlet collar or connection.

fan outlet area: the inside area of the fan outlet.

fan performance: a measure of fan operation in terms of volume, total pressures, static pressures, speed, power input, mechanical and static efficiency, at a stated air density.

fire point: the lowest temperature at which, under specified conditions, fuel oil gives off enough vapor to burn continuously when ignited.

fire scanner: device that is used to "look at" the main burner and/or the pilot flame. If the flame is there the scanner will be affected by some part of the flame and make or break an electric circuit to keep the fuel flowing.

fishtail burner: a burner consisting of a diverging chamber having a rectangular outlet that is materially longer than it is wide.

fixed carbon: the carbonaceous residue, less the ash, remaining in the test container after the volatile matter has been driven off in making the proximate analysis of a solid fuel.

fixed grate: a grate that does not have movement.

flame: a luminous body of burning gas or vapor.

flame detector: a device that indicates if fuel, such as liquid, gaseous, or pulverized, is burning, or if ignition has been lost. The indication may be transmitted to a signal or to a control system.

flame safeguard:

thermal: bimetallic strip thermocouple that is located in the pilot flame. If the pilot goes out a circuit is broken and the fuel valve is shut. Response time is 1 min to 3 min. Suitable for small installations.

electronic: electrode used in flame rectification system that detects pilot and main flame and prevents fuel flow if pilot is not detected or stops fuel flow if main flame is not detected. Response time is 1 sec to 4 sec. Suitable for large programmed installations.

Photo cell, ultraviolet, or infrared detectors "look at" the pilot and main flame and provide the same safeguard features as the electrode used in the flame rectification.

flammability: susceptibility to combustion.

flareback: a burst of flame from a furnace in a direction opposed to the normal flow, usually caused by the ignition of an accumulation of combustible gases.

flare type burner: a circular burner from which the fuel and air are discharged in the form of a cone.

flash point: the lowest temperature at which, under specified conditions, fuel oil gives off enough vapor to flash into momentary flame when ignited.

flat-flamed burner: a burner terminating in a substantially rectangular nozzle, from which fuel and air are discharged in a flat stream.

flue: a passage for products of combustion.

flue gas: the gaseous products of combustion in the flue to the stack.

forced draft boiler: a boiler that operates with the furnace pressure higher than atmospheric.

forced draft fan: a fan supplying air under pressure to the fuel burning equipment.

forced draft stoker: a stoker in which the flow of air through the grate is caused by a pressure produced by mechanical means.

front discharge stoker: a stoker so arranged that refuse is discharged from the grate surface at the same end as the coal feed.

fuel: a substance containing combustible material used for generating heat.

fuel–air mixture: mixture of fuel and air.

fuel–air ratio: the ratio of the weight, or volume, of fuel to air.

fuel bed: layer of burning fuel on a furnace grate.

fuel oil: a liquid fuel derived from petroleum or coal.

furnace draft: the draft in a furnace, measured at a point immediately in front of the highest point at which the combustion gases leave the furnace.

gas analysis: the determination of the constituents of a gaseous mixture.

gas burner: a burner for use with gaseous fuel.

grate: the surface on which fuel is supported and burned, and through which air is passed for combustion.

grate bars: those parts of the fuel supporting surface arranged to admit air for combustion.

gravity: weight index of fuels: liquid petroleum products expressed either as specific, Baume or API (American Petroleum Institute) gravity; weight index of gaseous fuels as specific gravity related to air under specified conditions; or weight index of solid fuels as specific gravity related to water under specified conditions.

hand-fired grate: a grate on which fuel is placed manually, usually by means of a shovel.

heat available: the thermal energy above a fixed datum that is capable of being absorbed for useful work. In boiler practice, the heat available in a furnace is usually taken to be the higher heating value of the fuel, corrected by subtracting radiation losses, unburned combustible, latent heat of the water in the fuel or of the water formed by the burning of hydrogen, and by adding the sensible heat in the air for combustion, all above ambient temperatures.

heat balance: an accounting of the distribution of the heat input and output.

heat release: the total quantity of thermal energy above a fixed datum introduced into a furnace by the fuel considered.

high-heat value: see *calorific value*.

hogged fuel: wood refuse after being chipped or shredded by a machine known as a "hog."

horizontal firing: a means of firing liquid, gaseous, or pulverized fuel, in which the burners are so arranged in relation to the furnace as to discharge the fuel and air into the furnace in approximately a horizontal direction.

hydrocarbon: a chemical compound of hydrogen and carbon.

ignition: the initiation of combustion.

ignition temperature: lowest temperature of a fuel at which combustion becomes self-sustaining.

ignition torch: see *lighting-off torch*.

illuminants: light oil or coal compounds that readily burn with a luminous flame such as ethylene, propylene, and benzene.

impeller: as applied to pulverized coal burners, a round metal device located at the discharge of the coal nozzle in circular type burners, to deflect the fuel and primary air into the secondary air stream; as applied to oil burners, same as *diffuser*.

inches water gage (in. w.g.): usual term for expressing a measurement of relatively low pressures or differentials by means of a U-tube. One inch w.g. (0.25 kPa) equals 5.2 lb/ft^2 or 0.036 lb/in.^{2}

incomplete combustion: the partial oxidation of the combustible constituent of a fuel.

induced draft boiler: a boiler that operates with the furnace pressure less than atmospheric due to action of an induced draft fan.

induced draft fan: a fan exhausting hot gases from the heat-absorbing equipment.

inert gaseous constituents: incombustible gases such as nitrogen that may be present in a fuel.

inlet boxes: an integral part of the fan enclosing the fan inlet or inlets to permit attachment of the fan to the duct system.

integral blower: a blower built as an integral part of a device to supply air thereto.

integral-blower burner: a burner of which the blower is an integral part.

intermittent firing: a method of firing by which fuel and air are introduced into and burned in a furnace for a short period, after which the flow is stopped, this succession occurring in a sequence of frequent cycles.

internal-mix oil burner: a burner having a mixing chamber in which high velocity steam or air impinges on jets of incoming liquid fuel that is then discharged in a completely atomized form.

intertube burner: a burner that terminates in nozzles discharging between adjacent tubes.

isolating transformer: one that provides for complete separation and overcurrent protection by fusing both leads of the primary circuit and the control lead of the secondary circuit.

lighting-off torch: a torch used for igniting fuel from a burner. The torch may consist of asbestos wrapped around an iron rod and saturated with oil or may be a small oil or gas burner.

lignite: a consolidated coal of low classification according to rank — moist (bed moisture only) Btu less than 8300 (MJ less than 8.76).

long-flame burner: a burner in which the fuel emerges in such a condition, or one in which the air for combustion is admitted in such a manner, that the two do not readily mix, resulting in a comparatively long flame.

low-heat value: the high heating value minus the latent heat of vaporization of the water formed by burning the hydrogen in the fuel.

luminosity: emissive power with respect to visible radiation.

manometer: device used to detect small changes in pressure, usually a tube with water, the pressure variations measured in inches of water.

manufactured gas: fuel gas manufactured from coal, oil, etc., as differentiated from natural gas.

mechanical atomizing oil burner: a burner that uses the pressure of the oil for atomization.

mechanical draft: the negative pressure created by mechanical means.

mechanical efficiency: the ratio of power output to power input.

mechanical stoker: a device consisting of a mechanically operated fuel feeding mechanism and a grate, used for the purpose of feeding solid fuel into a furnace, distributing it over the grate, admitting air to the fuel for the purpose of combustion, and providing a means for removal or discharge of refuse.

overfeed stoker: a stoker in which fuel is fed onto grates above the point of air admission to the fuel bed. Overfeed stokers are divided into four classes, as follows:

front feed inclined grate stoker: an overfeed stoker in which fuel is fed from the front onto a grate inclined downwards toward the rear of the stoker.

double-inclined side feed stoker: an overfeed stoker in which the fuel is fed from both sides onto grates inclined downwards toward the center line of the stoker.

chain or traveling grate: an overfeed stoker having a moving endless grate that conveys fuel into and through the furnace where it is burned, after which it discharges the refuse.

spreader stoker: an overfeed stoker that discharges fuel into the furnace from a location above the fuel bed and distributes the fuel onto the grate.

underfeed stoker: a stoker in which fuel is introduced through retorts at a level below the location of air admission to the fuel bed. Underfeed stokers are divided into three general classes, as follows:

side ash discharge underfeed stoker: a stoker having one or more retorts that feed and distribute solid fuel onto side tuyeres or a grate through which air is admitted for combustion and over which the ash is discharged at the side parallel to the retorts.

rear ash discharge underfeed stoker: a stoker having a grate composed of transversely spaced underfeed retorts, that feed and distribute solid fuel to intermediate rows of tuyeres through which air is admitted for combustion. The ash is discharged from the stoker across the rear end.

continuous ash discharge underfeed stoker: one in which the refuse is discharged continuously from the normally stationary stoker ash tray to the ash pit without the use of mechanical means other than the normal action of the coal feeding and agitating mechanism.

modulation of burner: control of fuel and air to a burner to match fluctuations of the load on the boiler.

moisture: water in the liquid or vapor phase.

moisture loss: the loss representing the difference in the heat content of the moisture in the exit gases and that at the temperature of the ambient air.

multifuel burner: a burner by means of which more than one fuel can be burned, either separately or simultaneously, such as pulverized fuel, oil, or gas.

multiple-retort stoker: an underfeed stoker consisting of two or more retorts, parallel and adjacent to each other, but separated by a line of tuyeres, and arranged so that the refuse is discharged at the ends of the retorts.

multiport burner: a burner having a number of nozzles from which fuel and air are discharged.

natural draft boiler: a boiler that operates with the furnace pressure less than atmospheric due to buoyant action of the venting system.

natural draft stoker: a stoker in which the flow of air through the grate is caused by difference of pressure between the furnace and the atmosphere.

natural gas: gaseous fuel occurring in nature.

neutral atmosphere: an atmosphere that tends neither to oxidize nor reduce immersed materials.

oil burner: a burner for firing oil.

oil cone: the cone of finely atomized oil discharged from an oil atomizer.

oil gas: gas produced from petroleum.

orifice: the opening from the whirling chamber of a mechanical atomizer or the mixing chamber of a steam atomizer through which the liquid fuel is discharged.

orsat: a gas-analysis apparatus in which certain gaseous constituents are measured by absorption in separate chemical solutions.

overfire draft: air pressure that exists in the furnace of a boiler when the main flame occurs.

oxidation: chemical combination with oxygen.

oxidizing atmosphere: an atmosphere that tends to promote the oxidation of immersed materials.

peat: an accumulation of compacted and partially devolatilized vegetable matter with high moisture content; an early stage of coal formation.

perfect combustion: the complete oxidation of all the combustible constituents of a fuel, utilizing all the oxygen supplied.

petroleum: naturally occurring mineral oil consisting predominately of hydrocarbons.

petroleum coke: solid carbonaceous residue remaining in oil refining stills after the distillation process.

pilot flame: the flame, usually gas or light oil, that ignites the main flame.

pour point: the temperature at which the oil flows.

preheated air: air at a temperature exceeding that of the ambient air.

primary air: air introduced with the fuel at the burners.

primary air fan: a fan to supply primary air for combustion of fuel.

producer gas: gaseous fuel obtained by burning solid fuel in a chamber where a mixture of air and steam is passed through the incandescent fuel bed. This process results in a gas, almost oxygen free, containing a large percentage of the original heating value of the solid fuel in the form of CO and H_3.

products of combustion: the gases, vapors, and solids resulting from the combustion of fuel.

puff: a minor combustion explosion within the boiler furnace or setting.

pulverized fuel: solid fuel reduced to a fine size.

purge meter interlock: a flowmeter so arranged that an air flow through the furnace above a minimum amount must exist for a definite time interval before the interlocking system will permit an automatic ignition torch to be placed in operation.

pyrites: a compound of iron and sulfur naturally occurring in coal.

radiation loss: a comprehensive term used in a boiler-unit heat balance to account for the conduction, radiation, and convection heat losses from the settings to the ambient air.

reciprocating grate: a grate element that has reciprocating motion, usually for the purpose of fuel agitation.

refinery gas: the commercially noncondensable gas resulting from fractional distillation of crude oil, or the cracking of crude oil or petroleum distillates. Refinery gas is either burned at the refineries or supplied for mixing with city gas.

register: the apparatus used in a burner to regulate the direction of flow of air for combustion.

relative humidity: the ratio of the weight of water vapor present in a unit volume of gas to the maximum possible weight of water vapor in unit volume of the same gas at the same temperature and pressure.

relay: electrical device that contains a coil that makes and/or breaks sets of contacts as the coil is energized and de-energized.

residual fuels: products remaining from crude petroleum by removal of some of the water and an appreciable percentage of the more volatile hydrocarbons.

return flow oil burner: a mechanical atomizing oil burner in which part of the oil supplied to the atomizer is withdrawn and returned to storage or to the oil line supplying the atomizer.

Ringlemann chart: a series of four rectangular grids of black lines of varying widths printed on a white background, and used as a criterion of blackness for determining smoke density.

rotary oil burner: a burner in which atomization is accomplished by feeding oil to the inside of a rapidly rotating cup.

safety control: devices incorporated in the burner control circuitry and on the burner to allow flow of the fuel only if required steps and conditions are met.

saturated air: air that contains the maximum amount of water vapor that it can hold at its temperature and pressure.

secondary air: air for combustion supplied to the furnace to supplement the primary air.

secondary combustion: combustion that occurs as a result of ignition at a point beyond the furnace (see also *delayed combustion*).

sediment: a noncombustible solid matter that settles out at bottom of a liquid; a small percentage is present in residual fuel oils.

smoke: small gasborne particles of carbon or soot, less than 1 μin. (0.025 μm) size, resulting from incomplete combustion of carbonaceous material and of sufficient number to be observable.

soot: unburned particles of carbon derived from hydrocarbons.

specific heat: the quantity of heat, expressed in Btu, required to raise the temperature of 1 lb (0.45 kg) of a substance 1°F (0.556°C).

specific humidity: the weight of water vapor in a gas–water vapor mixture per unit weight of dry gas.

spontaneous combustion: ignition of combustible material following slow oxidation without the application of high temperature from an external source.

spray angle: the angle included between the sides of the cone formed by liquid fuel discharged from mechanical, rotary atomizers and by some forms of steam or air atomizers.

spray nozzle: a nozzle from which a fuel is discharged in the form of a spray.

sprayer plate: a metal plate used to atomize the fuel in the atomizer of an oil burner.

stack: a vertical conduit, that, due to the difference in density between internal and external gases, creates a draft at its base.

stack draft: the magnitude of the draft measured at inlet to the stack.

stack effect: that portion of a pressure differential resulting from difference in elevation of the points of measurement.

standard air: dry air weighing 0.075 lb/ft^3 (1.2 kg/m^3) at sea level [29.92 in. (760 mm Hg) barometric pressure] and 70°F (21°C).

static pressure: the measure of potential energy of a fluid.

stationary grate: a grate having no moving parts.

steam atomizing oil burner: a burner for firing oil that is atomized by steam. It may be of the inside or outside mixing type.

stoker: see *mechanical stoker*.

strainer, fuel oil: metal screen with small openings to retain solids and particles in fuel oil that could detrimentally affect the operation of the oil burner.

stratification: nonhomogeneity existing transversely in a gas stream.

surface combustion: the nonluminous burning of a combustible gaseous mixture close to the surface of a hot porous refractory material through which it has passed.

tempering air: air at a lower temperature added to a stream of preheated air to modify its temperature.

tertiary air: air for combustion supplied to the furnace to supplement the primary and secondary air.

theoretical air: the quantity of air required for perfect combustion.

theoretical draft: the draft that would be available at the base of a stack if there were no friction or acceleration losses in the stack.

therm: a unit of heat applied especially to gas; 1 therm equals 100,000 Btu (105.5 MJ).

torching: the rapid burning of combustible material deposited on or near boiler-unit heating surfaces.

total air: the total quantity of air supplied to the fuel and products of combustion. Percent total air is the ratio of total air to theoretical air, expressed as percent.

turbulent burner: a burner in which fuel and air are mixed and discharged into the furnace in such a manner as to produce turbulent flow from the burner.

unburned combustible: the combustible portion of the fuel that is not completely oxidized.

vertical firing: an arrangement of a burner such that air and fuel are discharged into the furnace, in practically a vertical direction.

viscosity: measure of the internal friction of a fluid or its resistance to flow.

volatility: measurement of a fuel oil's ability to vaporize.

water gas: gaseous fuel consisting primarily of carbon monoxide and hydrogen made by the interaction of steam and incandescent carbon.

wide-range mechanical atomizing oil burner: a burner having an oil atomizer with a range of flow rates greater than that obtainable with the usual mechanical atomizers.

windbox: a chamber below the grate or surrounding a burner, through which air under pressure is supplied for combustion of the fuel.

SECTION 2
TYPES OF BOILERS

2.01 CLASSIFICATION

The two most general classifications of heating boilers pertain to the method of manufacture, i.e., by casting or fabrication. Those that are cast usually use iron, bronze, or brass in their construction. Those that are fabricated use steel, copper, or brass, with steel being the most common material used.

2.02 STEEL BOILERS

Steel boilers can be generally divided into two types, firetube and watertube. In firetube boilers, the gases of combustion pass through the tubes and the water circulates around them. In watertube boilers, the water passes through the tube and the combustion gases pass around them.

A. Firetube Boilers.

(a) Horizontal Return Tube (HRT). Figure 2.02A-1 shows a brick-set boiler of this type. The furnace may also be constructed of steel.

(b) Scotch-Type Boilers. The scotch boilers used in modern heating systems are similar to those originally designed for shipboard installation and are sometimes called scotch marine boilers. The furnace is a cylinder completely surrounded by water. See Figure 2.02A-2.

Most scotch boilers are of the dry-back or partial wetback design and are arranged for multiple gas passes. See Figure 2.02A-2.

(c) Firebox Boilers. Firebox boilers have the firebox integral with the boiler, such as the oil field or locomotive type, and may be single or multiple pass. The furnace of this type boiler is usually enclosed in water-cooled upper sheet, called a crown sheet. Various tube and shell configurations, characterizing different manufacturers' designs, complete the boilers. See Figures 2.02A-3, 2.02A-4, and 2.02A-5.

(d) Vertical Firetube Boilers. In vertical firetube boilers, the products of combustion pass up through the tubes that are surrounded by water. See Figure 2.02A-6.

B. Watertube Boilers. Watertube boilers are made in a variety of configurations with respect to tube and drum arrangement.

2.03 CAST IRON BOILERS

Cast iron boilers are made in three general types: horizontal sectional, vertical sectional, and one-piece.

Most of the sectional boilers are assembled with push nipples or grommet type seals, but some are assembled with external headers and screwed nipples.

NOTE: Manufacturer's recommendations should be followed when adjusting nipples or tie rods. Excess tension on tie rods may be detrimental to the boiler.

A. Horizontal Sectional Cast Iron Boilers. Horizontal sectional cast iron boilers are made up of sections stacked one above the other, like pancakes, and assembled with push nipples. See Figure 2.03A.

B. Vertical Sectional Cast Iron Boilers. Vertical sectional cast iron boilers are made up with sections standing vertically like slices in a loaf of bread. See Figure 2.03B.

C. One-Piece Cast Iron Boilers. One-piece cast iron boilers are those in which the pressure vessel is made as a single casting.

2.04 MODULAR BOILERS

A modular boiler is an assembly of small boilers designed to take the place of a single large boiler. The small boilers are called modules and are manifolded together at the jobsite, without any intervening stop valves. It is important that the manufacturer's installation instructions be followed to assure proper assembly, correct control location, and proper flow through each module.

Figures 2.04A and 2.04B show the two piping arrangements that are specified by various manufacturers.

There is sometimes confusion between modular boilers and multiple boilers. Modular boilers have no intervening stop valves so some controls can be mountedon the manifold. Multiple boilers have stop valves so every individual boiler must have all the controls required by the Code.

2.05 VACUUM BOILERS

Vacuum boilers are factory sealed steam boilers that are operated below atmospheric pressure.

Figure 2.02A-1
Horizontal Return Tube, Brick-Set

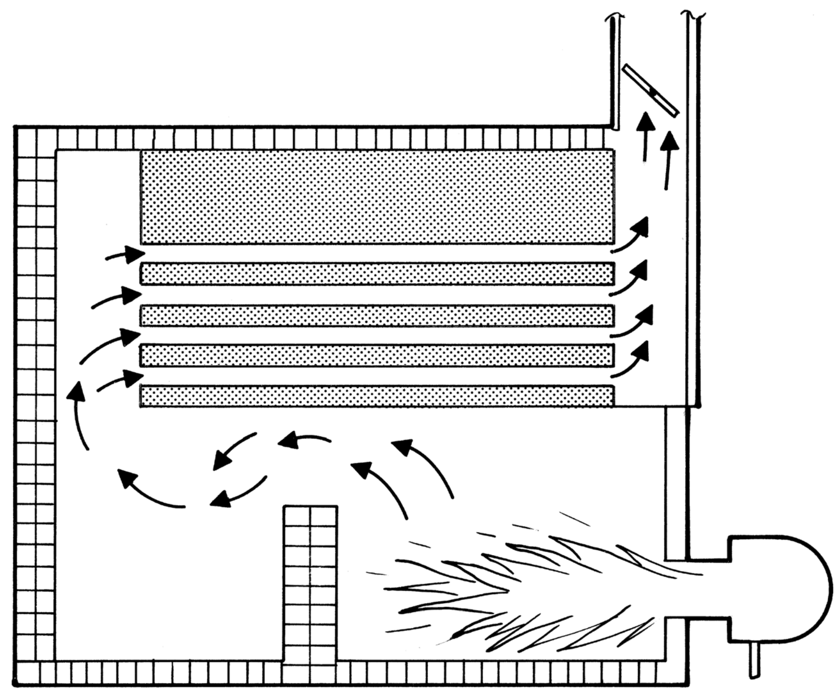


Figure 2.02A-2
Gas Flow Patterns of Scotch-Type Boilers

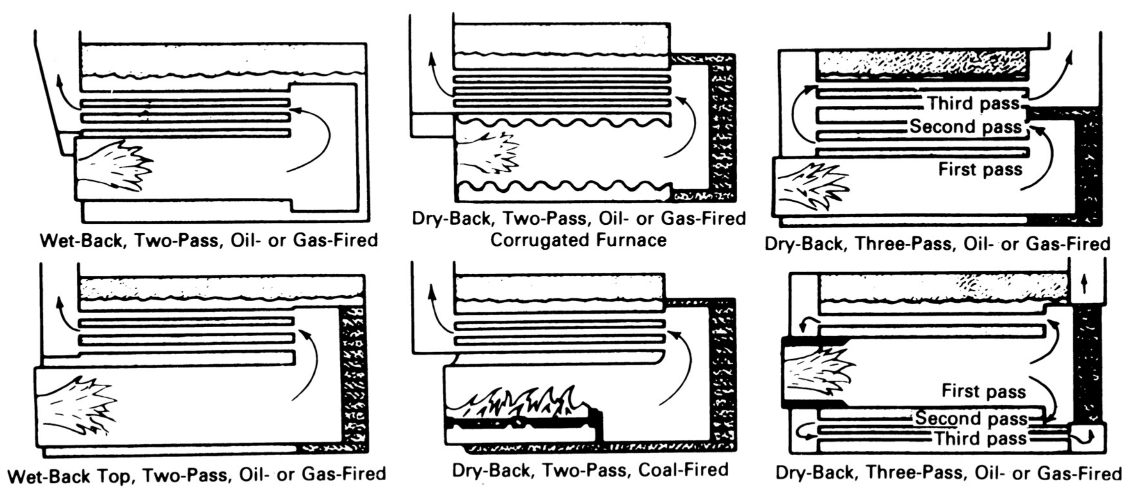


Figure 2.02A-3
Type C Firebox Boiler

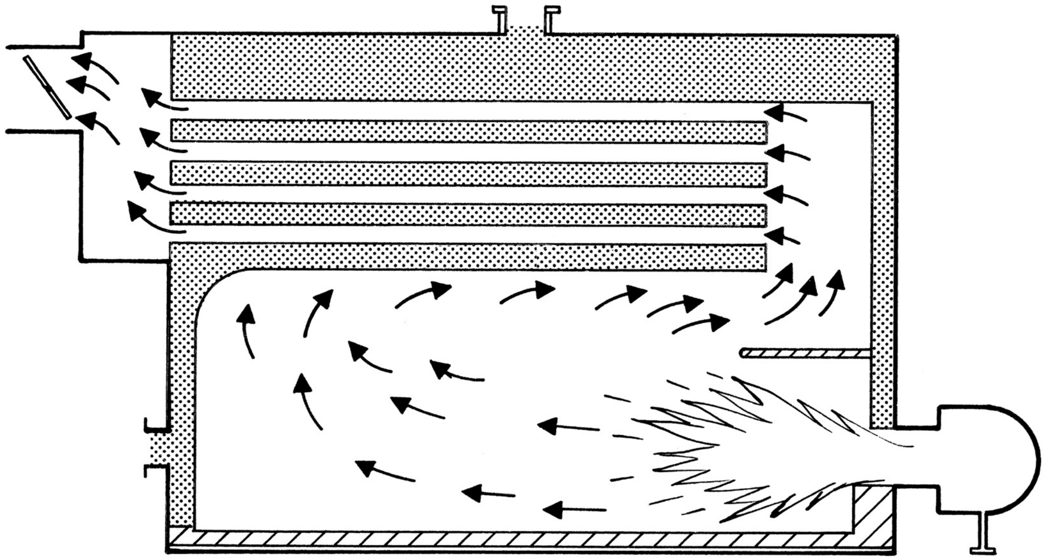


Figure 2.02A-4
Three-Pass Firebox Boiler

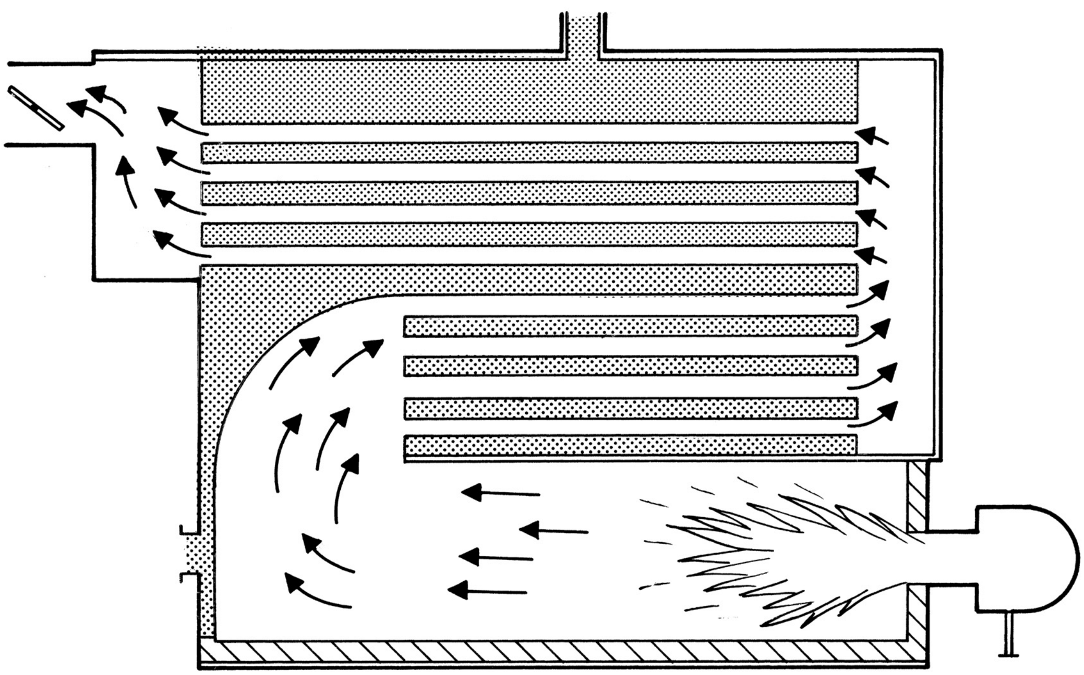


Figure 2.02A-5
Locomotive Firebox Boiler

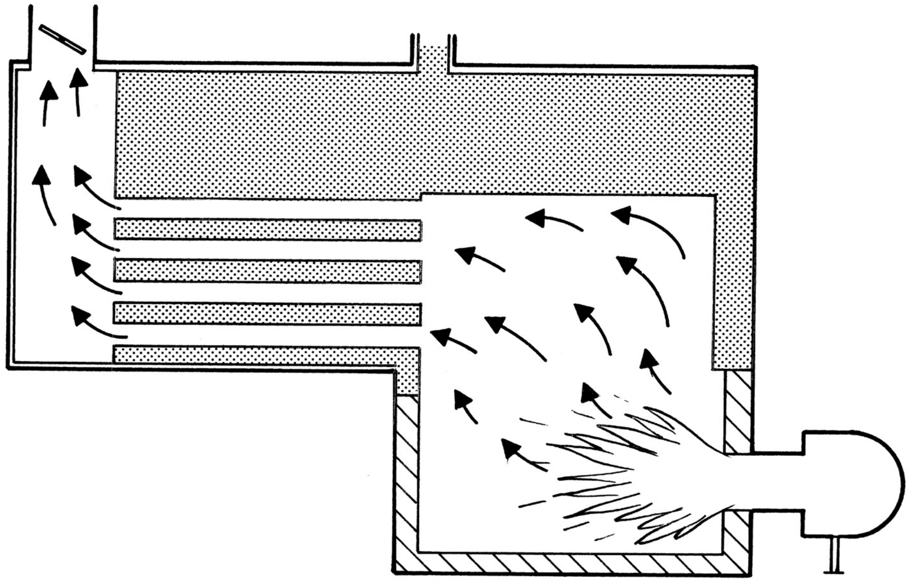


Figure 2.02A-6
Vertical Firetube Boiler

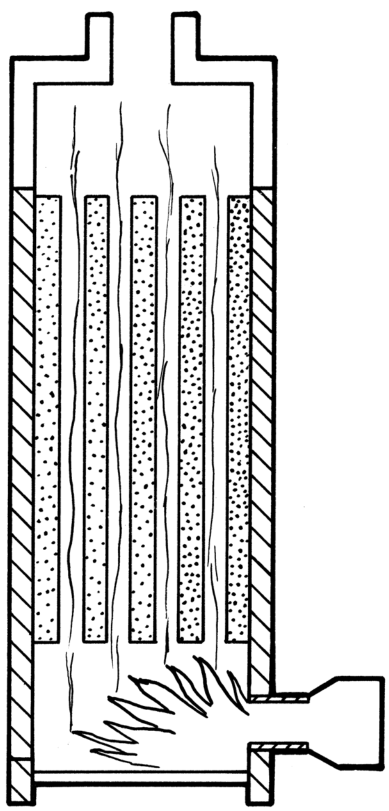


Figure 2.03A
Horizontal Sectional Cast Iron Boiler

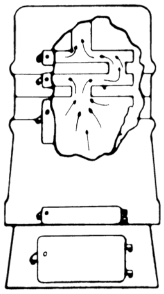


Figure 2.03B
Vertical Sectional Cast Iron Boiler

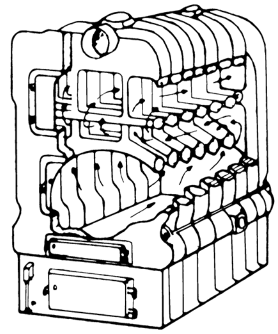


Figure 2.04A
Modules Connected With Parallel Piping

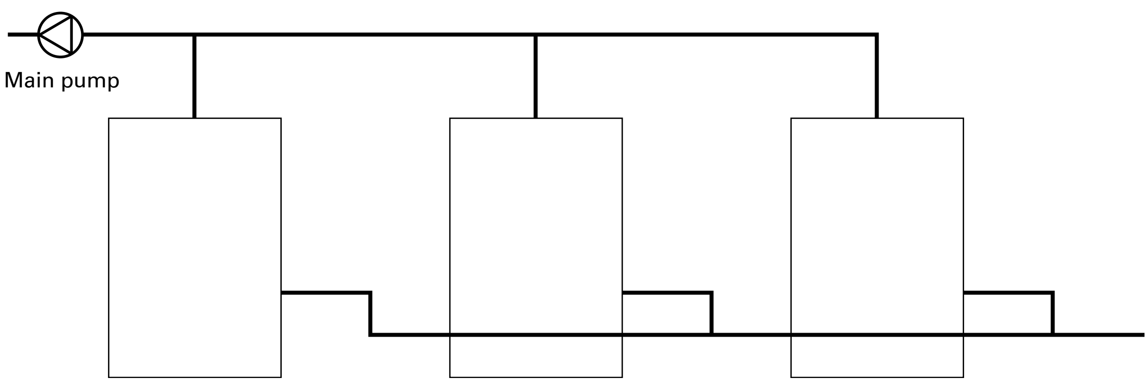
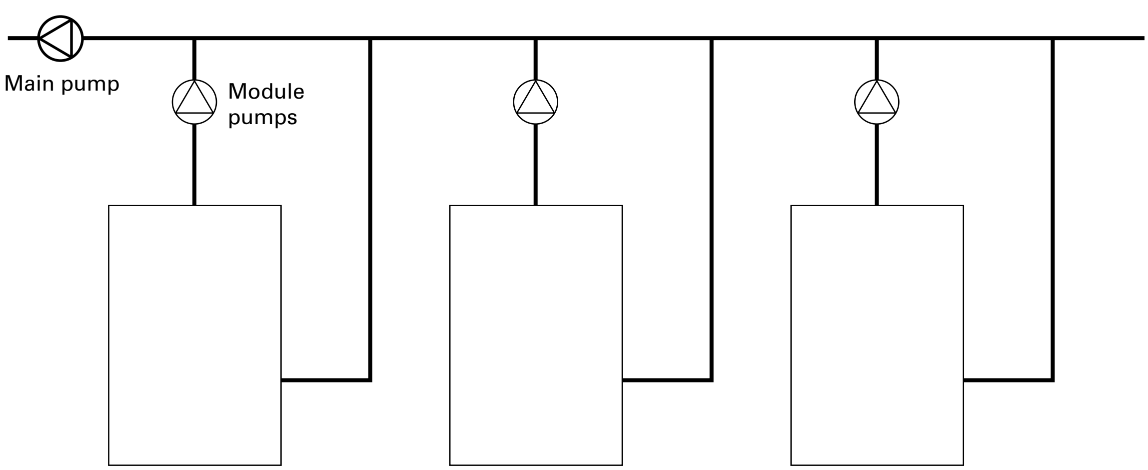


Figure 2.04B
Modules Connected With Primary-Secondary Piping



SECTION 3
ACCESSORIES AND INSTALLATION

ACCESSORIES

3.01 SAFETY AND SAFETY RELIEF VALVES

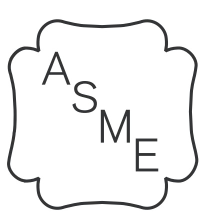
Safety and safety relief valves are used to relieve excessive pressure generated within a boiler. The safety or safety relief valve (or valves) is the final line of protection against overpressure in the boiler. They discharge a volume of steam and hot water when relieving (see I, Safety and Safety Relief Valve Discharge Piping). This is the most important single safety device on any boiler. These valves shall bear the Certification Mark with HV Designator as illustrated in Figure 3.01, to signify compliance with Section IV.

A. Safety Valves. A safety valve is an automatic pressure relieving device actuated by the pressure generated within the boiler and characterized by full-opening pop action. It is used for steam service. Valves are of the spring-loaded pop type and are factory set and sealed. See Figure 3.01A.

B. Safety Relief Valves. A safety relief valve is an automatic pressure relieving device actuated by the pressure generated within the boiler. It is used primarily on water boilers. Valves of this type are spring loaded without full-opening pop action and have a factory set nonadjustable pressure setting. See Figure 3.01B.

C. Temperature and Pressure Safety Relief Valves. A temperature and pressure safety relief valve is a safety relief valve, as described in B above, that also incorporates a thermal sensing relief element that is actuated by the upstream water temperature. It is set at 210°F (99°C) or lower.

Figure 3.01
Official Certification Mark



3.02 LOW-WATER FUEL CUTOFFS AND WATER FEEDERS

Low-water fuel cutoffs are designed to provide protection against hazardous low-water conditions in heating boilers. Records indicate that many boiler failures result from low-water conditions. Low-water fuel cutoffs may be generally divided into two types, float and probe.

A. Float Type Low-Water Fuel Cutoffs. Float type low-water fuel cutoffs may be in combination with a water feeder or constructed as a separate unit. The combination feeder cutoff units are generally used on steam boilers while the cutoff units are sometimes installed on hot water boilers, or as a second cutoff on steam boilers. A feeder cutoff combination adds water as needed to maintain a safe minimum water level and stops the firing device if the water level falls to the lowest permissible level. Both operations are accomplished by the movement of the float that is linked to the water valve or pump control and burner cutoff switch. The units that serve as fuel cutoffs only are basically the same as the combination unit but without the water feeder valve (see Figure 3.02A). A water feeder installation normally acts as an operating device to maintain a predetermined safe water level in the boiler.

B. Electric Probe Type Low-Water Fuel Cutoffs. Electric probe type low-water fuel cutoffs may be contained in a water column mounted externally on the boiler or may be mounted on the boiler shell. Some consist of two electrodes (probes) that under normal conditions are immersed in the boiler water with a small current being conducted from one electrode to the other to energize a relay. Others use one probe and the boiler shell, in effect, becomes the other probe. If the water level drops sufficiently to uncover the probes, the current flow stops and the relay operates to shut off the burner. See Figure 3.02B.

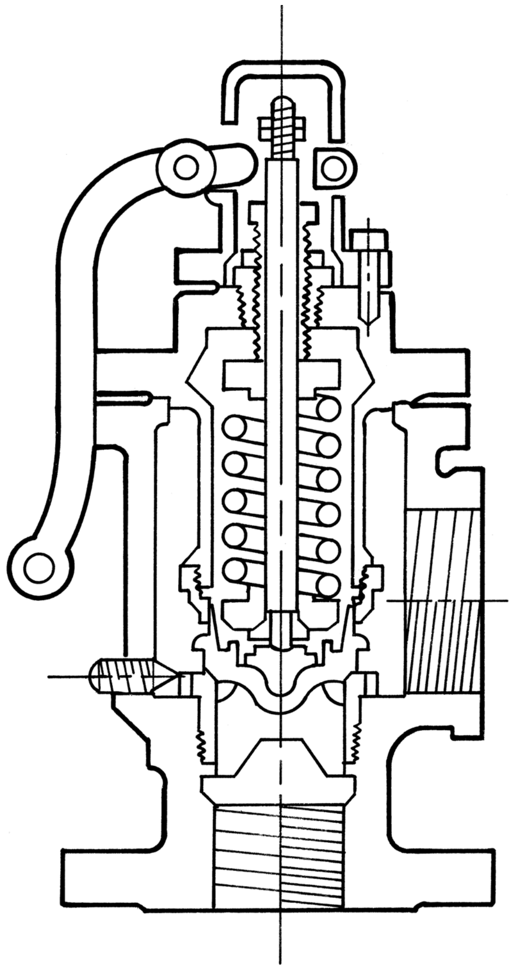
3.03 TRAPS

A steam trap is a device put on steam lines and on the outlet of heating units to permit the exit of air and condensate but to prevent the passage of steam. The types of steam traps in common use are: thermostatic, float, combination float and thermostatic, and bucket. See Figures 3.03-1, 3.03-2, 3.03-3, and 3.03-4.

3.04 AIR ELIMINATORS

Air eliminators are sometimes installed on hot water boilers to eliminate air from the system as it is released from the water within the boiler.

Figure 3.01A
Safety Valve



3.05 CONDENSATE RETURN PUMPS AND RETURN LOOP

Condensate return pumps are used on either one or two pipe steam systems to return condensate to the boiler where this cannot be done by gravity. They are generally used in conjunction with a reservoir (condensate return tank) and a float operated switch for starting the pump motor. Where two boilers are connected together and served from one condensate return pump, a vacuum breaker may be required on the idle boiler to prevent the formation of a vacuum that will affect the functioning of the feed valve. The return pipe connections of each boiler supplying a gravity return of a steam heating system should be so arranged as to form a loop substantially as shown in Figure 3.05 so that the water in each boiler cannot be forced below the safe water level. The loop is required in gravity systems and may be included in pump return systems.

Pumped feedwater returns, when connected to a return loop, should be connected directly to the lower boiler connection of the loop because under some circumstances a connection to the return loop near the boiler waterline may cause objectionable noise or water hammer.

3.06 VACUUM RETURN PUMP

The vacuum return pump is used in larger steam systems to create a partial vacuum in the return lines of the heating system and thus assist in the return of the condensate, elimination of air, and equal distribution of steam.

3.07 CIRCULATORS (CIRCULATING PUMPS)

Circulators are basically centrifugal pump units used on hot water heating systems to force the flow of water through the system.

Figure 3.01B
Safety Relief Valve

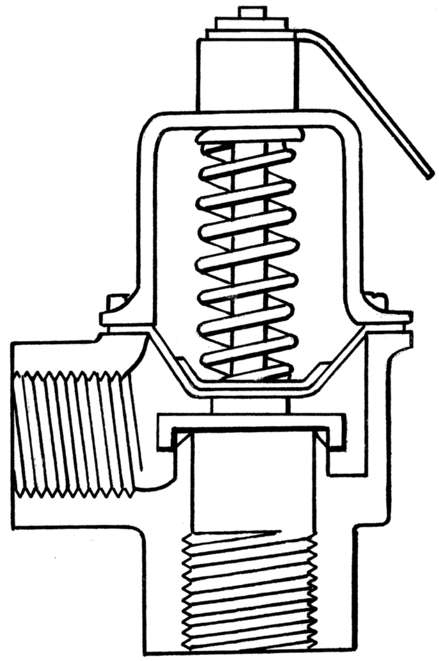


Figure 3.02A
Float Type Low-Water Cutoff

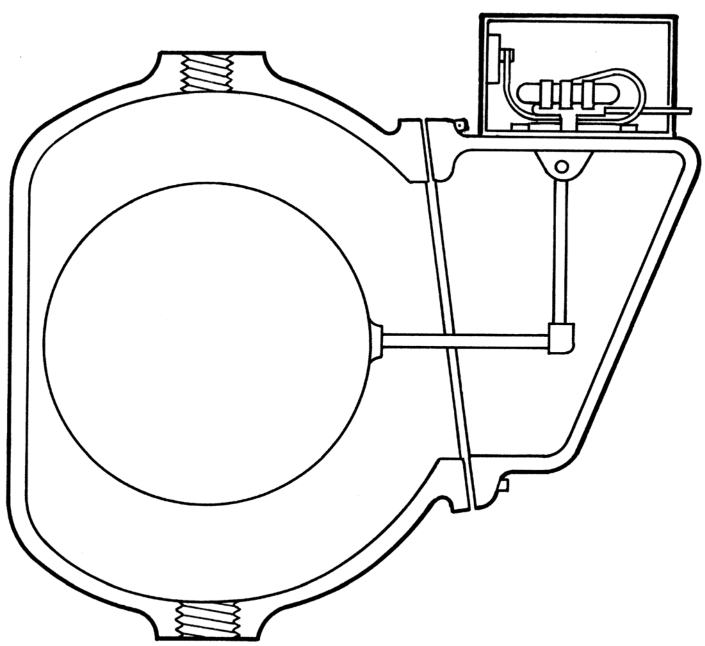
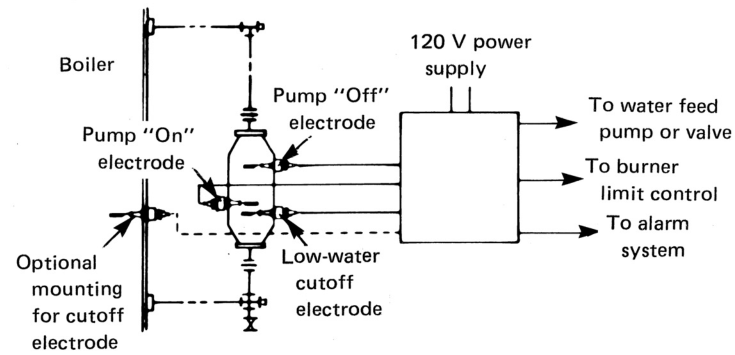
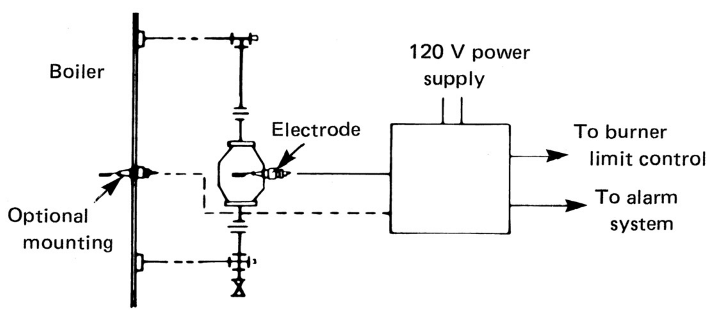


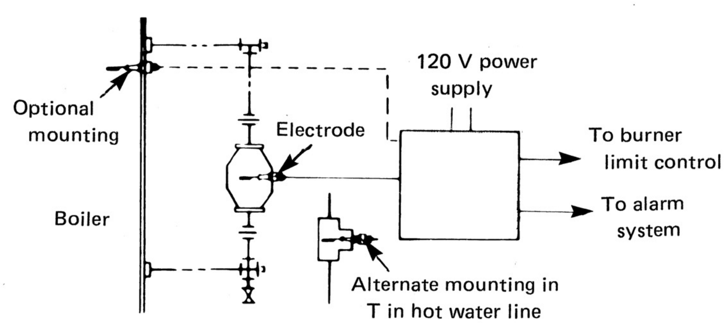
Figure 3.02B
Electric Probe Type Low-Water Control



Automatic Boiler Water Feed and Low-Water Cutoff — For Steam



Low-Water Cutoff — For Steam



Low-Water Cutoff — For Hot Water

Figure 3.03-1
Thermostatic Trap

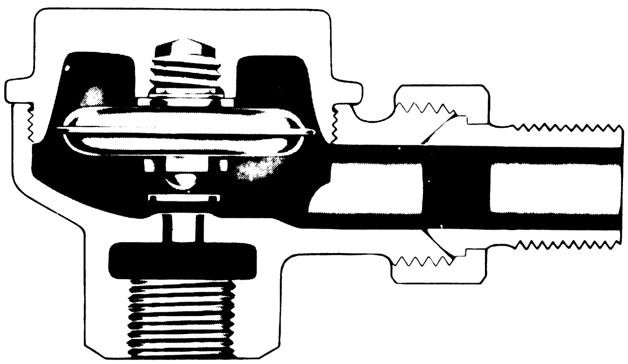


Figure 3.03-3
Float and Thermostatic Trap

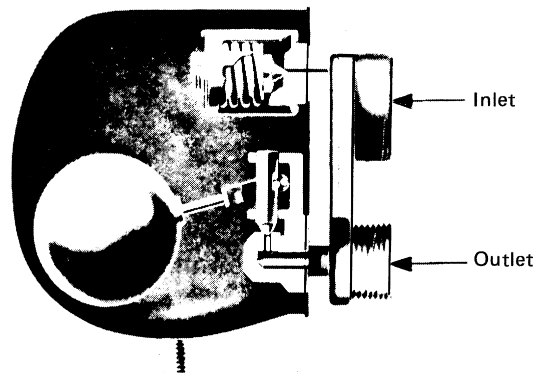


Figure 3.03-2
Float Trap

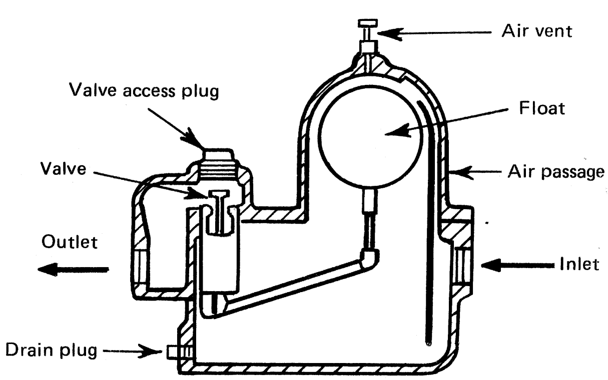


Figure 3.03-4
Bucket Trap With Trap Closed

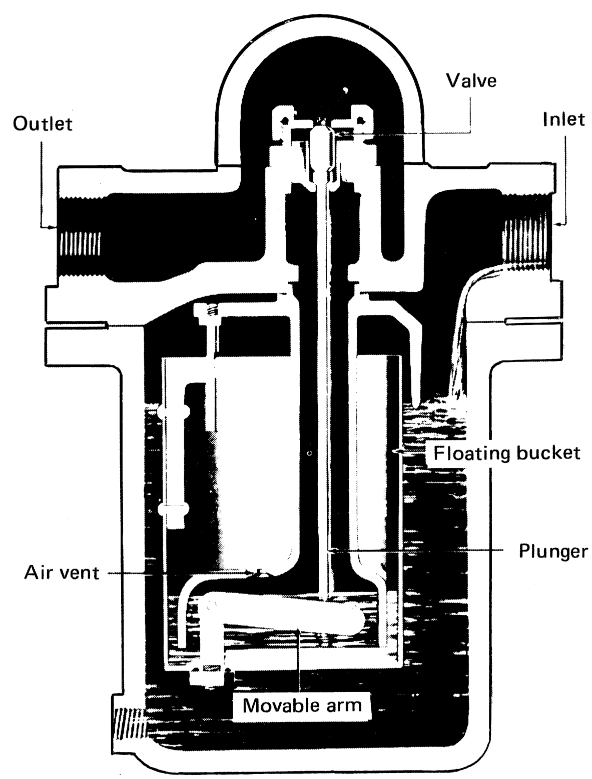
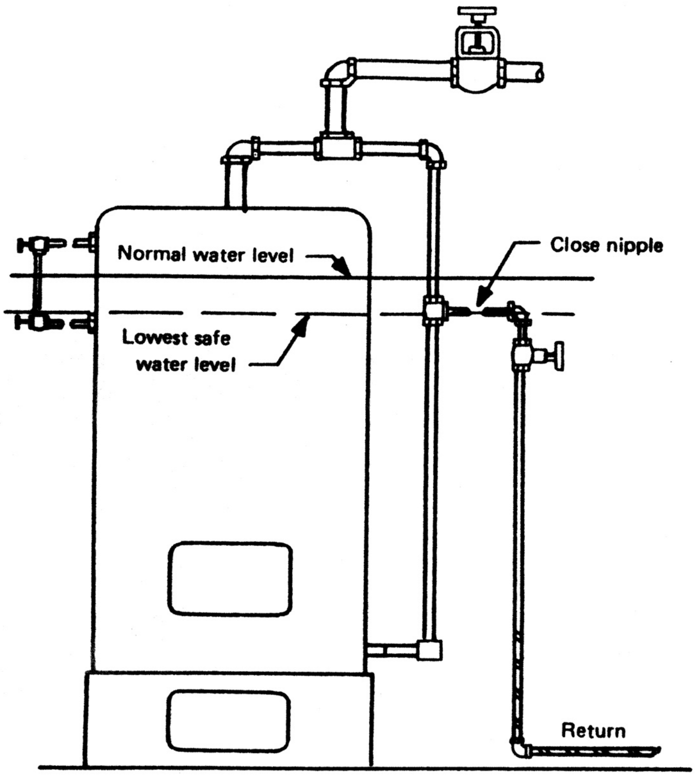


Figure 3.05
Typical Return Loop



3.08 EXPANSION TANK

Expansion tanks are used on hot water systems to allow for the expansion of the water when it is heated. An air cushion in the tank is compressed by the expanding water.

3.09 OIL PREHEATERS

Oil preheaters are used to condition the heavier grades of fuel oil for handling and burning. They may be used in the oil storage tank or at the burner (or at both locations), depending upon the requirements of the oil burned.

3.10 FUEL OIL STORAGE AND SUPPLY SYSTEMS

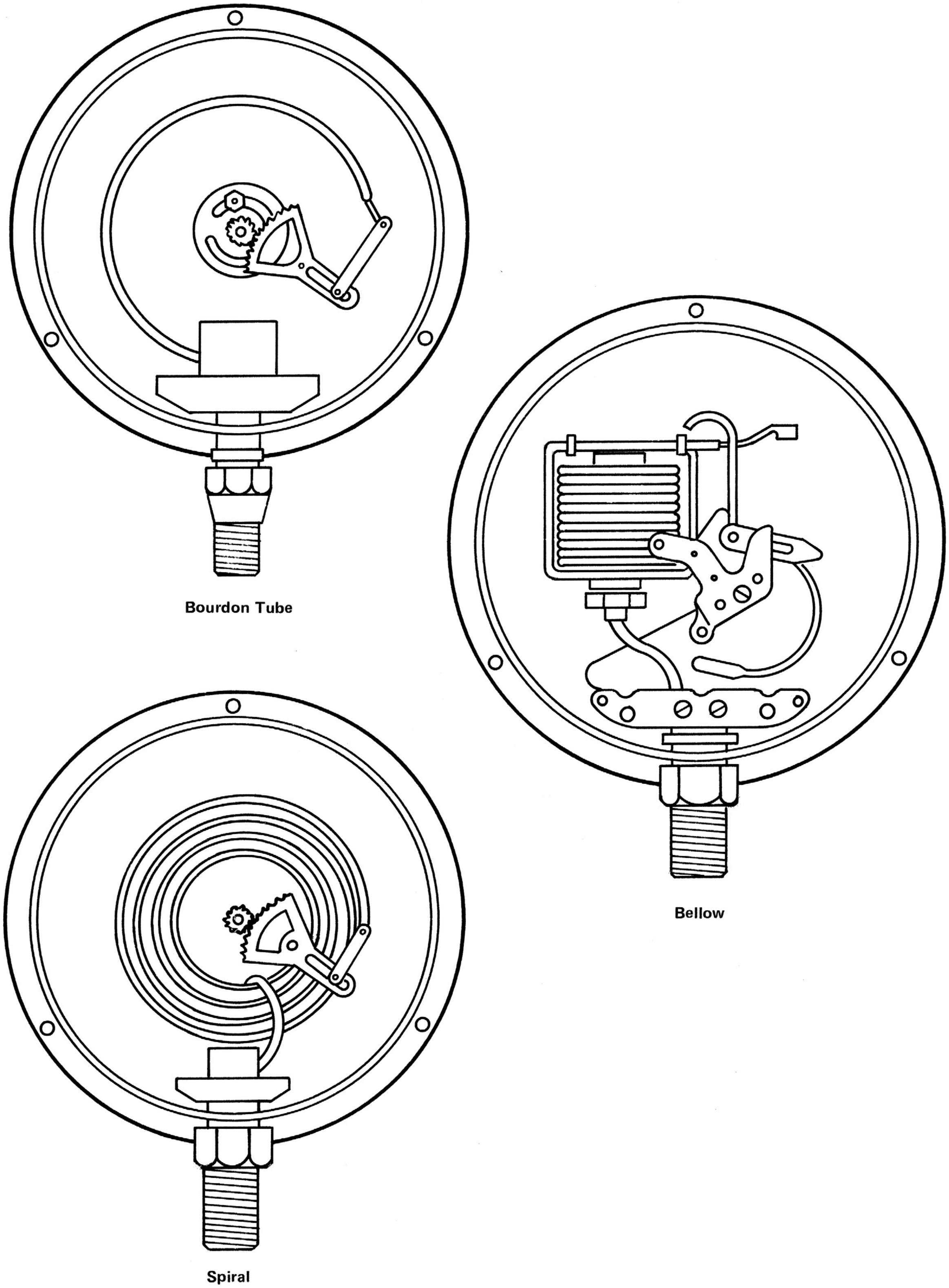
A fuel oil storage and supply system may consist of a tank, connecting piping, and necessary strainers only, or it may require a transfer pump, depending upon the location of the tank and the grade of oil being used. Oils of Grade 4, 5, or 6, and sometimes Grade 2 require hot water or steam heating coils to be installed in the tanks. The fuel oil temperature should be controlled to permit satisfactory flowing or pumping in the presence of low outside temperatures.

3.11 PRESSURE GAGE

Pressure gages are used on both steam and hot water boilers. There are three basic types of pressure gages, namely bourdon, bellow, and spiral (see Figure 3.11). The bourdon tube has the widest range of application and is by far the most common. It consists of a hollow tube with an oval cross section that tends to straighten when the pressure is increased. The end of the bourdon tube is connected to the gage pointer by a mechanical linkage. The material used in the bourdon tube is usually an alloy steel monel or stainless steel depending on the type of service. The bellow type gage is normally used for pressures below 30 psi (200 kPa). Gages are usually damaged by overpressure, corrosion of tube or linkage, or wear of linkage.

A. Gage Range. The gage range should be selected so that the gage will normally operate in the middle of the scale. For example, if the operating pressure is 50 psi (350 kPa), then a 100 psi (700 kPa) gage should be used. For steam heating boilers, the gage should have a range of not less than 30 psi (200 kPa) nor more than 60 psi (400 kPa); and for hot water boilers, not less than $1\frac{1}{2}$ times nor more than $3\frac{1}{2}$ times the safety relief valve setting.

Figure 3.11
Pressure Gages



B. Accuracy. The gage accuracy is expressed in percent of full scale reading. For example, if a 100 psi (700 kPa) gage is 2% accurate, then it will be within ±2 psi (±14 kPa) of the actual pressure. A gage is usually more accurate at mid-scale and should be calibrated at that point. Most gages used on boilers have an accuracy of 1% to $1^1/_2$%. An inspector gage is usually $^1/_2$% accurate and a laboratory gage may have an accuracy of $^1/_4$%.

C. Calibration. The gage used on a boiler should be calibrated at least once per year. This can be accomplished by comparing it to an inspector gage or using a deadweight tester. If an inspector gage is used, the accuracy of that gage should be verified with a deadweight tester at least once every 2 years. If the gage is damaged or cannot be calibrated to provide consistent readings, it should be discarded and replaced with a new gage.

D. Siphon Tube. On a steam boiler, a siphon tube (pigtail) is required to protect the gage from steam. A valve is also provided to facilitate demand and servicing of the gage.

INSTALLATION

NOTE: The following is taken from the mandatory rules of Section IV that apply to the boiler when manufactured and initially installed. The use of the word "shall" throughout reflects the mandatory nature of the Section IV requirements. The reader should consult the latest edition of Section IV for the current requirements.

3.20 PRESSURE RELIEVING VALVE REQUIREMENTS

A. Safety Valve Requirements for Steam Boilers.

(a) Each steam boiler shall have one or more officially rated safety valves, identified with the Certification Mark with V or HV Designator, of the spring pop type adjusted and sealed to discharge at a pressure not to exceed 15 psi (100 MPa).

(b) No safety valve for a steam boiler shall be smaller than NPS $^1/_2$ (DN 15). No safety valve shall be larger than NPS 4 (DN 100).

(c) The minimum relieving capacity of valve or valves shall be governed by the capacity marking on the boiler called for in HG-530 of Section IV.

(d) The minimum valve capacity in pounds per hour shall be the greater of that determined by dividing the maximum Btu output at the boiler nozzle obtained by the firing of any fuel for which the unit is installed by 1000, or shall be determined on the basis of the pounds of steam generated per hour per square foot of boiler heating surface as given in Table 3.20. For cast iron boilers the minimum valve capacity shall be determined by the maximum output method. In many cases a greater relieving capacity of valves will have to be provided than the minimum specified by these rules. In every case, the requirement of C(e) below shall be met.

Table 3.20
Minimum Pounds of Steam Per Hour Per Square Foot of Heating Surface ($kg/h/m^2$)

Boiler Heating Surface	Firetube Boilers	Watertube Boilers
Hand fired	5 (24)	6 (29)
Stoker fired	7 (34)	8 (39)
Oil, gas, or pulverized fuel fired	8 (39)	10 (49)
Waterwall heating surface:		
Hand fired	8 (39)	8 (39)
Stoker fired	10 (49)	12 (59)
Oil, gas, or pulverized fuel fired	14 (68)	16 (78)

GENERAL NOTES:
(a) When a boiler is fired only by a gas having a heat value not in excess of 200 Btu/ft^3 (7400 kJ/m^3), the minimum safety valve or safety relief valve relieving capacity may be based on the values given for hand fired boilers above.
(b) The minimum safety valve or safety relief valve relieving capacity for electric boilers shall be $3^1/_2$ lb/hr/kW (1.6 kg/h/kW) input.
(c) For heating surface determination, see 3.20B.
(d) For extended heating surface, the minimum $lb/hr/ft^2$ ($kg/h/m^2$) shall be determined by the Manufacturer (see B).

(e) The safety valve capacity for each steam boiler shall be such that with the fuel burning equipment installed, and operated at maximum capacity, the pressure cannot rise more than 5 psi (35 kPa) above the maximum allowable working pressure.

(f) When operating conditions are changed, or additional boiler heating surface is installed, the valve capacity shall be increased, if necessary, to meet the new conditions and be in accordance with C(e) above. The additional valves required, on account of changed conditions, may be installed on the outlet piping provided there is no intervening valve.

B. Heating Surface. The heating surface shall be computed as follows.

(a) Heating surface as part of a circulating system in contact on one side with water or wet steam being heated on the other side with gas or refractory being cooled, shall be measured on the side receiving heat.

(b) Boiler heating surface and other equivalent surface outside the furnace shall be measured circumferentially plus any extended surface.

(c) Waterwall heating surface and other equivalent surface within the furnace shall be measured as the projected tube area (diameter × length) plus any extended surface on the furnace side. In computing the heating surface for this purpose, only the tubes, fireboxes, shells, tubesheet, and the projected area of the headers need be considered, except that for vertical firetube steam boilers, only that portion of the tube surface up to the middle of the gage glass is to be computed.

(d) When extended surfaces or fins are used, the total surface representing the extended surface and its maximum designed generating capacity per square foot, as determined by the Manufacturer, and recorded in the remarks section of the Manufacturer's Data Report and noted on the stamping or nameplate as shown in Section IV, Figs. HG-530.2 and HG-530.3, shall be included in the total minimum relief valve capacity marked on the stamping or nameplate.

C. Safety Relief Valve Requirements for Hot Water Boilers.

(a) Each hot water heating or supply boiler shall have at least one officially rated safety relief valve of the automatic reseating type, identified with the Certification Mark with V or HV Designator, and set to relieve at or below the maximum allowable working pressure of the boiler.

(b) Hot water heating or supply boilers limited to a water temperature not in excess of 210°F (99°C) may have, in lieu of the valve(s) specified in (a) above, one or more officially rated temperature and pressure safety relief valves of the automatic reseating type identified with the Certification Mark with HV Designator, and set to relieve at or below the maximum allowable working pressure of the boiler.

(c) When more than one safety relief valve is used on either hot water heating or hot water supply boilers, the additional valves shall be officially rated and may have a set pressure within a range not to exceed 6 psi (41 kPa) above the maximum allowable working pressure of the boiler up to and including 60 psi (400 kPa), and 5% for those having a maximum allowable working pressure exceeding 60 psi (400 kPa).

(d) No safety relief valve shall be smaller than NPS $^3/_4$ (DN 20) nor larger than NPS $4^1/_2$ (DN 115) except that boilers having a heat input not greater than 15,000 Btu/h (4.4 kW) may be equipped with a rated safety relief valve of NPS $^1/_2$ (DN 15).

(e) The required steam relieving capacity, in pounds per hour, of the pressure relieving device or devices on a boiler shall be the greater of that determined by dividing the maximum output in Btu at the boiler nozzle obtained by the firing of any fuel for which the unit is installed by 1000, or shall be determined on the basis of pounds of steam generated per hour per square foot of boiler heating surface as given in Table 3.20. For cast iron boilers constructed to the requirements of Part HC of Section IV, the minimum valve capacity shall be determined by the maximum output method. In many cases a greater relieving capacity of valves will have to be provided than the minimum specified by these rules. In every case, the requirements of (g) below shall be met.

(f) When operating conditions are changed, or additional boiler heating surface is installed, the valve capacity shall be increased, if necessary, to meet the new conditions and shall be in accordance with (g) below. The additional valves required, on account of changed conditions, may be installed on the outlet piping provided there is no intervening valve.

(g) Safety relief valve capacity for each boiler with a single safety relief valve shall be such that, with the fuel burning equipment installed and operated at maximum capacity, the pressure cannot rise more than 10% above the maximum allowable working pressure. When more than one safety relief valve is used, the overpressure shall be limited to 10% above the set pressure of the highest set valve allowed by (a) above.

D. Permissible Mounting. Safety valves and safety relief valves shall be located in the top or side[1] of the boiler. They shall be connected directly to a tapped or flanged opening in the boiler, to a fitting connected to the boiler by a short nipple, to a Y-base, or to a valveless header connecting steam or water outlets on the same boiler. Coil or header type boilers shall have the safety valve or safety relief valve located on the steam or hot water outlet end. Safety valves and safety relief valves shall be installed with their spindles vertical. The opening or connection between the boiler and any safety valve or safety relief valve shall have at least the area of the valve inlet.

E. Requirements for Common Connections for Two or More Valves.

(a) When a boiler is fitted with two or more safety valves on one connection, this connection shall have a cross-sectional area not less than the combined areas of inlet connections of all the safety valves with which it connects.

(b) When a Y-base is used, the inlet area shall be not less than the combined outlet areas. When the size of the boiler requires a safety valve or safety relief valve larger than NPS $4^1/_2$ (DN 115), two or more valves having the required combined capacity shall be used. When two or more valves are used on a boiler, they may be single, directly attached, or mounted on a Y-base.

F. Threaded Connections. A threaded connection may be used for attaching a valve.

G. Prohibited Mountings. Safety and safety relief valves shall not be connected to an internal pipe in the boiler.

H. Use of Shutoff Valves Prohibited. No shutoff of any description shall be placed between the safety or safety relief valve and the boiler, or on discharge pipes between such valves and the atmosphere.

I. Safety and Safety Relief Valve Discharge Piping.

(a) A discharge pipe shall be used. Its internal cross-sectional area shall be not less than the full area of the valve outlet or of the total of the valve outlets discharging thereinto and shall be as short and straight as possible and so arranged as to avoid undue stress on the valve or valves. A union may be installed in the discharge piping close to the valve outlet (see Figure 3.20I). When an elbow

is placed on a safety or safety relief valve discharge pipe, it shall be located close to the valve outlet downstream of the union.

(b) The discharge from safety or safety relief valves shall be so arranged as to minimize the danger of scalding attendants. The safety or safety relief valve discharge shall be piped away from the boiler to a safe point of discharge, and there shall be provisions made for properly draining the piping (see Figure 3.20I). The size and arrangement of discharge piping shall be independent of other discharge piping and such that any pressure that may exist or develop will not reduce the relieving capacity of the relieving devices below that required to protect the boiler.

J. Temperature and Pressure Safety Relief Valves. Hot water heating or supply boilers limited to a water temperature of 210°F (99°C) may have one or more officially rated temperature and pressure safety relief valves installed. The requirements of 3.20B through 3.20I shall be met, except as follows:

(a) A Y-type fitting shall not be used.

(b) If additional valves are used, they shall be temperature and pressure safety relief valves.

(c) When the temperature and pressure safety relief valve is mounted directly on the boiler with no more than 4 in. maximum interconnecting piping, the valve may be installed in the horizontal position with the outlet pointed down.

K. Valve Replacement. Safety valves and safety relief valves requiring repairs shall be replaced with a new valve or repaired by the Manufacturer.

3.21 STEAM GAGES

A. Each steam boiler shall have a steam gage or a compound steam gage connected to its steam space or to its water column or to its steam connection. The gage or piping to the gage shall contain a siphon or equivalent device that will develop and maintain a water seal that will prevent steam from entering the gage tube. The piping shall be so arranged that the gage cannot be shut off from the boiler except by a cock placed in the pipe at the gage and provided with a tee- or lever-handle arranged to be parallel to the pipe in which it is located when the cock is open. The gage connection boiler tapping, external siphon, or piping to the boiler shall be not less than NPS $^1/_4$ (DN 8). Where steel or wrought iron pipe or tubing is used, the boiler connection and external syphon shall be not less than NPS $^1/_2$ (DN 15). Ferrous and nonferrous tubing having inside diameters at least equal to that of nominal pipe sizes listed above may be substituted for pipe.

B. The scale on the dial of a steam boiler gage shall be graduated to not less than 30 psi (200 kPa) nor more than 60 psi (400 kPa). The travel of the pointer from 0 psi to 30 psi (0 kPa to 200 kPa) pressure shall be at least 3 in. (75 mm).

3.22 WATER GAGE GLASSES

A. Each steam boiler shall have one or more water gage glasses attached to the water column or boiler by means of valved fittings not less than NPS $^1/_2$ (DN 15), with the lower fitting provided with a drain valve of a type having an unrestricted drain opening not less than $^1/_4$ in. (6 mm) in diameter to facilitate cleaning. Gage glass replacement shall be possible with the boiler under pressure. Water glass fittings may be attached directly to a boiler.

Boilers having an internal vertical height of less than 10 in. (254 mm) may be equipped with a water level indicator of the glass bull's-eye type provided the indicator is of sufficient size to show the water at both normal operating and low-water cutoff levels.

NOTE: Transparent material other than glass may be used for the water gage provided that the material will remain transparent and has proved suitable for the pressure, temperature, and corrosive conditions expected in service.

B. The lowest visible part of the water gage glass shall be at least 1 in. (25 mm) above the lowest permissible water level recommended by the boiler manufacturer. With the boiler operating at this lowest permissible water level, there shall be no danger of overheating any part of the boiler.

C. In electric boilers of the submerged electrode type, the water gage glass shall be so located to indicate the water levels both at startup and under maximum steam load conditions as established by the Manufacturer.

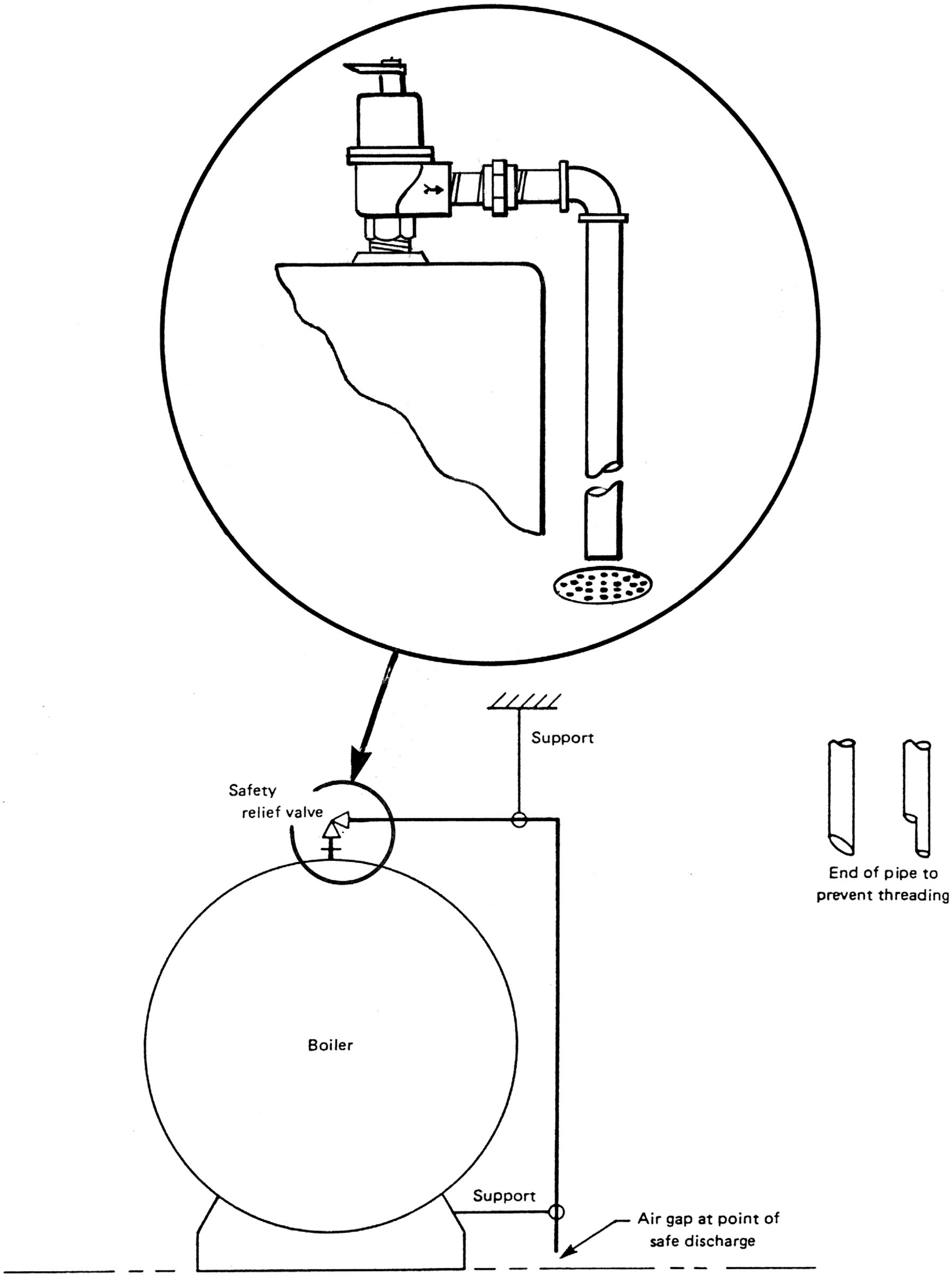
D. In electric boilers of the resistance heating element type, the lowest visible part of the water gage glass shall not be below the top of the electric resistance heating element. Each boiler of this type shall also be equipped with an automatic low-water electrical power cutoff so located as to automatically cut off the power supply to the heating elements before the surface of the water falls below the top of the electrical resistance heating elements.

E. A water level indicator using an indirect sensing method may be used in lieu of an operating water gage glass; however, a water gage glass must be installed and operable but may be shut off by valving. The water level indicator may be attached to a water column or directly to the boiler by means of valved fittings not less than NPS $^1/_2$ (DN 15). The device shall be provided with a drain valve of a type having an unrestricted drain opening not less than $^1/_4$ in. (6 mm) in diameter to facilitate cleaning. Service and replacement of internal parts and/or housing shall be possible with the boiler under pressure.

3.23 WATER COLUMN AND WATER LEVEL CONTROL PIPES

A. The minimum size of ferrous or nonferrous pipes connecting a water column to a steam boiler shall be 1 in. (DN 25). No outlet connections, except for damper regulator, feedwater regulator, steam gages, or apparatus that does not permit the escape of any steam or water

Figure 3.20I
Safety Relief Valve Discharge Pipe



except for manually operated blowdowns, shall be attached to a water column or the piping connecting a water column to a boiler (see 3.30C for introduction of feedwater into a boiler). If the water column, gage glass, low-water fuel cutoff, or other water level control device is connected to the boiler by pipe and fittings, no shutoff valves of any type shall be placed in such pipe, and a cross or equivalent fitting to which a drain valve and piping may be attached shall be placed in the water piping connection at every right angle turn to facilitate cleaning. The water column drain pipe and valve shall be not less than NPS $^3/_4$ (DN 20).

B. The steam connections to the water column of a horizontal firetube wrought boiler shall be taken from the top of the shell or the upper part of the head, and the water connection shall be taken from a point not above the center line of the shell. For a cast iron boiler, the steam connection to the water column shall be taken from the top of an end section or the top of the steam header, and the water connection shall be made on an end section not less than 6 in. (150 mm) below the bottom connection to the water gage glass.

3.24 PRESSURE CONTROL

Each automatically fired steam boiler shall be protected from overpressure by two pressure-operated controls.

A. Each individual automatically fired steam boiler or the assembled modular steam boiler shall have a safety limit control that will cut off the fuel supply to prevent steam pressure from exceeding the 15 psi (100 kPa) maximum allowable working pressure of the boiler. Each control shall be constructed to prevent a pressure setting above 15 psi (100 kPa).

B. Each individual steam boiler shall have a control that will cut off the fuel supply when the pressure reaches an operating limit, that shall be less than the maximum allowable pressure.

C. Shutoff valves of any type shall not be placed in the steam pressure connection between the boiler and the controls described in 3.24A and 3.24B. These controls shall be protected with a siphon or equivalent means of maintaining a water seal that will prevent steam from entering the control. The control connection boiler tapping, external siphon, or piping to the boiler shall not be less than NPS $^1/_4$ (DN 8), but where steel or wrought iron pipe or tubing is used, they shall not be less than NPS $^1/_2$ (DN 15). The minimum size of a siphon shall be NPS $^1/_4$ (DN 8) or $^3/_8$ in. (10 mm) O.D. nonferrous tubing.

D. ASME CSD-1 requires that operation of the pressure control described in 3.24A shall cause a safety shutdown requiring manual reset.

3.25 PRESSURE OR ALTITUDE GAGES

A. Each hot water heating or hot water supply boiler shall have a pressure or altitude gage connected to it or its flow connection in such a manner that it cannot be shut off from the boiler except by a cock with a tee or lever handle, placed on the pipe near the gage. The handle of the cock shall be parallel to the pipe in which it is located when the cock is open.

B. The scale on the dial of the pressure or altitude gage shall be graduated approximately to not less than $1^1/_2$ nor more than $3^1/_2$ times the pressure at which the safety relief valve is set.

C. Piping or tubing for pressure- or altitude-gage connections shall be of nonferrous metal when smaller than NPS 1 (DN 25).

3.26 THERMOMETERS

Each hot water heating or hot water supply boiler shall have a thermometer so located and connected that it shall be easily readable. The thermometer shall be so located that it shall at all times indicate the temperature of the water in the boiler at or near the outlet.

3.27 TEMPERATURE CONTROL

Each automatically fired hot water heating or hot water supply boiler shall be protected from over-temperature by two temperature-operated controls. The space thermostat used for comfort control is not considered one of the required temperature-operated controls.

A. Each individual automatically fired hot water heating or hot water supply boiler shall have a high temperature limit control that will cut off the fuel supply to prevent water temperature from exceeding its marked maximum water temperature at the boiler outlet. This control shall be constructed to prevent a temperature setting above the maximum.

B. Each individual hot water heating or hot water supply boiler shall have a control that will cut off the fuel supply when the system water temperature reaches a preset operating limit, that shall be less than the maximum water temperature.

C. ASME CSD-1 requires that operation of the temperature control described in 3.27A shall cause a safety shutdown requiring manual reset.

3.28 AUTOMATIC LOW-WATER FUEL CUTOFF AND/OR WATER FEEDING DEVICE (STEAM)

A. Each automatically fired steam or vapor-system boiler shall have an automatic low-water fuel cutoff so located as to automatically cut off the fuel supply before the surface of the water falls below the lowest visible part of the water gage glass. If a water feeding device is installed, it shall be so constructed that the water inlet valve cannot feed water into the boiler through the float chamber and so located as to supply requisite feedwater.

B. Such a fuel cutoff or water feeding device may be attached directly to a boiler. A fuel cutoff or water feeding device may also be installed in the tapped openings available for attaching a water glass directly to a boiler, provided the connections are made to the boiler with nonferrous tees or Ys not less than NPS $^1/_2$ (DN 15) between the boiler and the water glass so that the water glass is attached directly and as close as possible to the boiler; the run of the tee or Y shall take the water glass fittings, and the side outlet or branch of the tee or Y shall take the fuel cutoff or water feeding device. The ends of all nipples shall be reamed to full-size diameter.

C. Fuel cutoffs and water feeding devices embodying a separate chamber shall have a vertical drain pipe and a blowoff valve not less than NPS $^3/_4$ (DN 20), located at the lowest point in the water equalizing pipe connections so that the chamber and the equalizing pipe can be flushed and the device tested.

D. ASME CSD-1 requires two low-water cutoffs on steam boilers. Operation of the lower one shall

(a) with pumped returns, cause a safety shutdown requiring manual reset

(b) with gravity returns, sound an audible alarm.

3.29 LOW-WATER FUEL CUTOFF (HOT WATER)

A. Each automatically fired hot water heating boiler with heat input greater than 400,000 Btu/h (117 kW) shall have an automatic low-water fuel cutoff that has been designed for hot water service, and it shall be so located as to automatically cut off the fuel supply when the surface of the water falls to the level established in B below (see Figure 3.30-3).

B. As there is no normal waterline to be maintained in a hot water heating boiler, any location of the low-water fuel cutoff above the lowest safe permissible water level established by the boiler manufacturer is satisfactory.

C. A coil-type boiler or a watertube boiler with heat input greater than 400,000 Btu/h (117 kW) requiring forced circulation to prevent overheating of the coils or tubes shall have a flow-sensing device installed in the outlet piping in lieu of the low-water fuel cutoff required in A above to automatically cut off the fuel supply when the circulating flow is interrupted.

D. A means should be provided for testing the operation of the external low-water fuel cutoff without resorting to draining the entire system. Such means should not render the device inoperable except as described as follows. If the means temporarily isolates the device from the boiler during this testing, it shall automatically return to its normal position. The connection may be so arranged that the device cannot be shut off from the boiler except by a cock placed at the device and provided with a tee- or level-handle arranged to be parallel to the pipe in which it is located when the cock is open.

E. ASME CSD-1 requires that operation of the low-water cutoff on a hot water boiler shall cause a safety shutdown requiring manual reset.

3.30 PIPING

Figures 3.30-1, 3.30-2, 3.30-4A, and 3.30-4B show recommended piping arrangements for single boilers in battery. Guidance for the design of piping systems may be found in ASME B31.9, Building Service Piping.

A. Provisions for Expansion and Contraction. Provisions shall be made for the expansion and contraction of steam and hot water mains connected to boilers by providing substantial anchorage at suitable points and by providing swing joints (see 1.05 for definition) when boilers are installed in batteries, so there will be no undue strain transmitted to the boilers. See Figures 3.30-1, 3.30-2, 3.30-3, 3.30-4A, and 3.30-4B for typical schematic arrangements of piping incorporating strain absorbing joints for steam and hot water heating boilers.

B. Return Pipe Connections.

(a) The return pipe connections of each boiler supplying a gravity return steam heating system shall be so arranged as to form a loop substantially as shown in Figures 3.30-3 and 3.30-4B so that the water in each boiler cannot be forced out below the safe water level.

(b) For hand-fired boilers with a normal grate line, the recommended pipe sizes detailed as "A" in Figure 3.30-3 are NPS $1^1/_2$ (DN 40) for 4 ft^2 (0.4 m^2) or less firebox area at the normal grate line, NPS $2^1/_2$ (DN 65) for areas more than 4 ft^2 (0.4 m^2) up to 15 ft^2 (1.4 m^2), and NPS 4 (DN 100) for 15 ft^2 (1.4 m^2) or more.

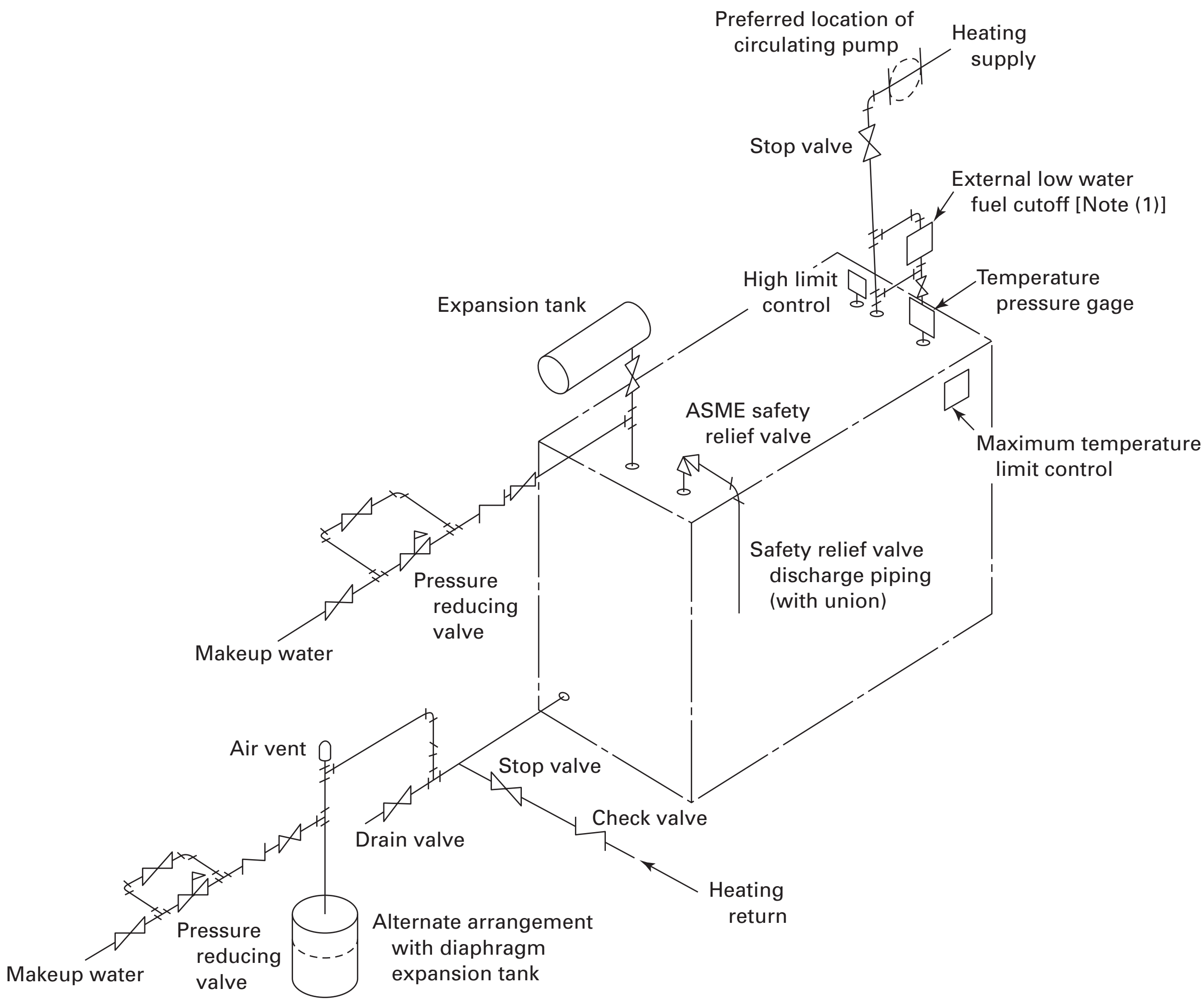
(c) For automatically fired boilers that do not have a normal grate line, the recommended pipe sizes detailed as "A" in Figure 3.30-3 are NPS $1^1/_2$ (DN 40) for boilers with minimum safety valve relieving capacity 250 lb/h (113 kg/h) or less; NPS $2^1/_2$ (DN 65) for boilers with minimum safety valve relieving capacity from 251 lb/h to 2,000 lb/h (900 kg/h), inclusive; and NPS 4 (DN 100) for boilers with more than 2,000 lb/h (900 kg/h) minimum safety valve relieving capacity.

(d) Provision shall be made for cleaning the interior of the return piping at or close to the boiler. Washout openings may be used for return pipe connections and the washout plug placed in a tee or a cross so that the plug is directly opposite and as close as possible to the opening in the boiler.

C. Feedwater and Makeup Water Connections.

(a) Steam Boilers. Feedwater or water treatment shall be introduced into a boiler through the return piping system or may be introduced through an independent connection. The water flow from the independent connection shall not discharge directly against parts of the boiler

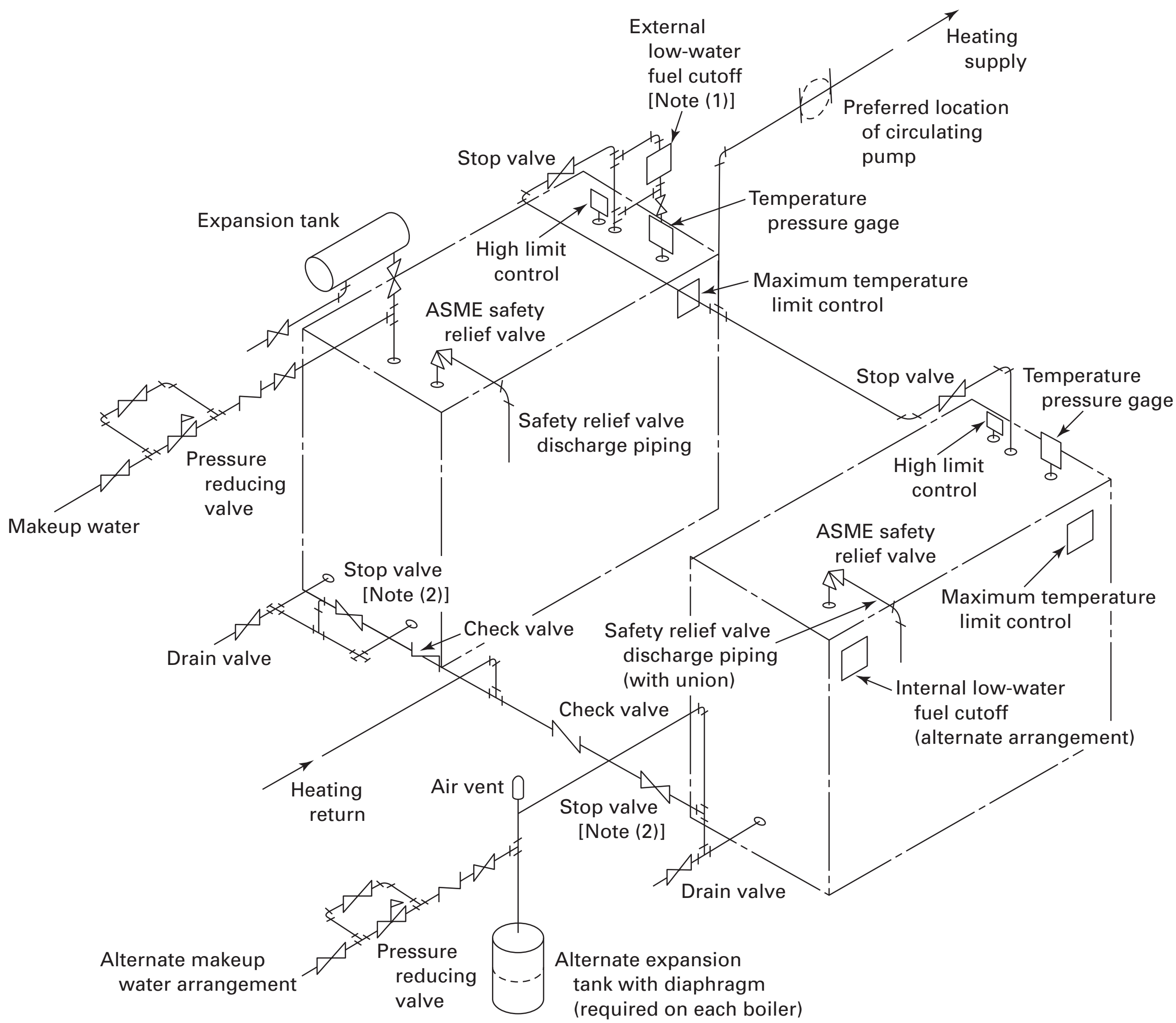
Figure 3.30-1
Single Hot Water Heating Boiler — Acceptable Piping Installation



GENERAL NOTE: Plumbing codes may require the installation of a reduced pressure principle backflow preventer on a boiler when the makeup water source is from a potable water supply.

NOTE:
(1) Recommended control. See 3.29. Acceptable shutoff valves or cocks in the connecting piping may be installed for convenience of control testing and/or service.

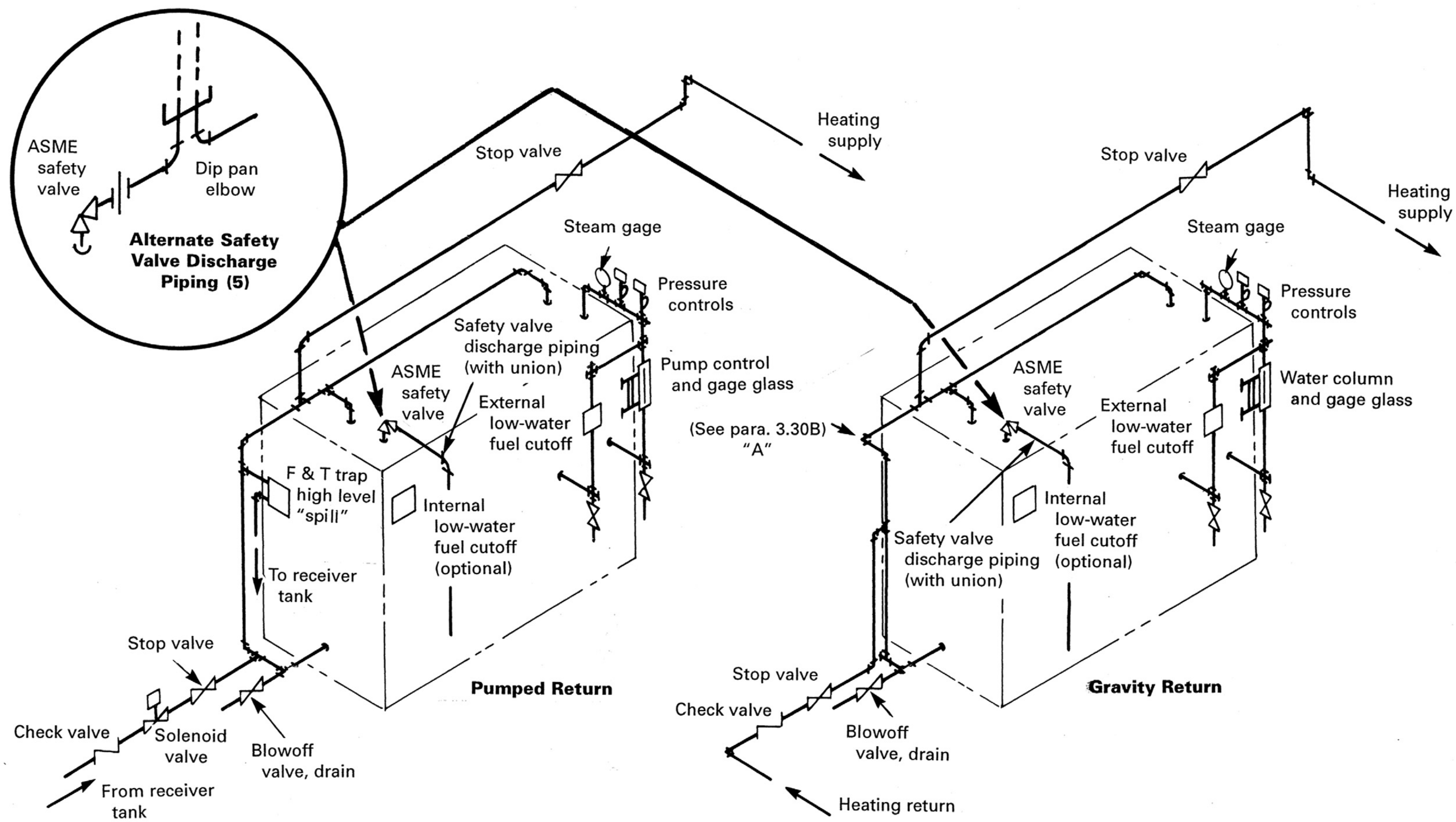
Figure 3.30-2
Hot Water Heating Boilers in Battery — Acceptable Piping Installation



GENERAL NOTE: Plumbing codes may require the installation of a reduced pressure principle backflow preventer on a boiler when the makeup water source is from a potable water supply.

NOTES:
(1) Recommended control. See 3.29. Acceptable shutoff valves or cocks in the connecting piping may be installed for convenience of control testing and/or service.
(2) The common return header stop valves may be located on either side of the check valves.

Figure 3.30-3
Single Steam Boilers — Acceptable Piping Installation



GENERAL NOTE: Plumbing codes may require the installation of a reduced pressure principle backflow preventer on a boiler when the makeup water source is from a potable water supply.

NOTES:

(1) Return loop connection was designed to eliminate the necessity of check valves on gravity return systems, but in some localities a check valve is a legal requirement.

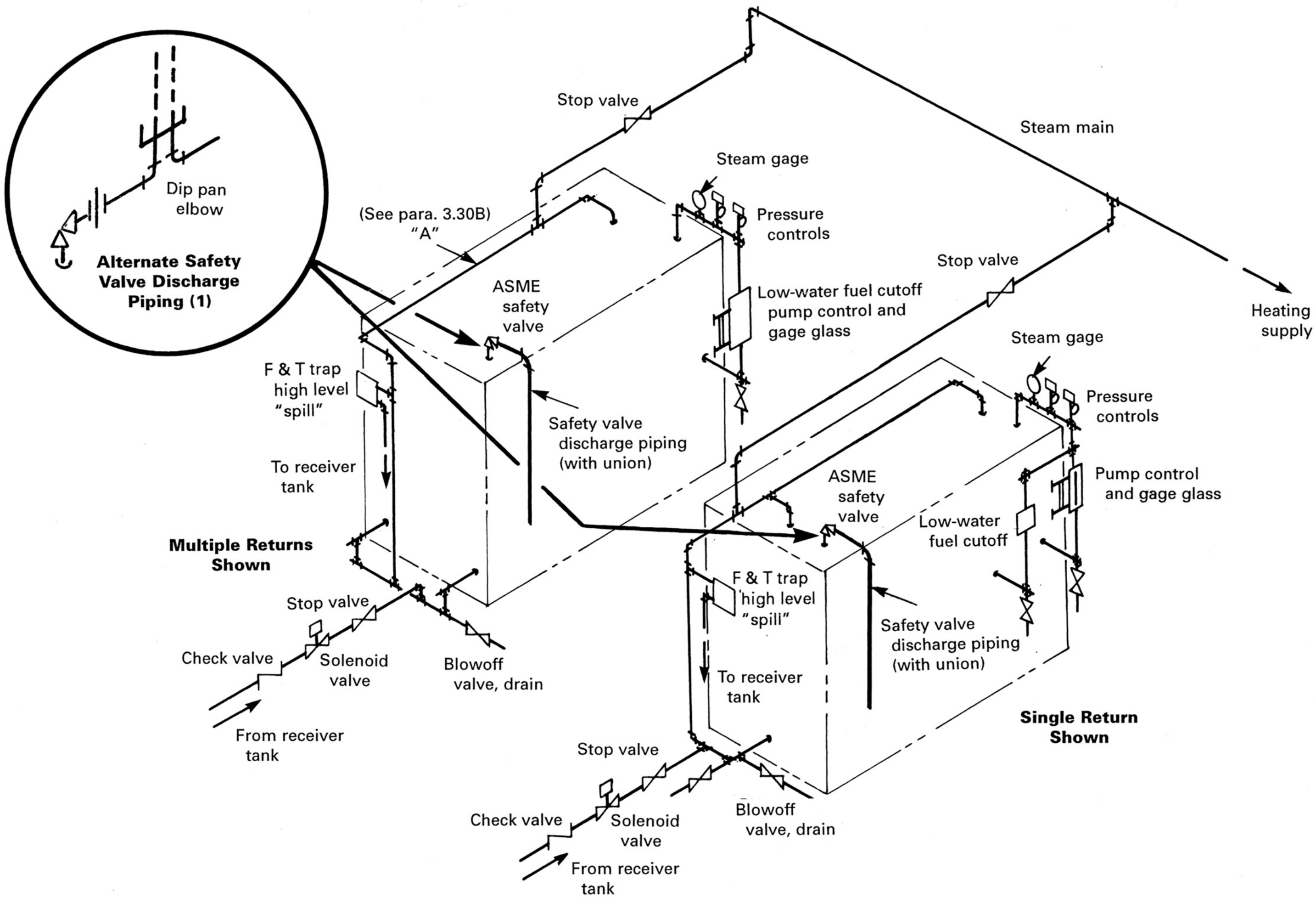
(2) When pump discharge piping exceeds 25 ft (7.6 m), install swing check valves at pump discharge.

(3) If pump discharge is looped above normal boiler waterline, install a spring-loaded check valve at return header and at pump discharge.

(4) Where supply pressures are adequate, makeup water may be introduced directly to a boiler through an independent connection.

(5) Recommended for 1 in. (25 mm) and larger safety valve discharge.

Figure 3.30-4A
Steam Boilers in Battery — Pumped Return — Acceptable Piping Installation



GENERAL NOTES:

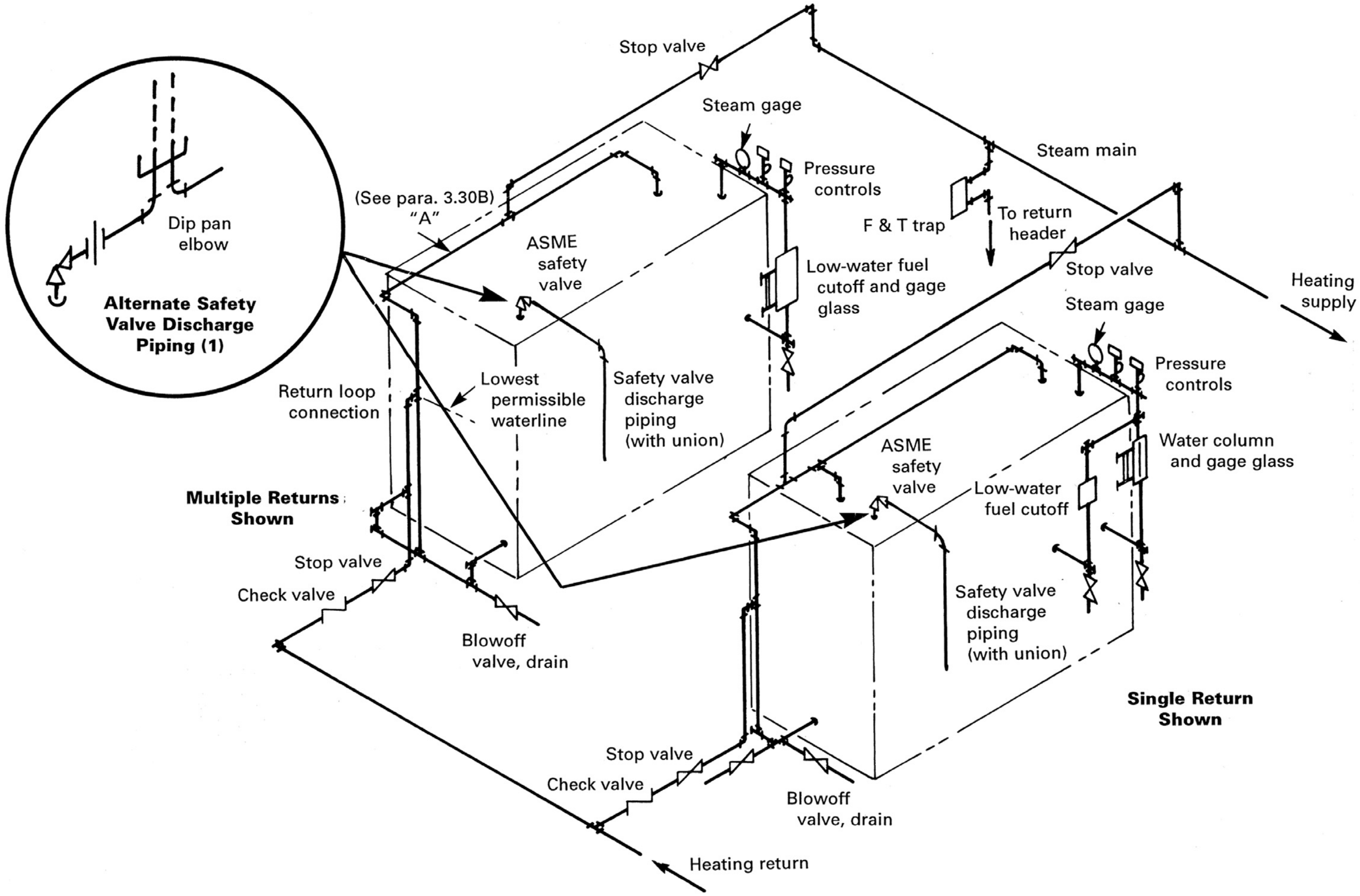
(a) Return connections shown for a multiple boiler installation may not always ensure that the system will operate properly. To maintain proper water levels in multiple boiler installations, it may be necessary to install supplementary controls or suitable devices.

(b) Plumbing codes may require the installation of a reduced pressure principle backflow preventer on a boiler when the makeup water source is from a potable water supply.

NOTE:

(1) Recommended for 1 in. (25 mm) and larger safety valve discharge.

Figure 3.30-4B
Steam Boilers in Battery — Gravity Return — Acceptable Piping Installation



GENERAL NOTES:

(a) Return connections shown for a multiple boiler installation may not always ensure that the system will operate properly. To maintain proper water levels in multiple boiler installations, it may be necessary to install supplementary controls or suitable devices.

(b) Plumbing codes may require the installation of a reduced pressure principle backflow preventer on a boiler when the makeup water source is from a potable water supply.

NOTE:

(1) Recommended for 1 in. (25 mm) and larger safety valve discharge.

exposed to direct radiant heat from the fire. Feedwater or water treatment shall not be introduced through openings or connections provided for inspection or cleaning, safety valve, blowoff, water column, water gage glass, or pressure gage. The pipe shall be provided with a check valve or a backflow preventer containing a check valve near the boiler and a stop valve or cock between the check valve and the boiler or between the check valve and the return pipe system.

(b) Hot Water Boilers. Makeup water may be introduced into a boiler through the piping system or through an independent connection. The water flow from the independent connection shall not discharge directly against parts of the boiler exposed to direct radiant heat from the fire. Makeup water shall not be introduced through openings or connections provided exclusively for inspection or cleaning, safety relief valve, pressure gage, or temperature gage. The makeup water pipe shall be provided with a check valve or a backflow preventer containing a check valve near the boiler and a stop valve or cock between the check valve and the boiler or between the check valve and the return piping system.

(c) Some jurisdictions may require installation of a backflow preventer in the feedwater connection.

3.31 PROVISIONS FOR THERMAL EXPANSION IN HOT WATER SYSTEMS

All hot water heating systems incorporating hot water tanks or fluid relief columns shall be so installed as to prevent freezing under normal operating conditions.

A. Systems With Open Expansion Tank. If the system is equipped with an open expansion tank, an indoor overflow from the upper portion of the expansion tank shall be provided in addition to an open vent, the indoor overflow to be carried within the building to a suitable plumbing fixture or the basement.

B. Closed-Type Systems. If the system is of the closed type, an airtight tank or other suitable air cushion shall be installed that will be consistent with the volume and capacity of the system, and it shall be suitably designed for a hydrostatic test pressure of $2\frac{1}{2}$ times the allowable working pressure of the system. Expansion tanks for systems designed to operate above 30 psi (200 kPa) shall be constructed in accordance with Section VIII, Division 1. Provisions shall be made for draining the tank without emptying the system, except for prepressurized tanks.

C. Minimum Capacity of Closed-Type Tank. The minimum capacity of the closed-type expansion tank may be determined from Table 3.31C-1 and Table 3.31C-2 or from the following equation where the necessary information is available:

$$V_t = \left[(0.00041T - 0.0466)V_s\right] / \left[(P_a / P_f) - (P_a / P_o)\right]$$

$$V_t' = \left[(0.000738T - 0.03348)V_s\right] / \left[(P_a / P_f) - (P_a / P_o)\right]$$

where

P_a = atmospheric pressure
P_f = fill pressure
P_o = maximum operating pressure
T = average operating temperature
V_s = volume of system, not including tanks
V_t = minimum volume of tanks

3.32 STOP VALVES

A. For Single Steam Boilers. A stop valve shall be installed in the supply pipe and return pipe connections to permit testing the safety valve without pressurizing the system.

B. For Single Hot Water Heating Boilers. Stop valves shall be located at an accessible point in the supply and return pipe connections as near the boiler nozzle as is convenient and practicable, of a single hot water heating boiler installation to permit draining the boiler without emptying the system, and to permit testing the safety relief valve without pressurizing the system.

Table 3.31C-1
Expansion Tank Capacities for Gravity Hot Water Systems

Installed Equivalent Direct Radiation, ft^2 (m^2) [Note (1)]	Tank Capacity, gal (m^3)
Up to 350 (32.5)	18 (0.07)
Up to 450 (41.8)	21 (0.08)
Up to 650 (68.4)	24 (0.09)
Up to 900 (83.6)	30 (0.11)
Up to 1,100 (102.2)	35 (0.13)
Up to 1,400 (130.0)	40 (0.15)
Up to 1,600 (148.6)	2 - 30 (2 - 0.11)
Up to 1,800 (167.2)	2 - 30 (2 - 0.11)
Up to 2,000 (185.8)	2 - 35 (2 - 0.13)
Up to 2,400 (222.9)	2 - 40 (2 - 0.15)

NOTE:
(1) For systems with more than 2,400 ft^2 (223 m^2) of installed equivalent direct water radiation, the required capacity of the cushion tank shall be increased on the basis of 1 gal [3.8 L (0.0038 m^3)] tank capacity/33 ft^2 (3.1 m^2) of additional equivalent direct radiation.

Table 3.31C-2
Expansion Tank Capacities for Forced Hot Water Systems

System Volume, gal (m^3) [Note (1)]	Tank Capacities, gal (m^3)	
	Prepressurized Diaphragm Type	Nonprepressurized Type
100 (0.38)	9 (0.034)	15 (0.057)
200 (0.76)	17 (0.064)	30 (0.114)
300 (1.14)	25 (0.095)	45 (0.170)
400 (1.51)	33 (0.125)	60 (0.227)
500 (1.89)	42 (0.159)	75 (0.284)
1,000 (3.79)	83 (0.314)	150 (0.568)
2,000 (7.57)	165 (0.625)	300 (1.136)

GENERAL NOTE: Based on average operating water temperature 195°F (91°C), fill pressure 12 psig (83 kPa gage), and maximum operating pressure 30 psig (200 kPa gage)

NOTE:
(1) System volume includes volume of water in boiler, radiation, and piping, not including the expansion tank. Expansion tank capacities are based on an acceptance factor of 0.4027 for prepressurized types and 0.222 for nonpressurized types. A procedure for estimating system volume and determining expansion tank sizes for other design conditions may be found in the Systems and Applications Volume of the ASHRAE Handbook.

C. For Multiple Boiler Installations. A stop valve shall be used in each supply and return pipe connection of two or more boilers connected to a common system. See Figures 3.30-2, 3.30-4A, and 3.30-4B.

D. Type of Stop Valve(s).

(a) All valves or cocks may be ferrous or nonferrous.

(b) The minimum pressure rating of all valves or cocks shall be at least equal to the pressure stamped upon the boiler, and the temperature rating of such valves or cocks, including all internal components, shall be not less than 250°F (120°C).

(c) Valves or cocks shall be flanged, threaded, or have ends suitable for welding or brazing.

(d) All valves or cocks with stems or spindles shall have adjustable pressure-type packing glands or self-adjusting seals suitable for the intended service. All plug-type cocks shall be equipped with a guard or gland suitable for the intended service. All $^1/_4$ turn valve operating mechanisms shall have a tee or lever handle arranged to be parallel to the pipe in which it is located when the cock is open.

(e) All valves or cocks shall have tight closure when under boiler hydrostatic test pressure.

E. Identification of Stop Valves by Tags. When stop valves are used, they shall be properly designated substantially as follows by tags of metal or other durable material fastened to them:

Supply Valve — Number ( )

Do Not Close Without Also Closing Return Valve — Number ( )

Return Valve — Number ( )

Do Not Close Without Also Closing Supply Valve — Number ( )

3.33 BOTTOM BLOWOFF AND DRAIN VALVES

A. Bottom Blowoff Valve. Each steam boiler shall have a bottom blowoff connection fitted with a valve or cock connected to the lowest water space practicable with a minimum size as shown in Table 3.33. The discharge piping shall be full size to the point of discharge.[2]

B. Drain Valve. Each steam or hot water boiler shall have one or more drain connections fitted with valves or cocks connecting to the lowest water containing spaces. The minimum size of the drain piping, valves, and cocks shall be NPS $^3/_4$ (DN 20). The discharge piping shall be full size to the point of discharge. When the blowoff connection is located at the lowest water containing space, a separate drain connection is not required.

C. Minimum Pressure Rating. The minimum pressure rating of valves and cocks used for blowoff or drain purposes shall be at least equal to the pressure stamped on the boiler but in no case less than 30 psi (200 kPa). The temperature rating of such valves and cocks shall not be less than 250°F (120°C).

3.34 OIL HEATERS

A. A heater for oil or other liquid harmful to boiler operation shall not be installed directly in the steam or water space within a boiler.

Table 3.33
Size of Bottom Blowoff Piping, Valves, and Cocks

Minimum Required Safety Valve Capacity, lb (kg) of Steam/hr [Note (1)]	Blowoff Piping, Valves, and Cocks Min. Size, NPS (DN)
Up to 500 (226)	$^3/_4$ (20)
501 to 1,250 (227 to 567)	1 (25)
1,251 to 2,500 (567 to 1 134)	$1^1/_4$ (32)
2,501 to 6,000 (1 135 to 2 721)	$1^1/_2$ (40)
6,001 (2 722) and larger	2 (50)

NOTE:
(1) To determine the discharge capacity of safety relief valves in terms of Btu, the relieving capacity in lb of steam/hr is multiplied by 1,000.

B. Where an external type heater for such service is used, means shall be provided to prevent the introduction into the boiler of oil or other liquid harmful to boiler operation.

3.35 SHUTDOWN SWITCHES AND CIRCUIT BREAKERS

A manually operated remote heating plant shutdown switch or circuit breaker should be located just outside the boiler room door and marked for easy identification. Consideration should also be given to the type and location of the switch to safeguard against tampering. If the boiler room door is on the building exterior, the switch should be located just inside the door. If there is more than one door to the boiler room, there should be a switch located at each door.

(a) For atmospheric-gas burners, and oil burners where the fan is on a common shaft with the oil pump, the complete burner and controls should be shut off.

(b) For power burners with detached auxiliaries, only the fuel input supply to the firebox need be shut off.

3.36 MODULAR BOILERS

A. Individual Modules.

(a) The individual modules shall comply with all the requirements of Part HG of Section IV . The individual modules shall be limited to a maximum input of 400,000 Btuh (gas) [115 kW (gas), 3 gal/hr (oil) [11 L/hr (oil), or 115 kW (electricity).

(b) Each module of a modular steam heating boiler shall be equipped with

(1) steam gage, see 3.21
(2) water gage glass, see 3.22
(3) operating limit control, see 3.24B
(4) low-water cutoff, see 3.28
(5) safety valve, see 3.20A
(6) bottom blowoff valve, see 3.33A
(7) drain valve, see 3.33B

(c) Each module of a hot water heating boiler shall be equipped with

(1) pressure/altitude gage, see 3.25
(2) thermometer, see 3.26
(3) operating temperature control, see 3.27B
(4) safety relief valve, see 3.20B
(5) drain valve, see 3.33B

B. Assembled Modular Boilers.

(a) The individual modules shall be manifolded together at the job-site without any intervening valves. The header or manifold piping is field piping and is exempt from Section IV requirements.

(b) The assembled modular steam heating boiler shall also be equipped with

(1) feedwater connection, see 3.30C
(2) return pipe connection, see 3.30B
(3) safety limit control, see 3.24A

(c) The assembled modular hot water heating boiler shall also be equipped with

(1) makeup water connection, see 3.30C
(2) provision for thermal expansion, see 3.31
(3) stop valves, see 3.32B
(4) high temperature limit control, see 3.27A
(5) low-water fuel cutoff, see 3.29

3.37 VACUUM BOILERS

Vacuum boilers shall comply with all the requirements of Mandatory Appendix 5 of Section IV.

3.38 STORAGE TANKS FOR HOT WATER SUPPLY SYSTEMS

If a system is to utilize a storage tank that exceeds a nominal water-containing capacity of 120 gal (454 L), the tank shall be constructed in accordance with the rules of Part HLW; Section VIII, Division 1; or Section X. For tanks constructed to Section X, the maximum allowable temperature marked on the tank shall equal or exceed the maximum water temperature marked on the boiler.

SECTION 4
FUELS

The principal fuels used are gas, oil, coal, wood products, and electricity as a source of heat.

4.01 GAS — NATURAL, MANUFACTURED, MIXED

Gas used for fuel may be in the form of natural, manufactured, mixed, or liquefied petroleum gas. Natural, manufactured, and mixed gases are normally distributed through underground piping. They require no storage facilities.

Heating values of these gases in Btu per cubic feet (MJ/m^3) are:

	Low	High
Natural gas	950 (35.4)	1150 (42.9)
Manufactured gas	350 (13.0)	600 (22.4)
Mixed gas	600 (22.4)	800 (29.8)

4.02 LIQUEFIED PETROLEUM GAS (LPG)

Liquefied petroleum gas is normally stored in tanks at high pressure so that it will be in a liquid state. Storage may be either above or below ground, with storage and handling requirements in accordance with NFPA Pamphlet #58 and local regulations. The liquefied fuel is reduced in pressure and its state is changed to a gas at the required pressure for the burner. Propane or butane gas has a heating value of 2,500 Btu/ft^3 to 3,300 Btu/ft^3 (93.2 MJ/m^3 to 123.0 MJ/m^3).

Modification of the fuel burning equipment is necessary when changing from liquefied petroleum gas to other gases or from other gases to liquefied petroleum gas.

4.03 FUEL OILS

Fuel oils are graded in accordance with specifications of the American Society for Testing and Materials. Oils are classified by their viscosities. Other characteristics of fuel oils that determine their grade, classification, and suitability for given uses are the flash point, pour point, water and sediment content, sulphur content, ash, and distillation characteristics. Fuel oils are prepared for combustion in most low-pressure boiler burners by atomization (spraying). The types of atomization commonly used are: high-pressure mechanical atomization, low-pressure mechanical atomization, centrifugal atomization (rotary cup), compressed air atomization, and steam atomization.

A. Grade Number 1. A light viscosity distillate oil intended for vaporizing pot type burners. The heating value is approximately 135,000 Btu/gal (37 700 MJ/m^3).

B. Grade Number 2. A distillate oil used for general purpose heating. The heating value is approximately 138,000 Btu/gal (38 500 MJ/m^3).

C. Grade Number 4. An oil heavier than Number 2 but not heavy enough to require preheating facilities. Because the oil is no longer available in many locations as a straight run distillate, but is a mix of Number 2 and heavier oils, it may be necessary in northern climates to provide tank heaters or small recirculating preheaters to insure delivery of the blended fuel to the burner. If the fuel is not blended properly, the Number 2 oil and the heavier oil may separate in time. Many dealers blend the two grades of oil in the tank truck while delivering to the location. This may result in physical separation of the two grades if they stand in the tank for any length of time. The heating value is approximately 147,000 Btu/gal (41 000 MJ/m^3).

D. Grade Number 5. This grade has been divided into hot Number 5 and cold Number 5. The "hot" grade requires preheating and the "cold" may be burned as is from the tank, but because of the increased demand for distillate products, the residual oils may be lower in quality and may require preheating for good results. Sometimes Grade Number 5 is a mix of Number 2 and Number 6.

The usual heating value is approximately 152,000 Btu/gal (42 400 MJ/m^3).

E. Grade Number 6. A residual type oil for use in burners equipped with recirculating preheaters. Number 6 fuel oil is sometimes referred to as Bunker C. The usual heating value is approximately 153,000 Btu/gal (42 700 MJ/m^3).

F. Preheating Requirements. The correct temperature range must be used for each grade of preheated oil. Improper preheating may cause poor combustion, smoke, and high fuel consumption. The oil delivered to the burner must be preheated to the temperature recommended by the burner manufacturer for the grade of fuel used.

4.04 COAL

Although automatic equipment for burning coal is not in common use, a brief treatment of coal is considered to be in order.

A. Anthracite Coal. Anthracite coal is dense, stonelike in structure, and shiny black in color. Because of its hardness, it can be handled with little breakage. When ignited, it burns freely with a short, relatively smokeless flame and does not coke. It has very little volatile matter and is commonly referred to as hard coal. Semianthracite is not so hard as anthracite and is higher in volatile matter. It is dark gray in color and of granular structure. Semianthracite swells considerably in size when burning, but it does not coke. Heating value of anthracite and semianthracite coals, as received, is 12,000 Btu/lb to 13,000 Btu/lb (27.9 MJ/kg to 30.2 MJ/kg).

B. Bituminous Coal. This classification covers a wide range of coals, from the high grades found in the eastern part of the United States to the lower grades of the western part. Bituminous coal, commonly called soft coal, is the most extensively used of all coals. The various types of soft coal differ in composition, properties, and burning characteristics. Some are firm in structure and present no handling problem, while others tend to break when handled. Bituminous coals ignite rather easily, and burn readily, usually with a long flame. Medium volatile and high volatile coals coke in the fire and smoke when improperly burned. The "as received" heating value of bituminous coals vary from approximately 10,500 Btu/lb to 14,500 Btu/lb (24.4 MJ/kg to 33.7 MJ/kg).

4.05 ELECTRICITY

Although electricity is in itself not a fuel, it is used as a source of heat for heating boilers. The two general methods of application are electrodes and immersed direct resistance elements. When electrodes are used, the boiler water serves as the heating element by offering resistance to the passage of current between the immersed electrodes. Direct resistance elements create heat by the resistance offered to the passage of electric current through the immersed element.

SECTION 5
FUEL BURNING EQUIPMENT AND FUEL BURNING CONTROLS

5.01 GAS BURNING EQUIPMENT

Gas burners fall into two general classes: atmospheric and power type.

A. Atmospheric Gas Burners. Atmospheric burners depend upon natural draft for combustion air. There are several types of atmospheric burners, most of which fall into the general classifications of single or multiport type. see Figure 5.01A.

B. Power Gas Burners. Power gas burners depend upon a blower to supply combustion air. They fall into two general classifications: natural draft and forced draft.

(a) Natural draft burners operate with a furnace pressure slightly less than atmospheric. The proper draft condition is maintained either by natural draft or an induced draft fan.

(b) Forced draft burners are designed to operate with a furnace pressure higher than atmospheric. These burners are equipped with sufficient blower capacity to force products of combustion through the boiler without the help of natural or induced draft.

C. Combination Fuel Burners. Combination fuel burners are designed for burning more than one fuel with either manual or automatic switchover from one fuel to another. The combinations of fuel generally used are natural-liquefied petroleum gas or gas oil. see Figure 5.01C.

5.02 OIL BURNING EQUIPMENT

An oil burner mechanically mixes fuel oil and air for combustion under controlled conditions. Ignition is accomplished by an electric spark, electric resistance wire, gas pilot flame, or oil pilot flame.

A. Pressure Atomizing Burners (Gun Type). Pressure atomizing (gun type) burners may be divided into two classes: high-pressure and low-pressure mechanical atomization.

(a) The high-pressure mechanical atomizing type is characterized by an air tube, usually horizontal, with a pressurized oil supply centrally located in the tube and arranged so that a spray of atomized oil is introduced at approximately 100 psig (700 kPa) and mixed in the combustion chamber with the air stream emerging from the air tube (see Figure 5.02A). The oil is supplied to the burner by a fuel delivery unit that serves as a pressure flow regulating device as well as a pumping device. Where electric ignition is employed, a high-voltage transformer is used to supply approximately 10,000 V to create an ignition arc across a pair of electrodes located above the nozzle. Where gas ignition is employed on a larger burner, a gas pilot is used. The firing rate is governed by the size of the nozzle used. Multiple nozzles are used on some of the larger burners and variable flow nozzles are used on others.

A low fire start on a modulating burner that employs a variable flow nozzle is accomplished by supplying the oil at a reduced pressure. A low fire start on a multiple nozzle burner is accomplished by permitting oil flow to only one or two of the nozzles.

(b) The low-pressure atomizing burner differs from the high-pressure type mainly by having means for supplying a mixture of oil and primary air to the burner nozzle. The air meeting the mixture in the furnace is "secondary air" that provides for complete combustion. The air pressure before mixing and the pressure of the air–oil mixture vary with different makes of burners, but are in the low range of 1 psig (7 kPa) to 15 psig (100 kPa) for air and 2 psig (14 kPa) to 7 psig (48 kPa) for the mixture. Capacity of the burners is varied by making pump stroke or orifice changes on the oil pumps.

B. Steam Atomizing Burners. Steam atomizing burners utilize steam to atomize heavy grade fuel oil. Steam is usually supplied by the boiler being operated.

C. Air Atomizing Burners. In this type of burner, the compressed air or steam is used as the atomizing medium.

An air compressor is usually provided as part of the burner although the air may be supplied from another source.

D. Horizontal Rotary Cup Burner. The horizontal rotary cup burner (see Figure 5.02D) utilizes the principle of centrifugal atomization. The oil is prepared for combustion by centrifugal force, spinning it off a cup rotating at high speed into an air stream, causing the oil to break up into a spray. This type can be used with all grades of fuel oil. Modulated firing can be provided on these burners.

5.03 COAL BURNING EQUIPMENT

Generally, stokers are used when burning coal. Stokers provide a mechanical means for feeding coal and supplying combustion air. They are built in several types, the most common of which are underfeed, spreader, and chain grate. See Figures 5.03-1, 5.03-2, and 5.03-3.

5.04 CONTROLS

Automatically fired boilers may be equipped with operating, limit, safety, and programming controls that may be electrically or pneumatically operated. These controls perform the following functions.

A. Operating Controls.

(a) Start, stop, and modulate the burner (if desired) in response to the systems demand, keeping steam pressure or hot water temperature at or below the limit control setting.

(b) Maintain proper water level in steam boiler.

(c) Maintain proper water pressure in hot water heating boilers.

B. Limit Controls.

(a) Stop burner when steam pressure or hot water temperature exceeds limit control setting. Steam boilers to operate at not more than 15 psi (100 kPa); hot water boilers to operate at temperatures not more than 250°F (120°C).

(b) Stop burner when water level drops below minimum safe level.

(c) When required, stop burner in case of unusual conditions such as:

(1) high stack temperature

(2) high or low gas fuel pressure

(3) high or low fuel oil temperature

C. Safety Controls.

(a) Stop fuel flow in case of ignition failure.

(b) Stop fuel flow in case of main flame interruption.

(c) Stop fuel flow in case of mechanical draft failure.

(d) Stop fuel flow in case of circuit failure.

D. Programming Controls. Programming controls, when used, provide proper sequencing of the above controls to insure that all conditions, necessary for proper burner operation, are satisfied. Included in a programmed control are prepurge and postpurge cycles to remove accumulated gases.

E. Spare Parts. Spare parts for controls, including electronic components that require time for procurement, should be maintained in stock supply.

F. Power for Electrically Operated Controls. All controls should be powered with a potential of 150 V or lower with one side grounded. A separate equipment ground conductor should be brought to the control panel frame with ground continuity assured to the fuel valve. All operating coils of control devices should be connected to the neutral side of the control circuit, and all control limit switches or contacts should be in the ungrounded (hot) side of the control circuit. If an isolating transformer is used, it should be bonded to the control panel frame. The equipment ground is not required when the isolating transformer is used. Do not fuse control transformers above their rated current value because these devices are current limiting and an oversize fuse may not blow under short circuit conditions.

G. Air for Pneumatically Operated Controls. Determine that compressed air for pneumatically operated controls is clean, dry, and available at adequate pressure.

H. Venting of Gas Controls. Venting of gas controls should conform to recognized installation standards.

I. Reference to ASME CSD-1. ASME CSD-1 contains specific requirements regarding the controls to be included in the fuel train, the timing of their operation, and the resulting action that must be achieved.

Figure 5.01A
Atmospheric Gas Burner

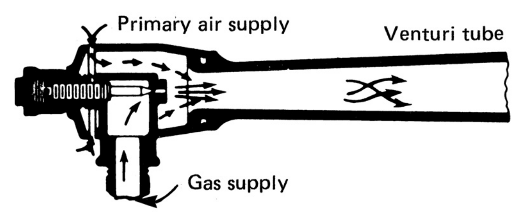


Figure 5.01C
Combination Fuel Burners

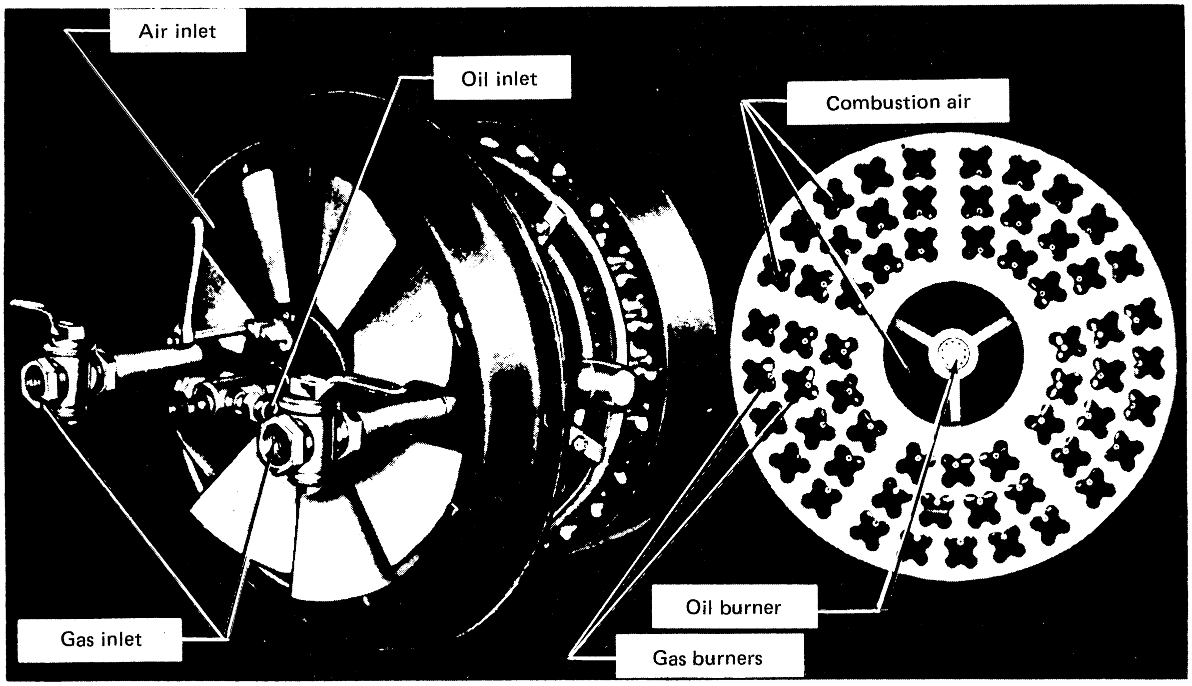


Figure 5.02A
High-Pressure Atomizing Burner

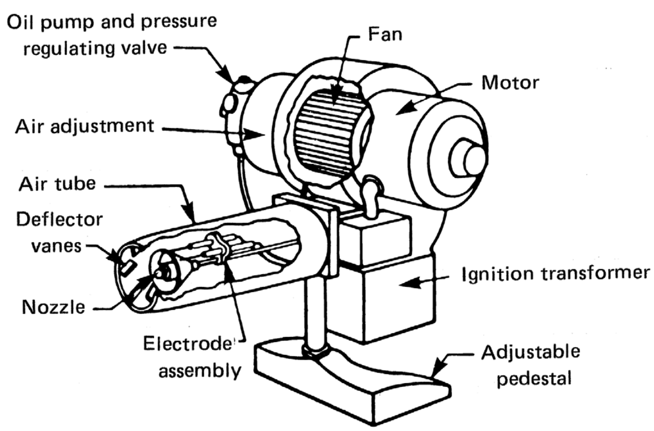


Figure 5.02D
Horizontal Rotary Cup Fuel Oil Burner

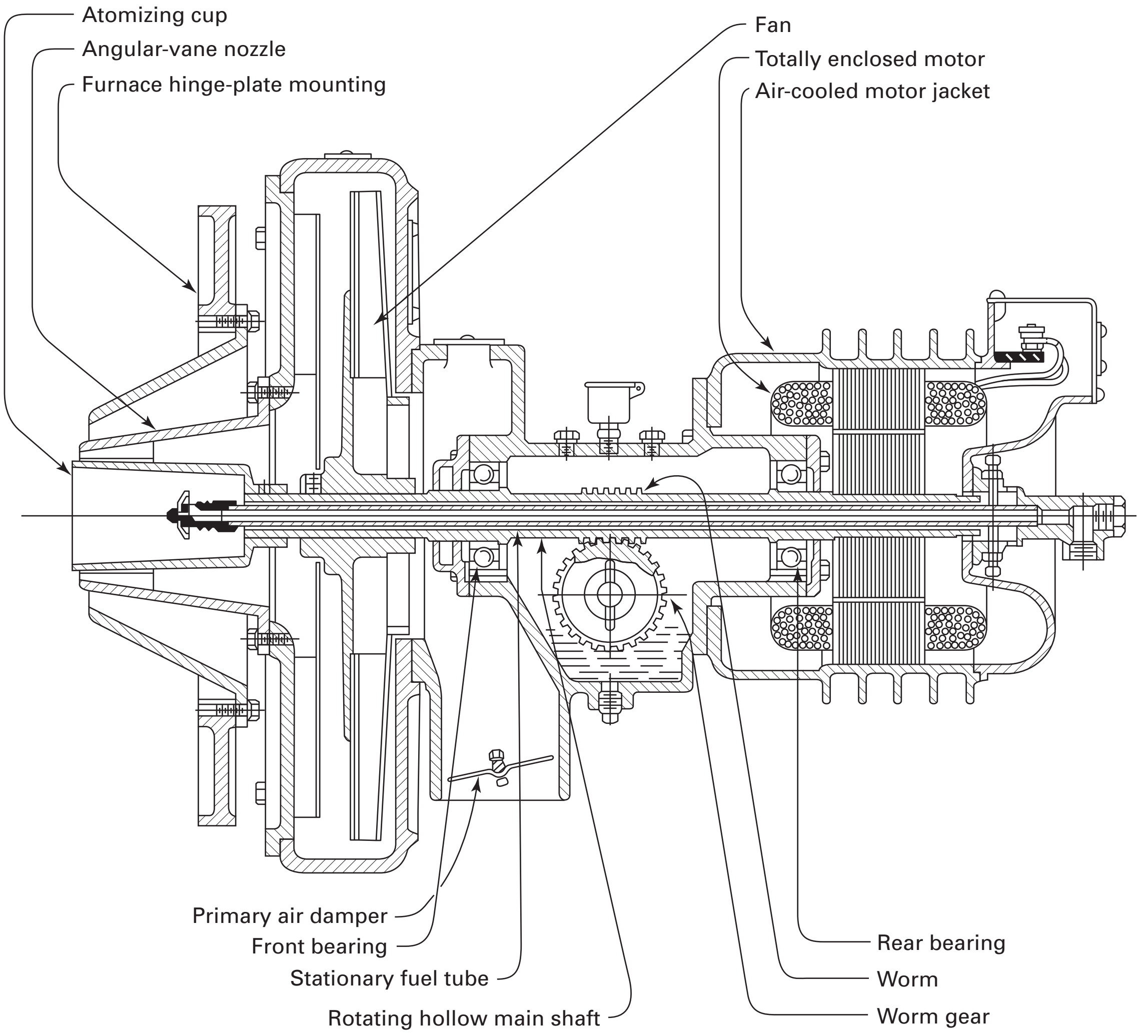


Figure 5.03-1
Underfeed Single-Retort Stoker

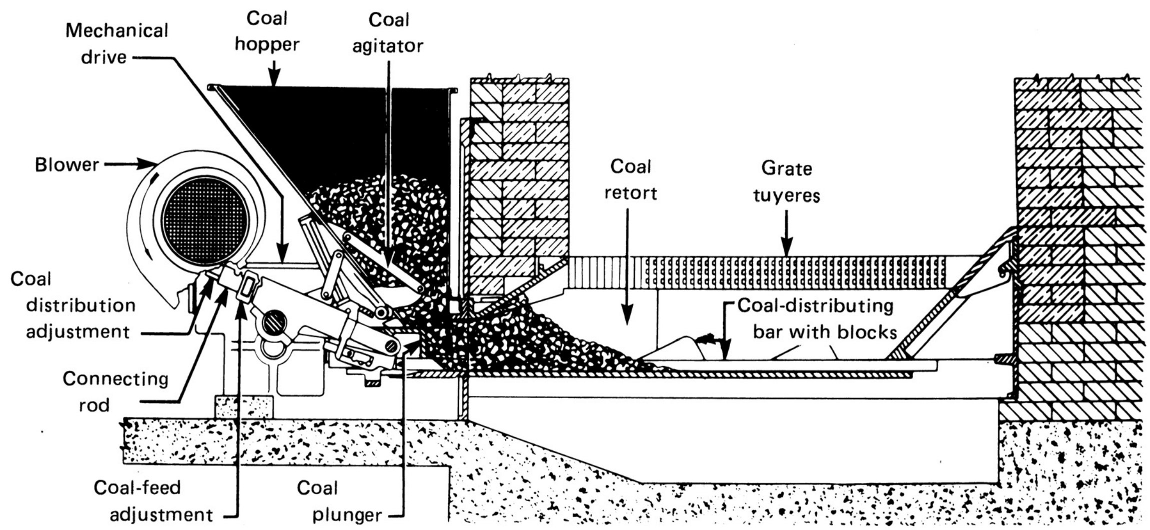


Figure 5.03-2
Overthrow Reciprocating Plate-Feed-Type Spreader Stoker

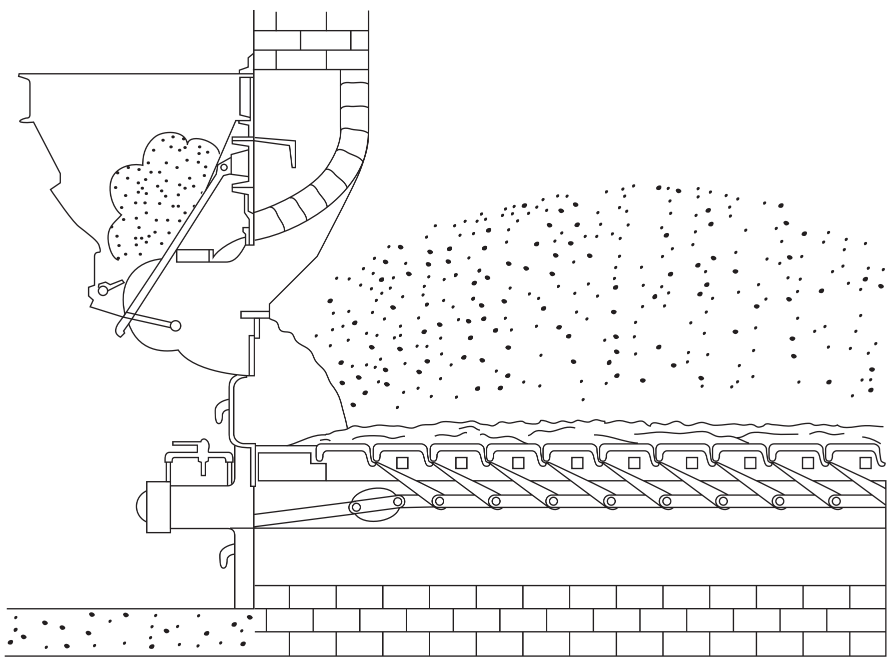
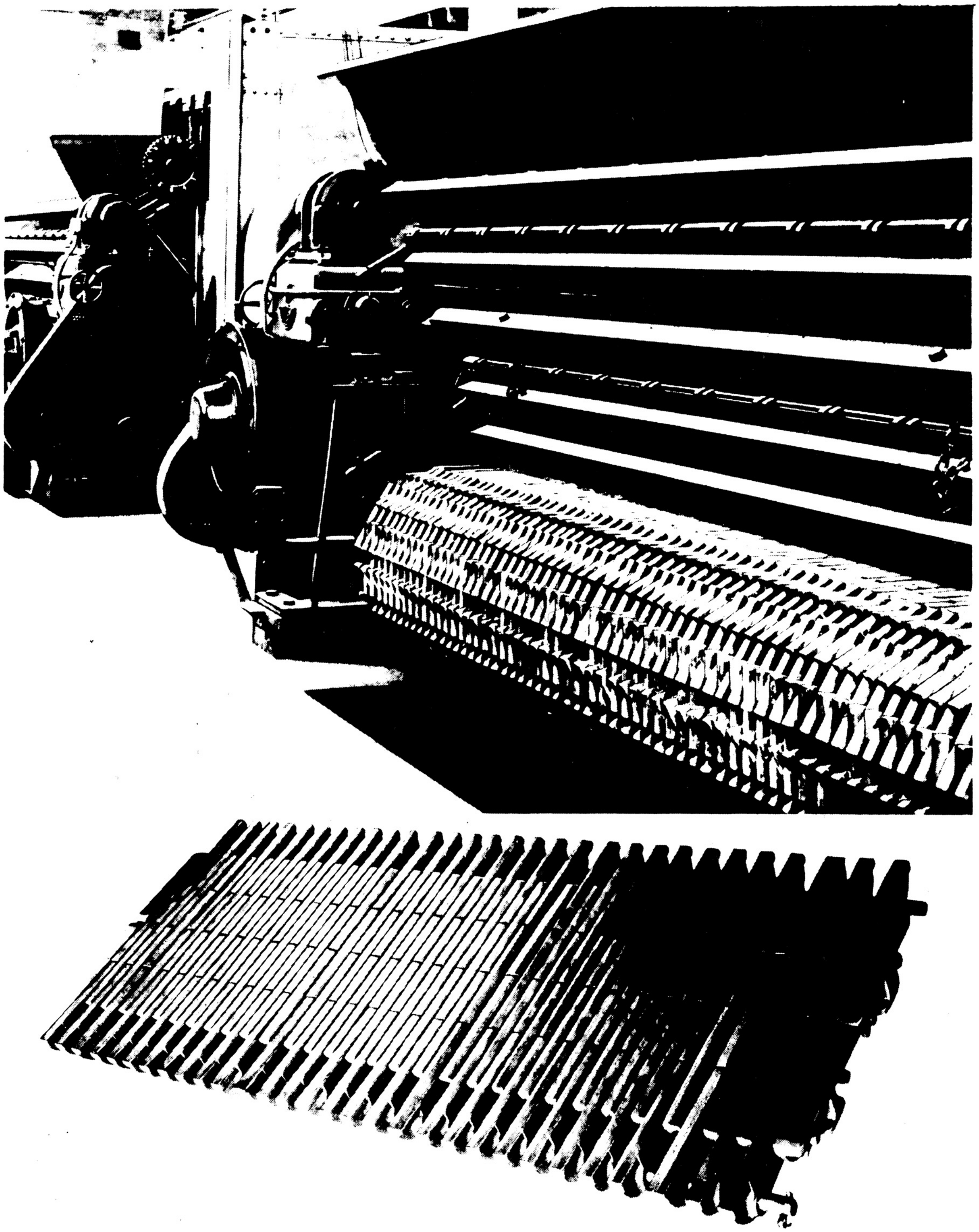


Figure 5.03-3
Chain Grate Stoker With Section Showing Links



SECTION 6
BOILER ROOM FACILITIES

6.01 GENERAL

A. Scope. This Section covers the recommended procedures for the safe, economical operation and maintenance of automatically fired boilers.

B. Intention. It is not intended that this Section serve as operating instructions for any specific heating plant. Due to the wide variety of types and makes of equipment used, this Section should be supplemented with Manufacturers' recommendations concerning maintenance and care and specific written operating instructions for each system.

C. Inspection of New Boilers.

(a) Inspection for Acceptance. Before any new heating plant (or boiler) is accepted for operation, a final (or acceptance) inspection should be completed and all items of exception corrected. In addition to determining that all equipment called for is furnished and installed in accordance with the plans and specifications, all controls should be tested by a person familiar with the control system.

(b) Inspection for Operating Integrity. Before a boiler is put into operation for the first time, it should be inspected by an authorized boiler inspector as required by law. If such an inspection is neither required or available, the boiler should be inspected by a reputable boiler insurance company inspector. It is also recommended that subsequent inspections be made by an Authorized Inspector at intervals required by law or as recommended by the boiler insurance company.

6.02 SAFETY

Safety is very important to boiler operation and it should be foremost in the minds of those who are assigned to operation and maintenance of heating systems. Only properly trained qualified personnel should work on or operate mechanical equipment, and adequate supervision should be provided.

6.03 LIGHTING

The boiler room should be well lighted and it should have an emergency light source for use in case of power failure. If a flashlight is used for this purpose, it should be maintained in usable condition and it should be protected against removal from the boiler room.

6.04 VENTILATION

The boiler room must have an adequate air supply to permit clean, safe combustion and to minimize soot formation. An unobstructed air opening should be provided. It may be sized on the basis of 1 in.^{2} free area per 2,000 Btu/hr (0.586 kW) maximum fuel input of the combined burners located in the boiler room, or as specified in the National Fire Protection Association standards for oil and gas burning installations for the particular job conditions. The boiler room air supply openings must be kept clear at all times.

6.05 WATER AND DRAIN CONNECTIONS

A. Water Connections. Proper and convenient water fill connections should be installed and provisions should be made to prevent boiler water from back-feeding into the service water supply. Provision should also be made in every boiler room for a convenient water supply that can be used to flush out the boiler and to clean the boiler room floor.

B. Drain Connections. Proper and convenient drain connections should be provided for draining boilers. Unobstructed floor drains, properly located in the boiler room, will facilitate proper cleaning of the boiler room. Floor drains that are used infrequently should have water poured into them periodically to prevent the entrance of sewer gases and odors. If there is a possibility of freezing, an antifreeze mixture should be used in the drain traps. See 9.09.

6.06 FIRE PROTECTION

Fire protection apparatus and fire prevention procedures for boiler room areas should conform to recommendations of NFPA.

6.07 HOUSEKEEPING

Generally, a neat boiler room indicates a well-run plant. The boiler room should be kept free of all material and equipment not necessary to the operation of the heating system. Good housekeeping should be encouraged and procedures should include routine inspections to maintain the desired level of cleanliness.

6.08 POSTING OF CERTIFICATES AND/OR LICENSES

Some states and municipalities require licensing or certification of personnel who operate or maintain heating equipment. Also, some authorities require posting of inspection certificates in the boiler room. The supervisor in charge of a given installation should make sure such requirements are met.

6.09 RECORDKEEPING, LOGS, ETC.

A. Drawings, Diagrams, Instruction Books, etc. All drawings, wiring diagrams, schematic arrangements, Manufacturers' descriptive literature and spare parts lists, and written operating instructions should be kept permanently in the boiler room or other suitable location so it will be available to those who operate and maintain the boiler. Where space permits, drawings and diagrams should be framed or sealed in plastic and hung adjacent to the related equipment. Other material should be assembled and enclosed in a suitable binder. When changes or additions are made, the data and drawings should be revised accordingly.

B. Log Book. A permanent log book should be provided in each boiler room to record maintenance work, inspections, certain tests, and other pertinent data. Brief details of repairs or other work done on a boiler plant (including time started, time completed, and signature of person in charge) should be recorded. Performance and results of tests, inspections, or other routines required by codes or laws, insurance company inspection reports, and initial acceptance test data should be recorded.

C. Maintenance Schedules and Records. A suggested chart type log for scheduling and recording work performed on maintenance, testing, and inspection during a 1-year period is shown in Mandatory Appendix I, I.01 (steam heating boilers) and I.02 (water heating boilers). The routine work normally performed on heating boilers is listed. As each portion of the work is completed, the person performing the work should enter the date and his initials in the appropriate space.

SECTION 7
OPERATION, MAINTENANCE, AND REPAIR — STEAM BOILERS

7.01 STARTING A NEW BOILER AND HEATING SYSTEM

A. Cleaning and Filling a New Boiler.

(a) Inspection for Foreign Objects. Prior to starting a new boiler, an inspection should be made to insure that no foreign matter such as tools, equipment, rags, etc., is left in the boiler.

(b) Checks Before Filling. Before putting water into a new boiler, make certain that the firing equipment is in operating condition to the extent that this is possible without actually lighting a fire in the empty boiler. This is necessary because raw water must be boiled [or heated to at least 180°F (82°C)] promptly after it is introduced into the boiler in order to drive off the dissolved gases that might otherwise corrode the boiler.

(c) Operation to Clean the System. Fill the boiler to the proper waterline and operate the boiler with steam in the entire system for a few days to bring the oil and dirt back from the system to the boiler. This is not necessary if the condensate is to be temporarily wasted to the sewer, in which case the system should be operated until the condensate runs clear.

(d) Boiling Out. The oils and greases that accumulate in a new boiler can usually be washed out by boiling as follows:

(1) Fill the boiler to the normal waterline.

(2) Remove plug from tapping on highest point on the boiler.

If no other opening is available, the safety valve may be removed, in which case the valve must be handled with extreme care to avoid damaging it.

(3) Add an appropriate boilout compound[3] through the prepared opening.

(4) Replace the plug, or the safety valves.

(5) Start the firing equipment and check operating, limit, and safety controls. Review Manufacturer's recommendations for boiler and burner startup.

(6) Boil the water for at least 5 hr.

(7) Stop the firing equipment.

(8) Drain the boiler in a manner and to a location that hot water can be discharged with safety.

(9) Wash the boiler thoroughly, using a high-pressure water stream.

(10) Fill the boiler to the normal waterline.

(11) Add boiler water treatment compound as needed.

(12) Boil the water or heat it to a temperature of 180°F (82°C) promptly.

(13) The boiler is now ready to be put into service or on standby.

(e) Second Boilout for Stubborn Cases. In stubborn cases this simple boilout may not remove all the oil and grease, and another boilout using a surface blowoff may be necessary. For this type of cleaning proceed as follows:

(1) Prepare the boiler for cleaning by running a temporary pipe line from the surface blowoff connection to an open drain or some other location where hot water may be discharged safely. If no such tapping is available, use the safety valve tapping, but run the pipe full size and as short a length as possible. Do not install a valve or any other obstruction in this line. Handle the safety valve carefully and protect it against damage while it is out of the boiler.

(2) Fill the boiler until water reaches the top of the water gage glass.

(3) Add a boilout compound.[3]

(4) Start the firing equipment and operate sufficiently to boil the water without producing steam pressure.

(5) Boil for about 5 hr.

(6) Open boiler feed pipe sufficiently to permit a steady trickle of water to run out the overflow pipe.

(7) Continue this slow boiling and trickle of overflow for several hours until the water coming from the overflow is clear.

(8) Stop the firing equipment.

(9) Drain the boiler in a manner and to a location that hot water can be discharged with safety.

(10) Remove covers and plugs from all washout openings and wash the water side of the boiler thoroughly, using a high-pressure water stream.

(11) Refill boiler till 1 in. (25 mm) of water shows in the gage glass.

NOTE: If water in the gage glass does not appear to be clear, repeat steps (2) through (11) and boil out the boiler for a longer time.

(12) Remove temporary piping.

(13) Add a charge of boiler water treatment compound.

(14) Close boiler.

(15) Replace safety valve.

(16) Boil or bring water temperature to at least 180°F promptly.

(17) The boiler is now ready to be put into service or standby.

7.02 STARTING A BOILER AFTER LAYUP (SINGLE BOILER INSTALLATION)

A. Procedure. When starting a boiler after layup, proceed as follows:

(a) Review Manufacturer's recommendations for start-up of burner and boiler.

(b) Set control switch in "Off" position.

(c) Make sure fresh air to boiler room is unobstructed.

(d) Check availability of fuel.

(e) Check water level in gage glass. Make sure gage glass valves are open.

(f) Use try cocks, if provided, to double-check water level.

(g) Vent combustion chamber to remove unburned gases.

(h) Clean glass on fire scanner, if provided.

(i) Set main steam shutoff valve in open position.

(j) Open cold water supply valve to water feeder if provided. Open suction and discharge valves on vacuum or condensate pumps and set electrical switches for desired operation. Vent boiler to remove air when necessary.

(k) Check operating pressure setting of boiler.

(l) Check manual reset, if provided, on low-water fuel cutoff and high-limit pressure control to determine if they are properly set.

(m) Set manual fuel oil supply or manual gas valve in open position.

(n) Place circuit breaker or fused disconnect switch in "On" position.

(o) Place all boiler emergency switches in "On" position.

(p) Place boiler control starting switch in "On" or "Start" position. Do not stand in front of boiler access or cleanout doors. This is a precautionary measure should a combustion explosion occur.

(q) Bring pressure and temperature up slowly. Stand by boiler until it reaches the established cut-out point to make sure the operating control shuts off the burner.

(r) During the pressure buildup period, walk around the boiler frequently to observe that all associated equipment and piping is functioning properly. Check for proper over-the-fire draft.

(s) Immediately after burner shuts off, inspect water column and open each try cock (if provided) individually to determine true water level.

(t) Enter in log book:

(1) date and time of startup

(2) any irregularities observed and corrective action taken

(3) time when controls shut off burner at established pressure, tests performed, etc.

(4) signature of operator

(u) Check safety valve for evidence of simmering. Perform try lever test. See Mandatory Appendix I, I.03.

B. Action in Case of Abnormal Conditions. If any abnormal conditions occur during light-off or pressure buildup, immediately open emergency switch. (Do not attempt to restart unit until difficulties have been identified and corrected.)

7.03 CONDENSATION

Following a cold start, condensation (sweating) may occur in a gas fired boiler to such an extent that it appears that the boiler is leaking. This condensation can be expected to stop after the boiler is hot.

7.04 CUTTING IN AN ADDITIONAL BOILER

When placing a boiler on the line with other boilers that are already in service, first start the boiler using the above procedures but have its supply stop valve and the return stop valve closed. If one is provided, open the drain valve between the stop valve at the boiler outlet and the steam main. When the pressure within the boiler is approximately the same as the pressure in the steam main, open the stop valve very slightly. If there is no unusual disturbance, such as noise, vibration, etc., continue to open the valve slowly until it is fully open. Open the valve in the return line.

CAUTION: When the stop valve at the boiler outlet is closed, the stop valve in the return line of that boiler must also be closed.

7.05 OPERATION

A. Water Level.

(a) Whenever going on duty, check the water level of all steaming boilers at once.

(b) Check the water gage regularly. The required frequency must be determined by trial. The check should be made when there is steam pressure on the boiler. Close the lower gage glass valve, then open the drain cock that is on the bottom of this valve, and blow the glass clear. Close the drain cock and open lower gage glass valve. Water should return to the gage glass immediately. If water return is sluggish, leave the lower gage glass open and close the upper gage glass valve. Then open the drain cock and allow water to flow until it runs clear. Close the drain valve and repeat the first test described, with the lower gage glass valve closed. If leaks appear around the water gage glass or fittings, correct the leaks at once. Steam leaks may result in a false waterline and they also may damage the fittings.

(c) If water disappears from the water gage glass, blow down gage glass to see if water appears. If it does not appear, then stop the fuel supply immediately. *Do not* turn on the water feed line. *Do not* open the safety valve. Let the boiler cool until the crown sheet is at hand touch temperature. Then add water to 1 in. (25 mm) in the gage glass. *Do*

not put the boiler back into service until the condition responsible for the low water has been identified and corrected.

B. Steaming Pressure. A common unsafe condition found in steam heating boilers is due to the failure of the safety valve(s) to open at the set pressure. This is usually due to the buildup of corrosive deposits between the disk and seat of the safety valve and is caused by a slight leakage or weeping of the valve.

The snap-action opening of a safety valve occurs when the boiler steam pressure on the underside of the valve disk overcomes the closing force of the valve spring. As the force of the steam pressure approaches the counteracting force of the spring, the valve tends to leak slightly and if this condition is permitted to exist, the safety valve can stick or freeze.

For this reason, the pressure differential between the safety valve set pressure and the boiler operating pressure should be at least 5 psi (35 kPa), i.e., the boiler operating pressure should not exceed 10 psig (70 kPa). If, however, the boiler operating pressure is greater than 10 psig (70 kPa), it should not exceed 15 psig (100 kPa) minus the blowdown pressure of the safety valve.

This pressure differential is also required to help insure that the safety valve will seat tightly after popping and when the boiler pressure is reduced to normal operating pressure.

It is very important that periodic testing of safety valves is carried out in accordance with Mandatory Appendix I, IV.

C. Blowdown. Where low-pressure steam boilers are used solely for heating and where practically all of the condensate is returned to the boiler, blow down only as often as concentration of solids require. Boilers used for process steam requiring high makeup should be blown down as required to maintain chemical concentrates at the desired level and to remove precipitated sediments. Boilers that are equipped with slow-opening blowoff valves and a quick-opening blowoff cock should have the levers or cocks opened first, followed by a gradual opening and closing of the slow-opening valve. When the slow-opening valve has been shut tight, then close the lever valve or cock.

CAUTION: Do not open the slow-opening valve first and pump the lever action valve open and closed as water hammer is apt to break the valve bodies or pipe fittings.

D. Appearance of Rust. If rust appears in the water gage glass, this is an indication of corrosion that must not be ignored. Check the boiler water to be sure that the water treatment compound is at proper strength and make sure the boiler is not requiring considerable quantities of makeup water. Check the return line and other parts of the system for evidence of corrosion.

E. Waterline Fluctuation. A wide fluctuation of waterline may indicate that the boiler is foaming or priming. This may be due to the water level in the boiler being carried too high, or, especially in low-pressure boilers, a very high rate of steaming. Foaming may also be caused by dirt or oil in the boiler water. Foaming can sometimes be cured by blowing the boiler down, draining 2 in. (50 mm) or 3 in. (75 mm), then refilling a few times. In persistent cases, it may be necessary to take the boiler out of service, drain, and wash out thoroughly as described for a new steam boiler installation, then refill, and put back into service.

F. Abnormal Water Losses. Where water losses from a steam boiler become abnormal, as indicated by the requirement of large amounts of manually fed makeup, an investigation should be made immediately to determine the cause. Boilers operated with automatic water feeders requiring an increase in water treatment should be investigated immediately for cause of loss of water. Proper repair or replacement of parts should be made at once rather than to increase the water treatment to protect the system due to excessive raw water makeup. If the operator cannot determine the cause of the water loss, a competent contractor should be contacted.

G. Makeup Water. When water makeup is needed and neither the boiler nor the condensate tank is equipped with an automatic water feeder, manually add water to the steam boiler.

(a) Use every practical means for excluding oxygen from the boiler water. One source of oxygen is makeup water; therefore, hold makeup to a minimum. If the boiler loses more than 3 in. (75 mm) of water per month, this indicates there probably is a leak in some part of the system. The leak should be found and corrected.

(b) If the system includes a pump for returning condensate or adding feedwater, be certain that the air vent at the receiver is operating properly.

(c) If large quantities of feedwater are required, deaerating equipment is recommended to remove dissolved gases, thereby reducing oxygen corrosion.

H. Low-Water Cutoff. Check the operation of the low-water cutoff, pump control, and the water feeder if one is installed. Follow the instructions on the tag or plate, attached to each control, to blow down the control regularly as recommended by the Manufacturer.

Periodically, the low-water cutoff may be tested under actual operating conditions. With the burner operating and the boiler steaming at proper water level, close all the valves in the feedwater and condensate return lines so the boiler will not receive any replacement water. Then carefully observe the waterline to determine where the cutoff switch stops the burner in relation to the lowest permissible waterline established by the boiler manufacturer.

If the burner cutoff level is not at, or slightly above, the lowest permissible waterline, in a new installation the low-water cutoff should be moved to the proper elevation, or in an existing installation it should be serviced, repaired, or replaced if necessary.

7.06 REMOVAL OF BOILER FROM SERVICE

A. Procedure. When a steaming boiler is to be taken out of service at the end of the heating season or for repairs, proceed as follows:

(a) While maintaining boiler water temperature, 180°F to 200°F (82°C to 93°C), drain off boiler water from bottom drain until it runs clear.

(b) Refill to top of gage glass, and add sufficient water treatment compound to bring the treatment up to strength.

(c) When all the dissolved gases are released (approximately 1 hr), shut down the firing equipment by disconnecting the main switch.

(d) For treatment of laid-up boilers, see D.

B. Cleaning. When the boiler is cool, clean the tubes and other fire side heating surfaces thoroughly, and scrape the surfaces down to clean metal. Clean the smokeboxes and other areas where soot or scale may accumulate. Soot is not corrosive when it is perfectly dry, but can be very corrosive when it is damp. For this reason, it is necessary to remove all the soot from a boiler at the beginning of the nonoperating season, or any extended nonfiring period.

C. Protection Against Corrosion. Swab the fire side heating surfaces with neutral mineral oil to protect against corrosion. If the boiler room is damp, place a tray of calcium chloride or unslaked lime in the combustion chamber and replace the chemical when it becomes mushy.

D. Water Level. Drain a steam boiler back to normal water level before putting the boiler back in service.

E. Periodic Checks. Check the boiler occasionally during the idle period and make certain it is not corroded.

7.07 MAINTENANCE

A. Cleaning. Clean the boiler tubes and other heating surfaces whenever required. The frequency of the cleaning can best be determined by trial. A general prediction applicable to all boilers cannot be made. Also, clean the smokeboxes when required.

B. Draining. A clean, properly maintained, steam heating boiler should not be drained unless there is a possibility of freezing, or the boiler has accumulated a considerable amount of sludge or dirt on the water side, or unless draining is necessary to make repairs. Very little sludge should accumulate in a boiler where little makeup water is added and where an appropriate water treatment is maintained at the proper strength.

C. Protection Against Freezing. Antifreeze solutions, when used in heating systems, should be tested from year to year as recommended by the manufacturer of the antifreeze that is used. Antifreeze solutions should not be circulated through the boiler proper. The antifreeze solution should be heated in an indirect heat exchanger.

D. Fire Side Corrosion. Previously in this manual some of the causes of water side corrosion have been stated and procedures recommended to minimize trouble from these sources. Boilers can also corrode on the fire side. Some fuels contain substances that cause fire side corrosion. Sulphur, vanadium, and sodium are among the materials that may contribute to this problem.

(a) Deposits of sulphur compounds may cause fire side corrosion. The probability of trouble from this source depends on the amount of sulphur in the fuel and on the care used in cleaning the fire side heating surfaces. This is particularly true when preparing a boiler for a period of idleness. Preventing this trouble depends also on keeping the boiler heating surfaces dry when a boiler is out of service.

(b) Deposits of vanadium, or vanadium and sodium compound, also may cause fire side corrosion, and these compounds may be corrosive during the season when boilers are in service.

(c) The person responsible for boiler maintenance should be certain that the fire side surfaces of the boilers in his care are thoroughly cleaned at the end of the firing season. If signs of abnormal corrosion are discovered, a reputable consultant should be engaged.

E. Safety Valves. Safety valves on steam boilers should be tested for proper operation in accordance with Appendix I, I.02 and I.03. ASME rated safety valves shall be installed on the boiler where required by jurisdictional regulations. When replacement is necessary, use only ASME rated valves of the required capacity.

F. Burner Maintenance.

(a) Oil Burners. Oil burners require periodic maintenance to keep the nozzle and other parts clean. Check and clean oil line strainers. Inspect and check the nozzle and check the oil level in the gear cases. Check and clean filters, air intake screens, blowers, and air passages. Check all linkages and belts, and adjust as required. Lubricate in accordance with manufacturer's recommendations. Check pilot burners and ignition equipment for proper flame adjustment and performance.

(b) Gas Burners. Check gas burners for presence of dirt, lint, or foreign matter. Be sure parts, gas passages, and air passages are free of obstructions. Linkages, belts, and moving parts on power burners should be checked for proper adjustment. On combination oil and gas burners, the gas outlets may become caked with carbon residues from unburned fuel oil afterprolonged periods of oil firing and require cleaning. Lubricate in accordance with Manufacturer's recommendations. Also check pilot burners and ignition equipment for proper flame adjustment and performance.

G. Low-Water Fuel Cutoff and Water Feeder Maintenance. Low-water fuel cutoffs and water feeders should be dismantled annually, by qualified personnel, to the extent necessary to insure freedom from obstructions and proper functioning of the working parts. Inspect connecting lines to boiler for accumulation of mud, scale, etc., and clean as required. Examine all visible wiring for brittle or worn insulation and make sure electrical contacts are clean and that they function properly. Give special attention to solder joints on bellows and float when this type of control is used. Check float for evidence of collapse and check mercury bulb (where applicable) for mercury separation or discoloration. *Do not attempt to repair mechanisms in the field. Complete replacement mechanisms, including necessary gaskets and installation instructions are available from the Manufacturer. After reassembly, test as per 7.05H.*

H. Flame Safeguard Maintenance.

(a) Thermal Type Detection Device. Check device for electrical continuity and satisfactory current generation in accordance with Manufacturer's instructions. After completing maintenance, test as per Appendix I, I.03I.A and I.03I.B, and make pilot turndown test as per Appendix I, I.03I.H.

(b) Electronic Type Detection Device. Replace vacuum tubes or transistors annually with type recommended by Manufacturer. Check operation of unit in accordance with Manufacturer's instructions and examine for damaged or worn parts. Do not attempt to repair these units in the field. Replacement assemblies are available from the Manufacturer on an exchange basis. Test as specified in Appendix I, I.03I.C, I.03I.D, I.03I.E, or I.03I.G for proper type control and make pilot turndown test as per Appendix I, I.03I.H.

I. Limit Control Maintenance. Maintenance on pressure limiting controls is generally limited to visual inspection of the device for evidence of wear, corrosion, etc. If control is mercury bulb type, check for mercury separation, and discoloration of bulb. If the control is defective, replace it. Do not attempt to make field repairs.

J. Cast Iron Boiler Maintenance.

(a) Heating Surfaces. Check the firebox gas passages and breeching for soot accumulation. Use a wire brush and vacuum cleaner, if required, to remove the soot or other dirt accumulations.

(b) Internal Surfaces. If the condition of the water in the boiler indicates that there is considerable foreign matter in it, the boiler should be allowed to cool, then drained and thoroughly flushed out. Remove the blowdown valves and plugs in the front and rear sections, and wash through these openings with a high-pressure water stream. This will normally remove any sludge or loose scale. If there is evidence that hard scale has formed on the internal surfaces, the boiler should be cleaned by chemical means as prescribed by a qualified water treatment specialist.

K. Steel Boiler Maintenance.

(a) Heating Surfaces. Remove all accumulations of soot, carbon, and dirt from the fire side of the boiler. Use flue brush to clean the tubes. Clean breeching and stack as required. Inspect refractory and make repairs as required.

(b) Internal Surfaces. Blow down as specified in 7.05C. If water does not run clear, the boiler should be cleaned. After the boiler is allowed to cool, the cleaning is accomplished by venting, draining the boiler, removing all manhole and handhole covers, and washing the inside of the boiler with a high-pressure water stream. Loosen any solidified sludge, scale, etc., with a hand scraper. Start at the top of the boiler and work down. Flush thoroughly after cleaning. Where access is limited or where scale buildup is difficult to remove, it may be necessary to clean the boiler chemically as prescribed by a qualified water treatment specialist.

L. Use of Flashlight for Internal Inspection. When practical, use a flashlight in preference to an extension light for internal inspection purposes. If an extension light is taken into a boiler, be sure the cord is rugged, in good condition, and that it is properly grounded. It should be equipped with a vapor-tight globe, substantial guard, and nonconducting holder and handle.

M. Leaking Tubes. If one tube in a boiler develops a leak due to corrosion, it is likely that other tubes are corroded also. Have the boiler examined by a capable and experienced inspector before ordering the replacement of one or a few tubes. If all the tubes will need replacement soon, it is preferable and less expensive to have all the work done at one time.

N. Use of Sealant. The use of sealant is not recommended in a steam boiler.

O. Maintenance of Condensate Return Systems. Inspect and clean the strainer ahead of the pump. Drain and flush condensate tank. Check pump packing, float switches, and vacuum switches as applicable. For detailed instructions, refer to Manufacturer's maintenance data and recommendations.

P. Maintenance Schedule. Listed below are suggested frequencies for the various routines and tests to be performed in connection with inspection and maintenance of boilers (see Appendix I, I.02 and I.03):

(a) Daily (Boilers in Service). Observe operating pressures, water level, and general conditions. Determine cause of any unusual noises or conditions and correct.

(b) Weekly (Boilers in Service)

(1) Test low-water fuel cutoff and/or water feeder. Blow down boiler if considerable makeup is used (see C).

(2) Test water column or gage glass.

(3) Observe condition of flame; correct if flame is smoky or if burner starts with a puff (for oil, observe daily).

(4) Check fuel supply (oil only).

(5) Observe operation of condensate or vacuum pump.

(c) Monthly (Boilers in Service)

(1) Safety valve — try lever test.

(2) Test flame detection devices.

(3) Test limit controls.

(4) Test operating controls.

(5) Sludge blowdown where required.

(6) Check boiler room floor drains for proper functioning.

(7) Inspect fuel supply systems in boiler room area.

(8) Check condition of heating surfaces (for preheated oil installation, inspect more frequently, twice a month).

(9) Check combustion air supply opening to ensure that it is not closed or stopped up.

(d) Annually

(1) internal and external inspection after thorough cleaning

(2) routine burner maintenance

(3) routine maintenance of condensate or vacuum return equipment

(4) routine maintenance of all combustion control equipment

(5) combustion and draft tests

(6) safety valve pop test

(7) slow drain test of low-water cutoff

(8) Inspect gas piping for proper support and tightness.

(9) Inspect boiler room ventilation louvers and intake.

7.08 BOILER REPAIRS

A. Precaution. Do not permit repairs to a boiler while it is in service, or under pressure, except with the approval and under the supervision of an authorized boiler inspector or responsible engineer.

B. Notification. When repair work is required, notify the authorized boiler and pressure vessel inspector and be guided by his recommendations.

C. Welding Requirements. All repair work should be done by experienced boiler mechanics. All welding should be done by qualified welders using procedures properly qualified according to Section IX.

D. Safety. Take every precaution necessary to insure against injury to men who are working in the boiler room and particularly to those working inside the steam space or in the combustion chamber of the boiler. Pull the main burner switch and lock it out and tag it, swing the burner out of place, if possible, close and lock valves, etc., *and always* have one man standing by outside when a man is working inside a boiler.

7.09 TESTS AND INSPECTIONS OF STEAM HEATING BOILERS

A. Tests. The tests recommended for burner efficiency, combustion safeguards, safety controls, operating controls, limit controls, safety valves, and safety relief valves are included in Mandatory Appendix I, I.03.

B. Inspection During Construction. This part of boiler inspection is covered in Section IV, Heating Boilers: HG-515, HG-520, and HG-533 (General Requirements); HW-900, HW-910, and HW-911 (Welding); HB-1500, HB-1501, HB-1502, and HB-1503 (Brazing); and HC-501 (Cast Iron).

C. Initial Inspection at Place of Installation. As opposed to inspection during manufacture that pertains primarily to conforming to Code construction requirements, this inspection will be concerned with whether boiler supports, piping arrangements, safety valves, other valves, water columns, gage cocks, steam gages, and other apparatus on the boiler meet Code and/or other jurisdictional requirements. The inspector usually represents the same jurisdiction that will be making subsequent periodic inspection.

D. Periodic Inspecting of Existing Boilers. The main purposes for reinspection include protection against loss or damage to the pressure vessel because of corrosion, pitting, etc., protection against unsafe operating conditions possibly caused by changes in piping or controls or lack of testing of safety devices. It is important that inspections be thorough and complete, and so that important elements may all be checked, the following recommended directions and instructions for such inspections are given.

(a) All steam heating boilers should be prepared for inspection, whenever necessary, by the owner or user when notified by the inspector.

The owner or user should prepare the boiler for an internal inspection and should prepare for and apply the hydrostatic test whenever necessary on the date specified in the presence of a duly qualified inspector.

(b) Before inspection, every part of a boiler that is accessible should be open and properly prepared for examination, internally and externally. In cooling down a boiler for inspection or repairs, the water should not be withdrawn until the setting is sufficiently cooled to avoid damage to the boiler and, when possible, it should be allowed to cool down naturally.

(c) Preparation. The owner or user should prepare a boiler for internal inspection in the following manner.

(1) Water should be drained and boiler washed thoroughly.

(2) All manhole and handhole plates, wash-out plugs, and water column connections should be removed and the furnace and combustion chambers thoroughly cooled and cleaned.

(3) All grates of internally fired boilers should be removed.

(4) Brickwork should be removed as required by the inspector in order to determine the condition of the furnace, supports, or other parts.

(5) Any leakage of steam or hot water into the boiler should be cut off by disconnecting the pipe or valve at the most convenient point.

(d) It is not necessary to remove insulation material, masonry, or fixed parts of the boiler unless defects or deterioration are suspected. Where there is moisture or vapor showing through the covering, the covering should be removed at once and a complete investigation made.

Every effort should be made to discover the true condition, even if it means drilling holes or cutting away parts.

(e) The inspector should get as close to the parts of the boiler as is possible in order to obtain the best possible vision of the surface and should use a good artificial light if natural light is inadequate.

(f) Whenever the inspector deems it necessary to test boiler apparatus, controls, etc., these tests should be made by a plant operator in the presence of the inspector, unless otherwise ordered.

(g) Scale, Oil, etc. The inspector should examine all surfaces of the exposed metal inside to observe any action caused by treatment, scale solvents, oil, or other substances that may have entered the boiler. Any evidence of oil should be noted carefully, as a small amount is dangerous, and immediate steps should be taken to prevent the entrance of any more oil into the boiler. Oil or scale on plates over the fire of any boiler is particularly bad, often causing sufficient weakening to bag or rupture.

(h) Corrosion, Grooving. Corrosion along or immediately adjacent to a seam is more serious than a similar amount of corrosion in the solid plate away from the seams. Grooving and cracks along longitudinal seams are especially significant as they are likely to occur when the material is highly stressed. Severe corrosion is likely to occur at points where the circulation of water is poor; such places should be examined very carefully.

For the purpose of estimating the effect of corrosion or other defects upon the strength of a shell, comparison should be made with the efficiency of the longitudinal joint of the same boiler, the strength of which is usually less than that of the solid sheet.

(i) Stays. All stays, whether diagonal or through, should be examined to see if they are in even tension. All fastened ends should be examined to note if cracks exist where the plate is punched or drilled. If stays are not found in proper tension, their proper adjustment should be recommended.

(j) Manholes and Other Openings. The manhole(s) and other reinforcing plates, as well as nozzles and other connections flanged or screwed into the boiler, should be examined internally as well as externally to see that they are not cracked or deformed. Wherever possible, observation should be made from the inside of the boiler as to the thoroughness with which its pipe connections are made to the boiler. All openings to external attachments, such as water column connections, openings in dry pipes, and openings to safety valves, should be examined to see if they are free from obstructions.

(k) Fire Surfaces — Bulging, Blistering, Leaks. Particular attention should be given to the plate or tube surface exposed to fire. The inspector should observe whether any part of the boiler has become deformed during operation by bulging or blistering. If bulges or blisters are of such size as would seriously weaken the plate or tube, and especially when water is leaking from such a defect, the boiler should be discontinued from service until the defective part or parts have received proper repairs. Careful observation should be made to detect leakage from any part of the boiler structure, particularly in the vicinity of seams and tube ends. Firetubes sometimes blister but rarely collapse; the inspector should examine the tubes for such defects; if they are found to have sufficient amount of distortion to warrant it, they should be replaced.

(l) Lap Joints. Lap joint boilers are apt to crack where the plates lap in the longitudinal or straight seam. If there is any sign of leakage or other distress at this joint, it should be investigated thoroughly to determine if cracks exist in the seam. Any cracks noted in shell plates are usually dangerous.

(m) Testing Staybolts. The inspector should test staybolts by tapping one end of each bolt with a hammer and, when practicable, a hammer or other heavy tool should be held at the opposite end to make the test more effective.

(n) Tube Defects. Tubes in horizontal firetube boilers deteriorate more rapidly at the ends toward the fire, and they should be carefully tapped with a light hammer on their outer surface to ascertain if there has been a serious reduction in thickness. The tubes of vertical tubular boilers are more susceptible to deterioration at the upper ends when exposed to the products of combustion without water cooling. They should be reached as far as possible either through the handholes, if any, or inspected at the ends.

The surface of tubes should be carefully examined to detect bulges or cracks or any evidence of defective welds. Where there is a strong draft, the tubes may become thinned by erosion produced by the impingement of particles of fuel and ash. A leak from a tube frequently causes serious corrosive action on a number of tubes in its immediate vicinity.

(o) Ligaments Between Tube Holes. The ligaments between tube holes in the heads of all firetube boilers and in shells of watertube boilers should be examined. If leakage is noted, broken ligaments are probably the reason.

(p) Pipe Connections and Fittings. The steam and water pipes, including connections to the water columns, should be examined for leaks; if any are found, it should be determined whether they are the result of excess strains due to expansion or contraction or other causes. The general arrangement of the piping in regard to the provisions for expansion and drainage, as well as adequate support at the

proper points, should be carefully noted. The location of the various stop valves should be observed to see that water will not accumulate when the valves are closed and thereby establish cause for water-hammer action.

The arrangement of connections between individual boilers and the main steam header should be especially noted to see that any change of position of the boiler due to settling or other causes has not placed an undue strain on the piping.

It should be ascertained whether all pipe connections to the boiler possess the proper strength in their fastenings, whether tapped into or welded to the boiler shell. The inspector should determine whether there is proper provision for the expansion and contraction of such piping and that there is no undue vibration tending to damage the parts subjected to it. This includes all steam and water pipes; special attention should be given to the blowoff pipes with their connections and fittings because the expansion and contraction due to rapid changes in temperature and water-hammer action bring a great strain upon the entire blowoff system. The freedom of the blowoff and drain connections on each boiler should be tested whenever possible by opening the valve for a few seconds at which time it can be determined whether there is excessive vibration.

(q) Water Column. The piping to the water column should be carefully inspected to see that there is no chance of water accumulating in the pipe forming the steam connection to the water column. The steam pipe should preferably drain toward the water column. The water pipe connection to the water column must drain toward the boiler.

The position of the water column relative to the fire surfaces of the boiler should be observed to determine whether the column is placed in accordance with Code requirements.

The attachments should be examined to determine their operating condition.

If examination is made with steam on the boiler, the water column and gage glass should be observed to see that the connections to the boiler are free as shown by the action of the water in the glass. The water columns and gage glasses should be blown down on each boiler to determine definitely the freedom of the connections to the boilers as well as to see that the blowoff piping from the columns and gage glasses are free. The gage glasses should be observed to see that they are clean and that they are properly located to permit ready observation. The freedom of the gage glass should be determined by test.

(r) Low-Water Cutoff and Water Feeder. All automatically fired steam or vapor boilers shall be equipped with an automatic low-water fuel cutoff or water feeding device so constructed that the water inlet valve cannot feed water into the boiler through the float chamber, if one is employed, and so located as to automatically cut off the fuel supply or supply requisite feedwater when the surface of the water falls below the lowest safe waterline. This line should not be lower than the bottom of the water glass.

Such a fuel or feedwater control device may be attached directly to the boiler shell or to the tapped openings provided for attaching a water glass direct to a boiler, provided that such connections from the boiler are nonferrous tees or Ys not less than $^1/_2$ in. pipe size between the boiler and the water glass so that the water glass is attached direct and as close as possible to the boiler. The straightway tapping of the Y or tee should take the water glass fittings and the side outlet of the Y or tee should take the fuel cutoff or water feeding device.

Designs employing a float and float bowl shall have a vertical straightway-valve drain pipe at the lowest point in the water equalizing pipe connections, by which the bowl and the equalizing pipe can be flushed and the device tested.

(s) Baffling in Watertube Boilers. In watertube boilers it should be noted as well as possible whether the proper baffling is in place. The absence of baffling often causes high temperatures on portions of the boiler structure that are not intended for such temperatures, and from this a dangerous condition may result. The location of combustion arches with respect to tube surfaces should be noted to make sure they do not cause the flame to impinge on a particular part of the boiler and produce overheating of the material and consequent danger of rupture.

(t) Localization of Heat. Localization of heat brought about by improper or defective burner or stoker installation or operation, creating a blowpipe effect upon the boiler, should be cause for shutdown of the boiler until the condition is corrected.

(u) Suspended Boilers — Freedom of Expansion. Where boilers are suspended, the supports and setting should be examined carefully, especially at points where the boiler structure comes near the setting walls or floor, to make sure that ash and soot will not bind the boiler structure at such points and produce excessive strains on the structure owing to the expansion of the parts under operating conditions.

(v) Safety Valves. As the safety valve is the most important safety device on the boiler, it should be inspected with the utmost care. There should be no accumulation of rust, scale, or other foreign substances in the body of the valve that will interfere with its free operation. The valve should not leak under operating conditions. The opening pressure and freedom of operation of the valve should be tested preferably by raising the steam pressure to the point of opening. If this cannot be done, the valve should be tested by opening with the try lever in accordance with the procedure in Appendix I, I.03. Where the valve has a discharge pipe the inspector should determine at the time the valve is operating whether or not the drain opening in the discharge pipe is free and in accordance with the Code requirement.

If the inspector deems it necessary, in order to determine the freedom of discharge from a safety valve, the discharge connection should be removed. Under no circumstances shall a stop valve be permitted between a steam boiler and its safety valve.

(w) Steam Gages. A test gage connection should be provided on the boiler so that the gage on the boiler can be tested under operating pressure. The steam gage should not be exposed to excessively high ambient temperatures and should be mounted with a siphon or trap between it and the boiler. Provisions should be made for blowing out the piping leading to the steam gage.

(x) Imperfect Repairs. When repairs have been made, especially tube replacements, the inspector should observe whether the work has been done safely and properly. Excessive rolling of tubes, where they are accessible, is a common fault of inexperienced workmen. When it is difficult to reach the tube end and observe the extent of rolling, however, they are frequently underrolled. This inevitably results in separation of the parts.

(y) Hydrostatic Tests. When there is a question or doubt about the extent of a defect found in a boiler, the inspector, in order to more fully decide upon its seriousness, should cause the application of hydrostatic pressure under the Code provisions.

A hydrostatic pressure test shall not exceed $1^1/_2$ times the maximum allowable working pressure. During the test, the safety valve should be removed from the boiler. It is suggested that the minimum temperature of the water be 70°F (21°C) and maximum 160°F (71°C). All controls and appurtenances unable to withstand the test pressure without damage should be removed during the test.

(z) Suggestions. The inspector, whether he is the employee of a state, province, municipality, or insurance company, should be well informed of the natural and neglectful causes of defects and deterioration of boilers. He should be extremely conscientious and careful in his observations, taking sufficient time to make the examinations thorough in every way, taking no one's statement as final as to conditions not observed by him, and, in the event of inability to make a thorough inspection, he should note it in his report and not accept the statement of others.

The inspector should make a general observation of the condition of the boiler room and apparatus, as well as of the attendants, as a guide in forming an opinion of the general care of the equipment. He should question responsible employees as to the history of old boilers, their peculiarities and behavior, ascertain what, if any, repairs have been made and their character, and he should investigate and determine whether they were made properly and safely.

SECTION 8
OPERATION, MAINTENANCE, AND REPAIR — HOT WATER BOILERS AND HOT WATER HEATING BOILERS

8.01 STARTING A NEW BOILER AND HEATING SYSTEM

A. Cleaning and Filling a New Boiler.

(a) Inspection for Foreign Objects. Prior to starting a new boiler an inspection should be made to insure that no foreign matter such as tools, equipment, rags, etc., is left in the boiler.

(b) Checks Before Filling. Before putting water into a new boiler, make certain that the firing equipment is in operating condition to the extent that this is possible without actually lighting a fire in the empty boiler. This is necessary because raw water must be boiled [or heated to at least 180°F (82°C)] promptly after it is introduced into the boiler in order to drive off the dissolved gases, that might otherwise corrode the boiler. In a hot water heating system, the boiler and entire system (other than the expansion tank) must be full of water for satisfactory operation. The red, or fixed, hand on the combination altitude gage and thermometer is normally set to indicate the amount of pressure required to fill the system with cold water. Water should be added to the system until the black hand registers the same or more than the red hand. To insure that the system is full, water should come out of all air vents when opened.

(c) Boiling Out. The oil and grease that accumulate in a new hot water boiler can be washed out in the following manner.

(1) Add an appropriate boilout compound.[3]

(2) Fill the entire system with water.

(3) Start the firing equipment.

(4) Circulate the water through the entire system.

(5) Vent the system, including the radiation.

(6) Allow boiler water to reach operating temperature, if possible.

(7) Continue to circulate the water for a few hours.

(8) Stop the firing equipment.

(9) Drain the system in a manner and to a location that hot water can be discharged with safety.

(10) Wash the water side of the boiler thoroughly, using a high-pressure water stream.

(11) Refill the system with fresh water.

(12) Bring water temperature to at least 180°F (82°C) promptly and vent the system at the highest point.

(13) Tighten handhole covers, manhole covers, and plugs while boiler is hot.

(14) The boiler is now ready to put into service or on standby.

8.02 STARTING A BOILER AFTER LAYUP (SINGLE BOILER INSTALLATION)

A. Procedure. When starting a boiler after layup, proceed as follows.

(a) Review Manufacturer's recommendations for startup burner and boiler.

(b) Fill boiler and system; vent air at high point in system.

(c) Check altitude gage and expansion tank to assure system is properly filled.

(d) Set control switch in "Off" position.

(e) Make sure fresh air to boiler room is unobstructed and manual dampers are open.

(f) Check availability of fuel.

(g) Vent combustion chamber to remove unburned gases.

(h) Clean glass on fire scanner, if provided.

(i) Observe proper functioning of water pressure regulator and turn circulator pumps on electrically.

(j) Check temperature control(s) for proper setting.

(k) Check manual reset button on low-water fuel cutoff and high-limit temperature control.

(l) Set manual fuel oil supply or manual gas valve in open position.

(m) Place circuit breaker or fuse disconnect in "On" position.

(n) Place all boiler emergency switches in "On" position.

(o) Place boiler control starting switch in "On" or "Start" position. (Do not stand in front of boiler doors or breeching.)

(p) Do not leave boiler until it reaches the established cutout point to make sure the controls shut off the burner.

(q) During the temperature and pressure buildup period, walk around the boiler frequently to observe that all associated equipment and piping is functioning properly. Visually check burner for proper combustion.

(r) Immediately after burner shuts off, inspect water pressure and open the highest vent to determine that system is completely full of water.

(s) Enter in log book:

(1) date and time of startup

(2) any irregularities observed and corrective action taken

(3) time when controls shut off burner at established temperature, tests performed, etc.

(4) signature of operator

(t) Check safety relief valve for evidence of leaking. Perform try lever test. see Appendix I, I.03.

B. Action in Case of Abnormal Conditions. If any abnormal conditions occur during lights off or temperature buildup, immediately open emergency switch. (Do not attempt to restart unit until difficulties have been identified and corrected.)

8.03 CONDENSATION

Following a cold start, condensation may occur in a gas fired boiler to such an extent that it appears that the boiler is leaking. This condensation can be expected to stop after the boiler is hot.

8.04 CUTTING IN AN ADDITIONAL BOILER

When placing a boiler on the line with other boilers that are already in service, start the boiler using the above procedures, but have its supply stop valve and the return stop valve closed. Bring to the same temperature as the operating boiler and partially open the supply valve(s). If there is no unusual disturbance, such as noise, vibration, etc., continue to open the valve slowly until it is fully open. Open the valve in the return line.

CAUTION: When the stop valve at the boiler outlet is closed, the stop valve in the return line of that boiler must also be closed.

8.05 OPERATION

A. Check of Pressure and Temperature. Whenever going on duty, check the pressure and temperature in all water boilers.

B. Position of Hands on Combination Gage. When the boiler is cold, the stationary and movable hands of the combination altitude pressure gage should be together; when the boiler is hot, the movable hand should be above the stationary hand. The stationary hand should be aligned with the movable hand at the time the system is initially filled, or it may be set to indicate the minimum pressure under which the system can operate and still maintain a positive pressure at the highest point in the system.

C. Operating Temperature and Pressure.

(a) Operating Temperature. The maximum operating temperature of the boiler water should never exceed 250°F (121°C), and should be as low as possible to heat the space adequately under design conditions. Higher temperatures will accelerate any corrosion process.

(b) Operating Pressure. A common unsafe condition found in hot water heating boilers is due to the failure of the safety relief valve(s) to open at the set pressure. This is usually due to buildup of corrosive deposits between the disk and seat of the valve and is caused by a slight leakage or weeping of the valve.

The opening of a safety relief valve occurs when the boiler water pressure on the underside of the valve disk overcomes the closing force of the valve spring. As the force of the water pressure approaches the counteracting force of the spring, the valve tends to leak slightly and if this condition is permitted to exist, the safety relief valve can stick or freeze.

For this reason, the pressure differential between the safety relief valve set pressure and the boiler operating pressure should be at least either 10 psi (69 kPa) or 25% of the valve set pressure, whichever is greater.

(c) Temperature and Pressure Safety Relief Valves. When boilers limited to a maximum temperature of 210°F (99°C) have a temperature and pressure safety relief valve installed, the operating temperature must be low enough to prevent routine operation of the thermal element. This could lead to degradation of the valve.

When the thermal element opens, it will not close until the temperature has been reduced by 25°F to 35°F (14°C to 19°C) below the opening temperature. Therefore, the maximum operating temperature should not exceed 160°F (70°C).

EXAMPLES:

(1) The operating pressure of a hot water heating boiler where the safety relief valve is set to open at 30 psi (200 kPa) should not exceed 20 psig (140 kPa).

(2) If the safety relief valve on a hot water heating boiler is set to open at 100 psi (630 kPa), the boiler operating pressure should not exceed 75 psig (520 kPa).

Section IV does not require that safety relief valves have a specified blowdown. To help insure that the safety relief valve will close tightly after popping and when the boiler pressure is reduced to the normal operating pressure, these pressure differentials between the valve set pressures and operating pressures should not be exceeded.

It is very important that periodic testing of safety relief valves is carried out in accordance with Appendix I, V.

8.06 REMOVAL OF BOILER FROM SERVICE

A. Procedure. For a water boiler, the procedure is to drain from the bottom of the boiler while it is still hot [180°F to 200°F (82°C to 93°C)] until the water runs clean, then to refill to the normal water fill pressure. This should be a yearly procedure. If water treatment is used in the system, sufficient treatment compound should be added to condition the added water. For further information, see D.

B. Cleaning. When the boiler (any of those referred to above) is cool, clean the tubes and other heating surfaces thoroughly, and scrape the surfaces down to clean metal. Clean the smokeboxes and other areas where soot or scale may accumulate. Soot is not corrosive when it is perfectly dry, but can be very corrosive when it is damp. For this reason, it is necessary to remove all the soot from a boiler at the beginning of the nonoperating season, or any extended nonfiring period.

C. Protection Against Corrosion. Swab the fire side heating surfaces with neutral mineral oil to protect against corrosion. If the boiler room is damp, place a tray of calcium chloride or unslaked lime in the combustion chamber and replace the chemical when it becomes mushy.

D. Periodic Checks. Check the boiler occasionally during the idle period and make certain it is not corroded. This is an opportune time to repaint the exposed metal parts of the boiler and to inspect and service the firing equipment and combustion chamber.

8.07 MAINTENANCE

A. Cleaning.

(a) General. Clean the boiler tubes and other heating surfaces whenever required. The frequency of the cleaning can best be determined by trial. A general prediction applicable to all boilers cannot be made. Also, clean the smokeboxes when required.

(b) Backwashing of Water Heater. Any water heater installed in or connected to a boiler should be backwashed periodically, using valves to reverse the direction of flow through the heater. The purpose of this backwashing is to reduce the amount of scale that will accumulate at the outlet side of the heater. Continue the backwashing until the water runs clear. The backwashing may be done frequently and the maximum interval should be determined by trial.

B. Draining. A clean, properly maintained heating boiler should not be drained unless there is a possibility of freezing, unless the boiler has accumulated a considerable amount of sludge or dirt on the water side, or unless draining is necessary to make repairs. Very little sludge should accumulate in a boiler where little makeup water is added and where an appropriate water treatment is maintained at the proper strength. If it proves necessary to drain the boiler and heating piping to do repair work, and the various parts of the system cannot be isolated to prevent such draining, it would be wise to consider the installation of valves and drains at that time to prevent this from occurring again. Considerable time and expense can be saved the next time repairs are necessary, and the amount of raw water required is also reduced.

C. Protection Against Freezing. Antifreeze solutions when used in heating systems shall be of the ethylene glycol base type with an inhibitor added.

Antifreeze concentrations should not be less than 33% nor greater than 66%. [100% antifreeze has a freezing point of about −6°F (−21°C) while a concentration of 68% has a freezing point of about −92°F (−69°C) and a 50% solution has a freezing point of about −34°F (−37°C).]

The service life of an antifreeze solution depends on such factors as heating system design and condition, hours of operation, solution and metal temperatures, aeration, and rate of contamination. Therefore, the antifreeze solution should be tested at least once a year and as recommended by the manufacturer of the antifreeze that is used.

High metal temperatures accelerate depletion of the antifreeze inhibitors. For maximum service life, the metal temperature in contact with the solution should be kept under 350°F (176°C). The fluid temperature should not exceed 250°F (120°C).

Antifreeze solution is harmful or may be fatal if swallowed; therefore, antifreeze solutions should be used only in closed circulating systems entirely separated from potable water supply systems.

Antifreeze solutions expand more than water for a given rise in temperature (i.e., a 50% by volume solution expands 4.8% by volume with a temperature increase from 32°F (0°C) to 180°F (82°C), while water expands 3% with this same rise in temperature). Allowance must be made for this expansion when an antifreeze solution is used in a heating system.

D. Fire Side Corrosion. Previously in this manual some of the causes of water side corrosion have been stated and procedures recommended to minimize trouble from these sources. Boilers can also corrode on the fire side. Some fuels contain substances that cause fire side corrosion. Sulphur, vanadium, and sodium are among the materials that may contribute to this problem.

(a) Deposits of sulphur compounds may cause fire side corrosion. The probability of trouble from this source depends on the amount of sulphur in the fuel and on the care used in cleaning the fire side heating surfaces. This is particularly true when preparing a boiler for a period of idleness. Preventing this trouble depends also on keeping the boiler heating surfaces dry when a boiler is out of service.

(b) Deposits of vanadium or vanadium and sodium compound also may cause fire side corrosion, and these compounds may be corrosive during the season when boilers are in service.

(c) The person responsible for boiler maintenance should be certain that the fire side surfaces of the boilers in his care are thoroughly cleaned at the end of the firing season. Also, he should observe the fire side surfaces and if signs of abnormal corrosion are discovered, a reputable consultant should be engaged.

E. Safety Relief Valves. Safety relief valves on hot water heating and hot water supply boilers should be tested for proper operation in accordance with Appendix I, I.02 and I.03. ASME rated valves shall be installed on the boiler where required by jurisdictional regulations. When replacement is necessary, use only ASME rated valves of the required capacity.

F. Burner Maintenance.

(a) Oil Burners. Oil burners require periodic maintenance to keep the nozzle and other parts clean. Check and clean oil line strainers. Inspect and check the nozzle and check the oil level in the gear cases. Check and clean filters, air intake screens, blowers, and air passages. Check all linkages and belts, and adjust as required. Lubricate in accordance with Manufacturer's recommendations. Check pilot burners and ignition equipment for proper flame adjustment and performance.

(b) Gas Burners. Check gas burners for presence of dirt, lint, or foreign matter. Be sure ports, gas passages, and air passages are free of obstructions. Linkages, belts, and moving parts on power burners should be checked for proper adjustment. On combination oil and gas burners, the gas outlets may become caked with carbon residue from unburned fuel oil after prolonged periods of oil firing and require cleaning. Lubricate in accordance with Manufacturer's recommendations. Also check pilot burners and ignition equipment for proper flame adjustment and performance.

G. Low-Water Fuel Cutoff. Low-water fuel cutoffs and water feeders should be dismantled annually by qualified personnel, to the extent necessary to insure freedom from obstructions and proper functioning of the working parts. Inspect connecting lines to boiler for accumulation of mud, scale, etc., and clean as required. Examine all visible wiring for brittle or worn insulation and make sure electrical contacts are clean and that they function properly. Give special attention to solder joints on bellows and float when this type of control is used. Check float for evidence of collapse and check mercury bulb (where applicable) for mercury separation or discoloration. *Do not attempt to repair mechanisms in the field*. Complete replacement mechanisms, including necessary gaskets and installation instructions, are available from the Manufacturer. After reassembly, test, if installation permits, without draining water from the boiler.

H. Flame Safeguard Maintenance.

(a) Thermal Type Detection Device. Check device for electrical continuity and satisfactory current generation in accordance with Manufacturer's instructions. After completing maintenance, test as per Appendix I, I.03I.A and I.03I.B, and make pilot turndown test as per Appendix I, I.03I.H.

(b) Electronic Type Detection Device. Replace vacuum tubes or transistors annually with type recommended by Manufacturer. Check operation of unit in accordance with Manufacturer's instructions and examine for damaged or worn parts. Do not attempt to repair these units in the field. Replacement assemblies are available from the Manufacturer on an exchange basis. Test as specified in Appendix I, I.03I.C, I.03I.D, I.03I.E, I.03I.F, or I.03I.G for proper type control and make pilot turndown test as per Appendix I, I.03I.H.

I. Limit Control Maintenance. Maintenance on temperature limiting control is generally limited to visual inspection of the device for evidence of wear, corrosion, etc. If control is mercury bulb type, check for mercury separation and discoloration of bulb. If the control is defective, replace it. Do not attempt to make field repairs.

J. Cast Iron Boiler Maintenance.

(a) Heating Surfaces. Check the firebox gas passages and breeching for soot accumulation. Use a wire brush and vacuum cleaner, if required, to remove the soot or other dirt accumulation.

(b) Internal Surfaces. If the condition of the water in the boiler indicates that there is considerable foreign matter in it, the boiler should be allowed to cool, then drained and thoroughly flushed out. Remove the washout plugs and wash through the openings with a high-pressure water stream. This will normally remove any sludge or loose scale. If there is evidence that hard scale has formed on the internal surfaces, the boiler should be cleaned by chemical means as prescribed by a qualified water treatment specialist.

K. Steel Boiler Maintenance.

(a) Heating Surfaces. Remove all accumulations of soot, carbon, and dirt from the fire side of the boiler. Use flue brush to clean the tubes. Clean breeching and stack as required. Inspect refractory and make repairs as required.

(b) Internal Surfaces. If the condition of the water in the boiler indicates that there is considerable foreign matter in it, the boiler should be allowed to cool, then drained and thoroughly flushed out. Remove all handhole and manhole covers and wash through these openings with a high-pressure water stream. This will normally remove any sludge or loose scale. If there is evidence that hard scale has formed on the internal surfaces, the boiler should be cleaned by chemical means as prescribed by a qualified water treatment specialist.

L. Use of Flashlight for Internal Inspections. When practical, use a flashlight in preference to an extension light for internal inspection purposes. If an extension light is taken into a boiler, be sure the cord is rugged, in good condition, and that it is properly grounded. It should be equipped with a vapor-tight globe, substantial guard, and nonconducting holder and handle.

M. Leaking Tubes. If one tube in a boiler develops a leak due to corrosion, it is likely that other tubes are corroded also. Have the boiler examined by a capable and experienced inspector before ordering the replacement of one or a few tubes. If all the tubes will need replacement soon, it is preferable and less expensive to have all the work done at one time.

N. Use of Sealants. Sealants may have a detrimental effect on boilers, pumps, safety relief valves, etc., and therefore their use is not recommended in hot water heating or hot water supply boilers.

O. Maintenance of Circulating Pumps and Expansion Tanks. Inspect the circulating pump(s) and lubricate in accordance with the Manufacturer's instructions. Check the operation of all associated controls, switches, etc. Examine expansion tank for dirt, tightness, and evidence of corrosion. Clean and repair as required. For detailed instructions, refer to the Manufacturer's literature, instructions, and data.

P. Maintenance Schedule. Listed below are suggested frequencies for the various routines and tests to be performed in connection with inspection and maintenance of boilers (see Appendix I.01 and I.02).

(a) Daily (Boilers in Service). Observe operating pressures and temperature and general conditions. Determine cause of any unusual noises or conditions and make necessary corrections.

(b) Weekly (Boilers in Service)

(1) Observe condition of flame; correct if flame is smoky or if burner starts with a puff (for oil, observe daily).

(2) Check fuel supply (oil only).

(3) Observe operation of circulating pump(s).

(c) Monthly (Boilers in Service)

(1) Safety relief valve — try lever test.

(2) Test flame detection devices.

(3) Test limit controls.

(4) Test operating controls.

(5) Check boiler room floor drains for proper functioning.

(6) Inspect fuel supply systems in boiler room area.

(7) Check condition of heating surfaces (for preheated oil installation, inspect more frequently: twice a month).

(8) Perform combustion and draft tests (preheated oil only).

(9) Test low-water fuel cutoff and/or water feeder if piping arrangement permits without draining considerable water from the boiler.

(d) Annually

(1) internal and external inspection after thorough cleaning

(2) routine burner maintenance

(3) routine maintenance of circulating pump and expansion tank equipment

(4) routine maintenance of entire combustion control equipment

(5) combustion and draft tests

(6) safety relief valve(s) — pop test

(7) slow drain test of low-water cutoff

(8) Inspect gas piping for proper support and tightness.

(9) Inspect boiler room ventilation louvers and intake.

8.08 BOILER REPAIRS

A. Precaution. Do not permit repairs to a boiler while it is in service, or under pressure, except with the approval and under the supervision of an authorized boiler inspector or responsible engineer.

B. Notification. When repair work is required, notify the authorized boiler and pressure vessel inspector and be guided by his recommendations.

C. Welding Requirements. All repair work should be done by experienced boiler mechanics. All welding should be done by qualified welders using procedures properly qualified according to Section IX.

D. Safety. Take every precaution necessary to insure against injury to men who are working in the boiler room and particularly to those working inside the boiler or in the combustion chamber of the boiler. Pull the main burner switch and lock it out and tag it, swing the burner out of place, if possible, close and lock valves, etc., *and always* have one man standing by outside when a man is working inside a boiler.

8.09 TESTS AND INSPECTIONS OF HOT WATER HEATING AND SUPPLY BOILERS

A. Tests. The tests recommended for burner efficiency, combustion safeguards, safety controls, operating controls, limit controls, safety valves and safety relief valves, are included in Mandatory Appendix I, I.03.

B. Inspection During Construction. This part of boiler inspection is covered in Section IV, Heating Boilers; HG-515, HG-520, and HG-533 (General Requirements); HW-900, HW-910, and HW-911 (Welding); HB-1500, HB-1501, HB-1502, and HB-1503 (Brazing); and HC-501 (Cast Iron).

C. Initial Inspection at Place of Installation. As opposed to inspection during manufacture that pertains primarily to conforming to Code construction requirements, this inspection will be concerned with whether boiler supports, piping arrangements, safety relief valves, other valves, water columns, gage cocks, altitude gages, thermometers, controls, and other apparatus on the boiler meet Code and/or other jurisdictional requirements. The inspector usually represents the same jurisdiction that will be making subsequent periodic inspections.

D. Periodic Inspecting of Existing Boilers. The main purposes for reinspection include protection against loss or damage to the pressure vessel because of corrosion, pitting, etc., protection against unsafe operating conditions possibly caused by changes in piping or controls or lack of testing of safety devices. It is important that inspections be thorough and complete, and so that important elements may all be checked, the following recommended directions and instructions for such inspections are given.

(a) All hot water heating and supply boilers should be prepared for inspection, whenever necessary, by the owner or user when notified by the inspector.

The owner or user should prepare the boiler for an internal inspection and should prepare for and apply the hydrostatic test whenever necessary on the date specified in the presence of a duly qualified inspector.

(b) Before inspection, every part of a boiler that is accessible should be open and properly prepared for examination, internally and externally. In cooling down a boiler for inspection or repairs, the water should not be withdrawn until the setting is sufficiently cooled to avoid damage to the boiler and, when possible, it should be allowed to cool down naturally.

(c) Preparation. The owner or user should prepare a boiler for internal inspection in the following manner.

(1) Water should be drained and boiler washed thoroughly.

(2) All manhole and handhole plates, wash-out plugs and water column connections should be removed and the furnace and combustion chambers thoroughly cooled and cleaned.

(3) All grates of internally fired boilers should be removed.

(4) Brickwork should be removed as required by the inspector in order to determine the condition of the furnace, supports, or other parts.

(5) Any leakage of hot water into the boiler should be cut off by disconnecting the pipe or valve at the most convenient point.

(d) It is not necessary to remove insulation material, masonry, or fixed parts of the boiler unless defects or deterioration are suspected. Where there is moisture or vapor showing through the covering, the covering should be removed at once and a complete investigation made.

Every effort should be made to discover the true condition, even if it means drilling holes or cutting away parts.

(e) The inspector should get as close to the parts of the boiler as is possible in order to obtain the best possible vision of the surface and to use a good artificial light if natural light is not adequate.

(f) Whenever the inspector deems it necessary to test boiler apparatus, controls, etc., these tests should be made by a plant operator in the presence of the inspector, unless otherwise ordered.

(g) Scale, Oil, etc. The inspector should examine all surfaces of the exposed metal inside to observe any action caused by treatment, scale solvents, oil, or other substances that may have entered the boiler. Any evidence of oil should be noted carefully, as a small amount is dangerous, and immediate steps should be taken to prevent the entrance of any more oil into the boiler. Oil or scale on plates over the fire of any boiler is particularly bad, often causing sufficient weakening to bag or rupture.

(h) Corrosion, Grooving. Corrosion along or immediately adjacent to a seam is more serious than a similar amount of corrosion in the solid plate away from the seams. Grooving and cracks along longitudinal seams are especially significant, as they are likely to occur when the material is highly stressed. Severe corrosion is likely to occur at points where the circulation of water is poor; such places should be examined very carefully.

For the purpose of estimating the effect of corrosion or other defects upon the strength of a shell, comparison should be made with the efficiency of the longitudinal joint of the same boiler, the strength of which is usually less than that of the solid sheet.

(i) Stays. All stays, whether diagonal or through, should be examined to see if they are in even tension. All fastened ends should be examined to note if cracks exist where the plate is punched or drilled. If stays are not found in proper tension, their proper adjustment should be recommended.

(j) Manholes and Other Openings. The manhole(s) and other reinforcing plates, as well as nozzles and other connections flanged or screwed into the boiler, should be examined internally as well as externally to see that they are not cracked or deformed. Wherever possible, observation should be made from the inside of the boiler as to the thoroughness with which its pipe connections are made to the boiler. All openings to external attachments, such as connections to a low-water cutoff and openings to safety relief valves, should be examined to see if they are free from obstructions.

(k) Fire Surfaces — Bulging, Blistering, Leaks. Particular attention should be given to the plate or tube surface exposed to fire. The inspector should observe whether any part of the boiler has become deformed during operation by bulging or blistering. If bulges or blisters are of such size as would seriously weaken the plate or tube, and especially when water is leaking from such a defect, the boiler should be discontinued from service until the defective part or parts have received proper repairs. Careful observation should be made to detect leakage from any part of the boiler structure, particularly in the vicinity of seams and tube ends. Firetubes sometimes blister but rarely collapse; the inspector should examine the tubes for such defects; if they are found to have sufficient amount of distortion to warrant it, they should be replaced.

(l) Lap Joints. Lap joint boilers are apt to crack where the plates lap in the longitudinal or straight seam. If there is any sign of leakage or other distress at this joint, it should be investigated thoroughly to determine if cracks exist in the seam. Any cracks noted in shell plates are usually dangerous.

(m) Testing Staybolts. The inspector should test staybolts by tapping one end of each bolt with a hammer and, when practicable, a hammer or other heavy tool should be held at the opposite end to make the test more effective.

(n) Tube Defects. Tubes in horizontal firetube boilers deteriorate more rapidly at the ends toward the fire and they should be carefully tapped with a light hammer on their outer surface to ascertain if there has been a serious reduction in thickness. They should be reached, as far as possible, either through the handholes, if any, or inspected at the ends.

The surface of tubes should be carefully examined to detect bulges or cracks or any evidence of defective welds. Where there is a strong draft, the tubes may become thinned by erosion produced by the impingement of particles of fuel and ash. A leak from a tube frequently causes serious corrosive action on a number of tubes in its immediate vicinity.

(o) Ligaments Between Tube Holes. The ligaments between tube holes in the heads of all firetube boilers and in shells of watertube boilers should be examined. If leakage is noted, broken ligaments are probably the reason.

(p) Pipe Connections and Fittings. All piping should be examined for leaks; if any are found, it should be determined whether they are the result of excess strains due to expansion or contraction or other causes. The general arrangement of the piping in regard to the provisions for expansion and drainage, as well as adequate support at the proper points, should be carefully noted.

The arrangement of connections between individual boilers and the supply and return headers should be especially noted to see that any change of position of the boiler due to settling or other causes has not placed an undue strain on the piping.

It should be ascertained whether all pipe connections to the boiler possess the proper strength in their fastenings, whether tapped into or welded to the boiler shell. The inspector should determine whether there is proper provision for the expansion and contraction of such piping and that there is no undue vibration tending to damage the parts subjected to it. This includes all water pipes; special attention should be given to the blowoff pipes with their connections and fittings because the expansion and contraction due to rapid changes in temperature and water-hammer action bring a great strain upon the entire blowoff system. The freedom of the blowoff and drain connection on each boiler should be tested, whenever possible, by opening the valve for a few seconds, at which time it can be determined whether there is excessive vibration.

(q) Low-Water Cutoff. All automatically fired hot water heating or supply boilers should be equipped with an automatic low-water fuel cutoff so located as to automatically cut off the fuel supply when the surface of the water falls below the lowest safe waterline. Such a fuel control device may be attached directly to the boiler shell or to the tapped openings provided for attaching a water glass direct to a boiler.

(r) Designs embodying a float and float bowl shall have a vertical straightway-valve drain pipe at the lowest point in the water equalizing pipe connections, by which the bowl and the equalizing pipe can be flushed and the device tested.

(s) Baffling in Watertube Boilers. In watertube boilers it should be noted as well as possible whether the proper baffling is in place. The absence of baffling often causes high temperatures on portions of the boiler structure that are not intended for such temperatures and from this a dangerous condition may result. The location of combustion arches with respect to tube surfaces should be noted to make sure they do not cause the flame to impinge on a particular part of the boiler and produce overheating of the material and consequent danger of rupture.

(t) Localization of Heat. Localization of heat brought about by improper or defective burner or stoker installation or operation, creating a blowpipe effect upon the boiler, should be cause for shutdown of the boiler until the condition is corrected.

(u) Suspended Boilers — Freedom of Expansion. Where boilers are suspended, the supports and setting should be examined carefully, especially at points where the boiler structure comes near the setting walls or floor, to make sure that ash and soot will not bind the boiler structure at such points and produce excessive strains on the structure owing to the expansion of the parts under operating conditions.

(v) Safety Relief Valves. As the safety relief valve is the most important safety device on the boiler, it should be inspected with the utmost care.

There should be no accumulation of rust, scale, or other foreign substances in the body of the valve that will interfere with its free operation. The valve should not leak under operating conditions. The opening pressure and freedom of operation of the valve should be tested preferably by raising the water pressure to the point of opening (Pop Test, Appendix I, I.03IV.B). If this cannot be done, the valve should be tested by opening with the try lever in accordance with the procedure in Appendix I, I.03. Where the valve has a discharge pipe, the inspector should determine at the time the valve is operating whether or not the drain opening in the discharge pipe is free and in accordance with the Code requirement.

If the inspector deems it necessary, in order to determine the freedom of discharge from a safety relief valve, the discharge connection should be removed. Under no circumstances shall a stop valve be permitted between a boiler and its safety relief valve.

(w) Combination Temperature and Pressure Gages. A test gage connection should be provided on the boiler so that the gage on the boiler can be tested under operating conditions. The gage should not be exposed to excessively high ambient temperatures.

(x) Imperfect Repairs. When repairs have been made, especially tube replacements, the inspector should observe whether the work has been done safely and properly. Excessive rolling of tubes, where they are accessible, is a common fault of inexperienced workmen. When it is difficult to reach the tube end and observe the extent of rolling, however, they are frequently underrolled. This inevitably results in separation of the parts.

(y) Hydrostatic Tests. When there is a question or doubt about the extent of a defect found in a boiler, the inspector, in order to more fully decide upon its seriousness, should cause the application of hydrostatic pressure under the Code provisions.

A hydrostatic pressure test shall not exceed $1^1/_2$ times the maximum allowable working pressure. During the test, the safety relief valve should be removed from the boiler, as should all controls and appurtenances unable to withstand the test pressure without damage. It is suggested that the minimum temperature of the water be 70°F (21°C) and the maximum 160°F (71°C).

(z) Suggestions. The inspector, whether he is the employee of a state, province, municipality, or insurance company, should be well informed of the natural and neglectful causes of defects and deterioration of boilers. He should be extremely conscientious and careful in his observations, taking sufficient time to make the examinations thorough in every way, taking no one's statement as final as to conditions not observed by him, and, in the event of inability to make a thorough inspection, he should note it in his report and not accept the statement of others.

The inspector should make a general observation of the boiler room and apparatus, as well as of the attendants, as a guide in forming an opinion of the general care of the equipment. He should question responsible employees as to the history of old boilers, their peculiarities and behavior, ascertain what, if any, repairs have been made and their character, and he should investigate and determine whether they were made properly and safely.

SECTION 9
WATER TREATMENT

9.01 SCOPE

This Section covers recommended procedures for the treatment of water in steam and hot water heating boilers.

9.02 CONSIDERATIONS

In deciding whether or not to treat the water, and if so, what type of treatment to use, the following factors should be considered:

(a) the type of boiler, i.e., cast iron or steel, steam or hot water;

(b) the nature of the raw water, i.e., hard or soft, corrosive or scale forming;

(c) preliminary treatment of the water, i.e., softeners, preheaters, deaerators;

(d) the amount of makeup water and blowdown required;

(e) the use of the steam, i.e., for heating only or for other purposes; and

(f) the amount of supervision and control testing available.

9.03 SERVICES OF WATER TREATMENT SPECIALISTS

Each boiler installation should be considered on an individual basis. If there appears to be any question regarding treatment required, review the final decision with a reputable water treatment company. These companies furnish a service and/or chemicals for boiler water treatment. They are in a position to make recommendations based on local water conditions and the particular installation involved. They also furnish test kits accompanied by simple analytical procedures for day-to-day analysis by the local maintenance people. Samples are taken at suitable intervals and sent to their laboratories for confirmatory analysis. In setting up arrangements with such concerns, do not hesitate to ask the chemical equation of the treatments prescribed.

9.04 CONFORMITY WITH LOCAL ORDINANCES

Make sure the boiler compound used does not violate any local ordinance with respect to disposal of blowdowns, draining of boilers, etc.

9.05 BOILER WATER TROUBLES

A. Corrosion. Raw water, as received from the city mains or wells, contains impurities including dissolved gases such as oxygen and carbon dioxide. When the water is soft, this makes the water acid and corrosive. The boiler system metal and condensate return lines will be attacked. This can be general overall corrosion or localized pitting or cracking in stressed metal. High temperatures accelerate these reactions. If uncorrected, serious pitting can result with possible rupture of boiler tubes. Rusty water in the gage glass is a sure sign of corrosion in the heating system or in the boiler itself.

B. Scale Deposits. All raw water contains dissolved salts. Where the water is hard, these are mainly calcium and magnesium compounds. Under boiler operating conditions, these salts come out of solution and form scale deposits on the hot boiler metal. This is due to decomposition of the bicarbonates and to the decreased solubility of calcium salts at higher temperatures. As the water is evaporated, the solids are left behind and the scale deposits build up. Scale forms an insulating barrier on the boiler tubes, resulting in heat losses and lower efficiency. Scale deposits can also cause overheating and failure of boiler metal.

C. Metal (Caustic) Embrittlement. Under certain conditions of high caustic alkalinity where the metal is under stress, cracks can develop in the metal below the waterline and under rivets, welds, and longitudinal seams. This type of failure is not common and is confined to steel boilers.

D. Foaming, Priming, and Carryover. These difficulties, occurring in steam boilers only, are closely associated and refer to the formation of froth and sudson the surface of the water. Where this is severe, boiler water is carried over with the steam. Excessive dissolved solids carried over can form deposits in the steam piping and valves. There is also a loss in efficiency.

9.06 CHEMICALS USED

The following chemicals are commonly used for boiler water treatment.

A. Inorganic.

(a) Caustic Soda (sodium hydroxide) — $NaOH$

(b) Trisodium Phosphate (TSP) — Na_3PO_4

(c) Sodium Acid Phosphate — NaH_2PO_4

(d) Sodium Tripolyphosphate — $Na_5P_3O_{10}$

(e) Sodium Borate — $Na_2B_4O_7$
(f) Sodium Sulphite — Na_2SO_3
(g) Sodium Nitrate — $NaNO_3$
(h) Sodium Nitrite — $NaNO_2$

B. Organic.
(a) Sodium Alginate and other seaweed derivatives
(b) Quebrancho Tannin
(c) Lignin Sulfonate
(d) Starch

9.07 FUNCTIONS OF CHEMICALS

A. Caustic Soda. Caustic soda is used to insure proper pH and complete precipitation of the magnesium salts. The optimum pH is 11.0 with a permissible minimum of 7.0.

B. Chromates and Sulphites. Sodium chromate and sodium sulphite are used to control corrosion. Sodium sulphite is an oxygen scavenger picking up the oxygen that converts the sulphite to sodium sulphate.

CAUTION: Chromate is still recognized as one of the best inhibitors for protection of metal, although it is now prohibited by most states or cities for use as water treatment due to the toxic effect of the chromate when dumped in rivers, streams, and sanitary sewage systems.

C. Phosphates. The various sodium phosphates serve to precipitate the hard water salts as insoluble lime and magnesia phosphates. Polyphosphates are a form of phosphate that sequester rather than precipitate.

D. Nitrates and Nitrites. Nitrates serve to prevent metal embrittlement. Nitrites act similarly to sulphites, but under certain conditions where dissimilar metals are immersed in the boiler water, particularly copper or brass and soft solder, nitrites can cause very severe localized corrosion unless suitable inhibiting agents are present. Until recently, nitrites have not been commonly used where the water is boiled. Their use is generally confined to hot water systems.

E. Organic Agents. The organic agents act as protective colloids. When the inorganic treatment chemicals precipitate the hard water salts, these organic agents tend to keep the insoluble matter in suspension as a sludge and prevent the formation of dense adherent scale on the heat transfer boiler surfaces.

F. Boiler Compounds. Commercial boiler compounds are, for the most part, mixtures of the chemicals described in the above part. They may be either solid or liquid. The latter are solutions of the chemicals and may present easier handling and feeding. While the combinations are many, there are two widely used basic types.

(a) those based on chromates

(b) those based on alkaline salt combinations plus sodium sulphite

9.08 TREATMENT ALTERNATIVES

A. External or Internal Treatment. Water for boiler use may be treated externally or internally. One practical external treatment is by means of a zeolite softener. Where the water is very hard, it is frequently more economical to install a softener than to pay for the extra treatment required by the hard water. Using softened water, however, can create other problems. Corrosion is aggravated due to increased carbon dioxide, and foaming is apt to occur. The use of deaerators to remove oxygen and carbon dioxide by heating the water before it enters the boiler might be considered external treatment. In general, however, the principal problem is internal treatment.

B. Seasonal or Continuous Treatment. In considering boiler water treatment, installations can be divided into three categories, as follows:

(a) Class 1 — No treatment

(b) Class 2 — Seasonal or semiseasonal treatment with limited chemical control

(c) Class 3 — Complete treatment with continuous chemical control

C. Treatment of Cast Iron Boilers. Cast iron boilersare more resistant to corrosion than steel boilers. In small low-pressure heating units, particularly where the metal is cast iron, it may be practical to rely on annual cleanouts and operate without any treatment. Where the steam system is tight, free from leaks, and all the steam is returned to the boiler as condensate, the amount of makeup water is small. The corrosive gases exhaust themselves on the metal, and while scale forms, it is not excessive, so that the interference with heat transfer is not large. Where no treatment is used, it may be necessary after several years to use acid cleaning to remove the scale. It should be remembered, however, that a perfect system does not exist (in general, at best, a 90% to 95% condensate return can be expected), and that it might be safer to follow the recommendations given under Class 2 above, seasonal or semiseasonal treatment.

9.09 BLOWDOWN

The purpose of blowdown is to keep the amount of dissolved solids and sludge in the boiler water under control. As the water is turned into steam, the solids remain behind and unless there is 100% condensate return, the solid content tends to build up. As a rule of thumb, about 1000 ppm can be considered as a safe maximum. A hard water containing 200 ppm in the feedwater would tolerate five concentrations in the boiler. On the other hand, a soft water with 25 ppm solids could be concentrated 40 times before reaching the critical point. To maintain satisfactory operation conditions the first water would require 20% blowdown while the second would require only 2%. With soft water, blowdown can possibly be held to once or twice a season. With hard water, blowdown may be necessary once a month or even once a week. Blowdown should be held to a minimum, since it involves heat losses and, if excessive, wastes treatment chemicals. Drains receiving blowdown water should be connected to the sanitary sewer.

9.10 FEEDERS

Simple feeders are preferable, particularly where the treatment is to be added periodically, i.e., more than once or twice a season. Where there is any appreciable amount of blowdown, or loss of condensate, additional treatment will be necessary from time to time. A number of different types may be employed. These include open-type gravity feeders where the treatment is to be fed manually in one slug or in periodic small shots; closed-type gravity-drip and bypass feeders where the treatment is to be fed in proportion to the amount of makeup water; and pot type proportional feeders where slowly dissolving treatment crystals or briquettes are used.

9.11 PROCEDURES

A. Determination of Water Containing Capacity. Determine the water containing capacity of the boiler so instructions can be given regarding the required amount of boiler water treatment compound. If this information is not given on the boiler, in the boiler catalog, or other publications, then meter the water at the time of the initial filling and record the information.

B. Making a pH or Alkalinity Test. The condition of the boiler water can be quickly tested with hydrion paper that is used in the same manner as litmus paper, except it gives specific readings. A color chart on the side of the small hydrion dispenser gives the reading in pH. Hydrion paper is inexpensive and obtainable from any chemical supply house or through your local druggist. If a more precise measurement of pH is desired, a color slide comparator kit is recommended.

C. Mixing and Handling Chemicals. The chemicals, if liquid, should be diluted; or if solid, dissolved in accordance with the supplier's directions before adding them to the system. If the treatment is a solid, make sure it is fully dissolved. A simple hand paddle to stir the solution is frequently all that is necessary. If the chemicals are slow to dissolve, a steam line for heating the water and agitating the mixture may be used to accelerate solution. The use of compressed air for this purpose is undesirable since additional oxygen will be introduced that will neutralize reducing agents such as sodium sulphite. Since the treatment chemicals may be highly alkaline or skin irritating, it is advisable to wear goggles and gloves when they are being handled and mixed.

CAUTION: Do not permit the dry material or the concentrated solution to come in contact with skin or clothing.

D. Treatment of Laid-Up Boilers. When steel boilers are out of service for any length of time, such as a layup for the summer, they must be protected from corrosion. This may be done either by draining them and keeping the surfaces thoroughly dry or by completely filling the boiler with properly treated water.

(a) Dry Method. The boiler is drained, flushed, and inspected. The surfaces are then thoroughly dried by means of hot air. If the boiler room is dry and well ventilated, the boiler may be left open to the atmosphere. An alternate procedure is to use a suitable moisture absorbent, such as quicklime or silica gel, that is placed in the boiler in a suitable location. The boiler is then tightly closed. Every two or three months the boiler should be checked and the lime or gel replaced or regenerated if necessary. The dry method is not used on cast iron boilers.

(b) Wet Method. The boiler is drained, flushed, and inspected. It is then filled to the normal water level and steamed for a short time with the boiler vented to the atmosphere to expel dissolved gases. If the boiler is to be used to heat water or for reheat in connection with an air conditioning system, it may be left in this state ready to operate. If, however, it is to be completely idle for some time, it is preferable to fill the boiler to the top of the drum. In any case, treatment should be used. This may be the treatment regularly being used, or a caustic soda (400 ppm) and sodium sulphite mixture (100 ppm), or sodium chromate, in which case a minimum of at least 100 ppm should be maintained on steam boilers and 300 ppm on hot water boilers. During the down time, if feasible, it is good practice to occasionally circulate the water with a pump. This is necessary to prevent stratification and insure that fresh inhibitor is in contact with the metal. This is also true of hot water systems. It is a well-known fact that corrosion is apt to be more serious during the down time than when the boiler is actually in service. The wet method is generally used on cast iron boilers.

9.12 WATER TREATMENT TERMS

Brief explanations for some of the terms and abbreviations used in this Section are given below.

acid: any chemical compound containing hydrogen that dissociates to produce hydrogen ions when dissolved in water. Capable of neutralizing hydroxides or bases to produce salts.

acidity: the state of being acid; the degree of quantity of acid present

alkali: any chemical compound of a basic nature that dissociates to produce hydroxyl ions when dissolved in water. Capable of neutralizing acids to produce salts.

alkalinity: the state of being alkaline; the degree or quantity of alkali present. In water analysis, it represents the carbonates, bicarbonates, hydroxides, and occasionally the borates, silicates, and phosphates present as determined by titration with standard acid and generally expressed as calcium carbonate in parts per million.

amines: a class of organic compounds that may be considered as derived from ammonia by replacing one or more of the hydrogen ions with organic radicals. They are basic in character and neutralize acids. Those used in water treatment are volatile and are used to maintain a suitable pH in steam and condensate lines.

blowdown: the water removed under pressure from the boiler through the drain valve to eliminate sediment and reduce total solids

buffer: a chemical that tends to stabilize the pH of a solution preventing any large change on the addition of moderate amounts of acids or alkalies

catalyst: a substance that by its presence accelerates a chemical reaction without itself entering into the reaction

chelating: the property of a chemical when dissolved in water that keeps the hard water salts in solution and thus prevents the formation of scale. Generally applied to organic compounds such as the salts of ethylenediaminetetraacetic acid (EDTA).

colloid: a fine dispersion in water that does not settle out but that is not a true solution. Protective colloids have the ability of holding other finely divided particles in suspension.

condensate: the water formed by the cooling and condensing of steam

dispersant: a substance added to the water to prevent the precipitation and agglomeration of solid scale; generally a protective colloid

grains per gallon (gpg): a measure used to denote the quantity of a substance present in water (1 gpg = 17.1 ppm)

hydrazine: a strong reducing agent having the equation N_2 NNH_2 in the form of a colorless hygroscopic liquid. Used as an oxygen scavenger.

inhibitor: a compound that slows down or stops an undesired chemical reaction such as corrosion or oxidation

makeup: water added from outside the boiler water system to the condensate

molecular weight: the sum of the atomic weights of all the constituent atoms in the molecule of a compound

muriatic acid: commercial hydrochloric acid

neutralize: the counteraction of acidity with an alkali or of alkalinity with an acid to form neutral salts

orthophosphate: a form of phosphate that precipitates rather than sequesters hard water salts

parts per million (ppm): the most commonly used method of expressing the quantity of a substance present in water. More convenient to use than percent due to the relatively small quantities involved.

pH: a scale used to measure the degree of acidity or alkalinity of a solution. The scale runs from 1 (strong acid) to 14 (strong alkali) with 7 (distilled water) as the neutral point.

polymerization: the union of a considerable number of simple molecules, called monomers, to form a giant molecule, known as a polymer, having the same chemical composition

polyphosphate: a form of phosphate that sequesters rather than precipitates hard water salts

precipitation: the formation and settling out of solid particles in a solution

sequestering: the property of a chemical when dissolved in water that keeps the hard water salts in solution and thus prevents the formation of scale. Generally applied to inorganic compounds such as sodium tripolyphosphate or sodium hexametaphosphate.

titration: a method for determining volumetrically the concentration of a desired substance in solution by adding a standard solution of known volume and strength until the chemical reaction is completed as shown by a change in color of suitable indicator

zeolite: originally a group of natural minerals capable of removing calcium and magnesium ions from water and replacing them with sodium. The term has been broadened to include synthetic resins that similarly soften water by ion exchange.

MANDATORY APPENDIX I
EXHIBITS

I.01 EXHIBIT A

See Figure I.01-1.

Figure I.01-1
Exhibit A

EXHIBIT A

Maintenance, Testing, and Inspection Log Steam Heating Boilers	Building:	Month:	Year:
	Address:	Fuel Type:	
Person(s) to be Notified in Emergency (Name and Telephone No.)		Boiler No.:	

DAILY CHECKS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
(1) Observe Water Level																															
(2) Record Pressure																															
(3) Record Flue Gas Temperature																															

WEEKLY CHECKS (Enter Date)

	WEEK 1	WEEK 2	WEEK 3	WEEK 4
(1) Test Low Water Cutoff				
(2) Test Gage Glass				
(3) Observe Flame Condition				

MONTHLY CHECKS (Enter Date)

(1) Manual Lift Safety Valve				
(2) Review Condition of or Test Each Item	(A) Linkages		(F) Floor Drains	
	(B) Damper Controls		(G) Flame Detection Device	
	(C) Stop Valves		(H) Limit Controls	
	(D) Refractory		(I) Operating Controls	
	(E) Flue-Chimney Breeching			
(3) Inspect Fuel Piping				
(4) Combustion Air Adequate/Unobstructed				

General Comments:

(Instructions on Reverse)

Figure I.01-1
Exhibit A (Cont'd)

EXHIBIT A (Back)

INSTRUCTIONS

I. Fill in the name of the building, its location, boiler number, fuel type used, and the year. Name the person to be contacted in an emergency or malfunction.

II. Daily Checks

(1) Observe water level in the water column sight glass (see ASME Section VI — 7.05A).
(2) Record boiler pressure indicated by the gage at the boiler.
(3) Record the flue gas temperature. (This should be read with the boiler running and at pressure.)

III. Weekly Checks (Record the date the test or check was completed.)

(1) Drain float chamber while boiler is running to determine if the control will shut down the boiler (see ASME Section VI — 7.05H).
(2) Close the lower gage gas valve, then open drain cock which is on the bottom of this valve and blow the glass clear. Close the drain cock and open lower gage glass valve. Water should return to the gage glass immediately [see ASME Section VI — 7.05A(2)].
(3) Observe flame condition.

IV. Monthly Checks (Record the date the test or check was completed.)

(1) Lift try-lever to full open and release it to snap shut (see ASME Section VI — Exhibit C IV-A).
(2) Review the condition of or test each item:
 (A) Check linkages for damage or disconnection (see ASME Section VI — 7.07F)
 (B) Watch damper controls during operation to be sure they operate properly
 (C) Check stop valves
 (D) If possible without opening boiler, check the refractory for cracking and deterioration
 (E) Check the flue-chimney breeching for signs of leakage, damage, or deterioration
 (F) Test floor drains to be sure they are draining properly
 (G) Test flame detection device
 (H) Test limit controls
 (I) Test operating controls
(3) Inspect fuel piping for leakage and damage.

V. Log Retention

Retain this log for at least 1 year (see ASME Section VI — 6.09C).

I.02 EXHIBIT B

See Figure I.02-1

Figure I.02-1
Exhibit B

EXHIBIT B

Maintenance, Testing, and Inspection Log Hot Water Heating Boilers	Building:	Month:	Year:
	Address:	Fuel Type:	
Person(s) to be Notified in Emergency (Name and Telephone No.)		Boiler No.:	

DAILY CHECKS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
(1) Record Pressure																															
(2) Record Boiler Water Temperature																															
(3) Record Flue Gas Temperature																															

WEEKLY CHECKS (Enter Date)

	WEEK 1	WEEK 2	WEEK 3	WEEK 4
(1) Observe Flame Condition				
(2) Observe Circulating Pumps				

MONTHLY CHECKS (Enter Date)

(1) Manual Lift Relief Valve				
(2) Review Condition of or Test Each Item	(A) Flame Detection Devices		(F) Refractory	
	(B) Limit Controls		(G) Stop Valves	
	(C) Operating Controls		(H) Check Valves	
	(D) Floor Drains		(I) Drain Valves	
	(E) Fuel Piping		(J) Linkages	
(3) Observe Gage Glass on Expansion Tank				
(4) Combustion Air Adequate/Unobstructed				

General Comments:

(Instructions on Reverse)

Figure I.02-1
Exhibit B (Cont'd)

EXHIBIT B (Back)

INSTRUCTIONS

I. Fill in the name of the building, its location, boiler number, fuel type used, and the year. Name the person to be contacted in an emergency or malfunction.

II. Daily Checks

(1) Record pressure (see ASME Section VI — 8.05).
(2) Record temperature (see ASME Section VI — 8.05).
(3) Record the flue-gas temperature. (This should be read with the boiler running and at pressure.)

III. Weekly Checks (Record the date the test or check was completed.)

(1) Observe flame condition.
(2) Observe circulating pumps for proper operation.

IV. Monthly Checks (Record the date the test or check was completed.)

(1) Lift try-lever to full open and release it to snap shut (see ASME Section VI — Exhibit C IV-A).
(2) Review the condition of or test each item:
  (A) Test flame detection devices (see ASME Section VI — 8.07H)
  (B) Test limit controls
  (C) Test operating controls
  (D) Test floor drains to be sure they are draining properly
  (E) Check fuel piping for leakage
  (F) If possible without opening boiler, check the refractory for cracking and deterioration
  (G) Check stop valves
  (H) Inspect check valves
  (I) Check drain valves
  (J) Check linkages for damage or disconnection
(3) Observe water level of gage glass on expansion tank. (Optional)
(4) Check combustion air supply for obstructions and adequacy of air flow.

V. Log Retention

Retain this log for at least 1 year (see ASME Section VI — 6.09C).

I.03 EXHIBIT C: TESTS

Periodic tests of all important boiler components are required to maintain them in good working condition and to assure safety. Adequate precautions should be taken while tests are being performed to protect personnel making the tests, building occupants, and equipment. In addition to the usual mechanic's tools, one or more test leads, a test pressure gage, a test thermometer, and volt-ohmmeter will be required in connection with certain tests. The test leads should consist of approximately 3 ft (1 m) of insulated No. 14 gage stranded wire, equipped with properly insulated alligator clips. The test gage should be a good quality inspector's gage, graduated in increments of not more than 1 psi each. These gages require periodic calibration. This can be done only in a properly equipped laboratory. The thermometer should read to at least 400°F (200°C) with no more than 2 deg per graduation.

Following are recommended procedures for making various tests.

I. FLAME SAFEGUARD DEVICE

A. Gas — Thermal Type.

(a) While burner is in operation, shut off manual gas valve.

(b) Turn off pilot gas cock and time the interval for the automatic gas valve to close. This time should be no longer than that recommended by the Manufacturer.

(c) If test is okay, relight pilot, turn on main gas valve, and allow burner to fire.

(d) Check burner for proper operation.

B. Oil — Thermal Type, Stack Switch.

(a) Shut off the manual valve in the oil supply line and time the interval required for the oil solenoid valve to close. Check this time against that recommended by the Manufacturer.

(b) If test is okay, refire burner and observe its operation.

(c) The manual shutoff must be a gate valve installed just ahead of the oil solenoid valve.

C. Gas — Electronic Flame Rod Type With Standing Pilot.

(a) With the burner firing normally, turn off the main gas cock.

(b) Turn off the pilot gas cock and time the interval required for the safety shutoff gas valve to close. Should be 4 sec or less. Check with Manufacturer's data.

(c) If test is okay, relight pilot, reset controls, and fire boiler. Observe operation.

D. Gas — Electronic Flame Rod With Interrupted Ignition.

(a) With the burner firing normally, turn off the main gas cock and time the interval for the shutoff gas valve to close. Should be 4 sec or less. Check with Manufacturer's data.

(b) If test is okay, open main gas cock, reset controls, and fire burner. Observe operation.

E. Gas — Electronic Flame Scanner Type. Same as D above.

F. Oil — Electronic Flame Scanner Type.

(a) With burner firing normally, shut off the manual valve in the oil supply line and time the interval for the oil solenoid valve to close. Should be 4 sec or less. Check with Manufacturer's data.

(b) If test is okay, open manual oil valve, reset controls, and refire burner. Observe operation.

G. Oil or Gas — Electric Type With Proven Pilot Flame Detection.

(a) With burner in off cycle, manually shut off the fuel to the main burner and to the pilot burner.

(b) Operate the necessary control to start the main burner.

(c) After the prepurge period the pilot assembly will be energized, but, because no flame is detected, the automatic pilot valve will shut off in about 10 sec, and the main automatic fuel valve will not be energized.

(d) If test is okay, open manual valve to pilot and reset controls. Test main burner for flame detection.

(e) Test gas as per I.03I.D.

(f) Test oil as per I.03I.F.

H. Pilot Turndown Test.

(a) This test is required to prove that the main automatic fuel valve cannot be energized when the pilot flame is in a condition such that the main burner cannot be ignited safely.

(b) If this condition exists, the flame detection device must be adjusted to function properly.

(c) Consult the Manufacturer's instructions for making this test since each device may require different procedures.

I. Reference to ASME CSD-1. ASME CSD-1 contains specific requirements regarding the controls to be included in the fuel train, the timing of their operation, and the resulting action that must be achieved.

II. COMBUSTION EFFICIENCY TESTS

A combustion efficiency test should be made on each fuel burning unit at least once each year (except on gas-fired units with nonadjustable secondary air; on these units only the draft and stack temperature need be checked). More frequent tests should be made on large units and on boilers burning preheated oil. Where burners have variable firing rates, the efficiency should be checked at the different rates.

A. Oil Burners.

(a) Measure the over-the-fire draft and compare to that recommended by the burner manufacturer. Adjust secondary air as required. This reading should range from

0.02 in. (0.005 kPa) to 0.05 in. (0.012 kPa) of water negative pressure for natural or induced draft installations up to 15 gal/hr (57 l/hr). Readings for forced draft installations will be somewhat higher and will be positive pressure readings. If necessary, a small hole may be drilled in the firebox door to accommodate the draft gage. On forced draft units, the hole should be plugged when not in use.

(b) Following Manufacturer's instructions, use a smoke-measuring instrument to obtain a smoke reading. No unit should be allowed to operate with a smoke density in violation of local ordinances. Air adjustments, nozzle condition, nozzle location, combustion chamber size, and air leakage all affect the combustion of fuel.

(c) Using the CO_2 analyzer, take a reading in the breeching ahead of any openings (barometric dampers, cleanouts, etc.). A small hole may be drilled for this purpose. The theoretical maximum CO_2 ranges from 15% for No. 1 and No. 2 oil to 16.5% for No. 6 oil. Actual readings should range from 9% to 12% for light oil and from 10% to 14% for heavy oil. Adjustments should be made to provide the highest CO_2 reading without smoke. Reduced secondary air resulting from a dirty fan or a change in barometric conditions may cause smoking at the higher CO_2 readings.

(d) Measure the stack temperature at the same point that the CO_2 readings were taken. Subtract the room temperature from this reading. The result will be the net stack temperature. The net temperature should range from 400°F (204°C) to 600°F (316°C). About 500°F (260°C) is desirable for modern units designed to burn oil. Units converted from coal will run somewhat higher. Low stack temperatures cause condensation and deterioration of the brickwork, whereas high stack temperatures indicate that the heat of combustion is not being absorbed by the heat transfer surfaces of the boiler. Insufficient draft may cause low stack temperature and poor combustion, whereas excess draft can result in high stack temperature. The result in either case is a loss in boiler efficiency.

(e) After the tests are made in the order listed above, adjustments should be made to bring the readings within the proper range; however, do not sacrifice one measurement to improve another beyond practical limits. After correcting one reading, recheck the others to determine that they are still within the proper range. The percent CO_2 draft, smoke density, and stack temperature should be regulated to provide the best overall safe boiler efficiency.

B. Gas Burners.

(a) Measure the over-the-fire draft and compare to that recommended by the burner manufacturer. Adjust secondary air as required. This reading should range from 0.02 in. to 0.05 in. water (0.005 kPa to 0.012 kPa) negative pressure for natural or induced draft installations. Readings for forced draft installations will be somewhat higher and will be positive pressure readings. If necessary, a small hole may be drilled in the firebox door to accommodate the draft gage. On forced draft units, the hole should be plugged when not in use.

(b) Using the CO_2 analyzer, take a reading in the breeching ahead of any openings (barometric dampers, cleanouts, etc.). A small hole may be drilled for this purpose. The theoretical maximum CO_2 for natural gas is approximately 12%. Actual readings should range from 7% to 10%, depending on the amount of excess combustion air. Adjustments should be made to provide the highest CO_2 reading while maintaining proper flame color and shape. This test is not required for boilers with nonadjustable secondary air inlets and draft hood.

(c) Measure the stack temperature at the same point that the CO_2 readings were taken. Subtract the room temperature from this reading. The result will be the net stack temperature. This should range from 400°F to 600°F. About 500°F is desirable for modern units designed to burn gas. Units converted from other fuels may run higher. Low stack temperature causes condensation and deterioration of the brickwork, whereas high stack temperature indicates that the heat of combustion is not being absorbed by the heat transfer surfaces of the boiler. Insufficient draft may cause low stack temperature and poor combustion, whereas excess draft can result in high stack temperature. Both will cause a loss in boiler efficiency. If problems are encountered with boilers having nonadjustable secondary air inlets and draft hood, the manufacturer should be consulted.

(d) After the test is made in the order listed above, make adjustments to bring the readings within the proper range; however, do not sacrifice one measurement to improve another beyond practical limits. After correcting one reading, recheck the others to determine that they are still within the proper range. The draft, percent CO_2, and stack temperature should be regulated to provide the best overall safe boiler efficiency.

(e) Carbon monoxide (CO) readings should also be obtained during the above test. The maximum amount of CO allowed is usually 0.04%. This can be obtained using direct reading instruments or alarm type instruments that function when the maximum CO is reached. Excessive CO leaking from the flue system is dangerous and can cause death.

C. Draft Measurements at the Boiler Breeching. In order that the accuracy of the draft measurement may be checked, an additional reading may be taken at the breeching, on the furnace side of any draft regulators, cleanouts, etc. This reading will probably range from 0.07 in. to 0.10 in. (1.8 mm to 2.5 mm) of water negative pressure for natural or induced draft installations. For forced draft units, the reading will be less than the over-the-fire draft, but should be a positive pressure. Both readings should be recorded when the heat transfer surfaces are clean and the boiler properly adjusted. They can then be compared to later periodic readings. If the readings at the breeching remained constant, for example, and the over-the-fire reading changed, this would indicate a possible inaccuracy in the over-the-fire measurement. If the difference between the two readings increased, this would indicate a soot buildup or other restriction in the combustion chamber or gas passages (tubes). This is very helpful in determining the need for cleaning the heat transfer surfaces of the boiler. This measurement is primarily used to check oil burning units and large forced draft gas-fired units.

III. LIMIT CONTROL TESTS

All limit controls should be tested periodically. Here again, the Manufacturer's data should be consulted for complete details. A test gage should be used to check the operation of all pressure controls. In general, the tests are to be performed as follows.

A. High-Limit Steam Pressure Control. Disconnect power to boiler controls and place a test lead across the contacts of the operating steam pressure controller. Check setting of high-limit control. It should be higher than operating control, but lower than 15 psi (100 kPa). Restore power to controls and fire boiler. Allow boilers to fire until steam pressure reaches setting of high-limit control. Control should operate at this point, shutting off flow of fuel to burner. If test is O.K., disconnect power and remove the test lead. Reset high-limit control, and fire boiler. Observe boiler for proper operation.

B. Draft-Limit Control. This control must be tested to determine that it will shut down the burner when the over-the-fire draft falls below the minimum allowable of 0.02 in. water (0.005 kPa). Using a draft gage to measure the over-the-fire draft, restrict the flow of secondary air until draft drops slightly below 0.02 in. water (0.005 kPa). At this point, the burner should cut off. Care should be exercised so as not to shut off the secondary air completely during this test. If test is okay, reset controls and refire boiler. If control does not shut off burner, adjust or replace as required. On natural or induced draft installations, the draft gage will be measuring a negative pressure difference, the pressure over the fire being less than room pressure, whereas for forced draft installations, the gage will be measuring a positive pressure.

C. Boiler Room Temperature-Limit Control. Some installations have a temperature-limit control or other device that will shut down the burner in the event of a rise in temperature in the vicinity of the boiler. These devices protect against flashbacks, oil fires, and overheated boilers. If possible, trip device manually while burner is firing. Burner should shut down. If test is okay, reset device, refire boiler, and check operation. If device cannot be operated manually, shut down boiler, disconnect power, and open control circuit through device. Attempt to refire boiler. Burner should not operate. If test is okay, reconnect circuit, fire boiler, and check operation.

D. Electrical Limit Controls. All electrical current limiting or overload devices, including fuses and thermal overload elements, should be inspected to determine that they are properly sized and in good condition. Switches, starters, and relays should be checked for proper operation.

E. Low Gas Pressure Control. Check Manufacturer's data to determine minimum allowable operating gas pressure to burner. Connect manometer on gas manifold just ahead of burner. With burner firing normally, close main gascock gradually until pressure drops to minimum specified by manufacturer. Burner should shut off. If test is okay, reset controls, refire boiler, and check operation.

F. High Gas Pressure Control. (If used — for systems where high-pressure gas, over 1 psi (7 kPa), is furnished upstream of regulator.) Check Manufacturer's instructions for maximum operating pressure of the burner. Connect manometer on gas manifold just downstream of pressure regulator. With burner shut down, adjust pressure regulator to provide pressure slightly in excess of this maximum pressure. Operate burner controller to call for heat; burner should not start. If test is okay, readjust pressure regulator to normal burner operating pressure, and check burner operation.

G. Oil Pressure Supervisory Switch. (If used — on installation with separate pump set.) Manually turn down burner cock to burner until oil pressure drops below minimum recommended by the burner manufacturer. Burner should shut off. If test is okay, reset firing cock, restart burner, and check operation.

H. Air Pressure Supervisory Switch. (If used.) Check Manufacturer's instructions for minimum static pressure required. Adjust air damper to decrease air to burner; burner should shut off when pressure drops below minimum recommended air pressure. If test is okay, readjust to desired air pressure, and check operation of the burner.

I. Emergency Disconnect Switch. All boilers should be equipped with an emergency disconnect switch located outside the boiler room door.

(a) For atmospheric-gas burners, and oil burners where the fan is on a common shaft with the oil pump, the complete burner and controls should be shut off.

(b) For power burners with detached auxiliaries, only the fuel input supply to the firebox need be shut off.

(c) To test, throw switch to "Off" position while the boiler is operating. This should kill all power to the controls [see para. (a)] or the fuel supply [see para. (b)]. If the test is okay restore switch, refire boiler, and observe for proper operation. On units with program controls, it may be necessary to completely recycle before refiring.

IV. SAFETY VALVE TESTS (STEAM BOILERS)

As precautionary measures, all personnel concerned with conducting a pop or capacity test should be briefed on the location of all shutdown controls in the event of an emergency, and there should be at least two people present. Care should be taken to protect those present from escaping steam.

A. Try Lever Test. Every 30 days that the boiler is in operation or after any period of inactivity a try lever test should be performed as follows: with the boiler under a minimum of 5 psi (35 kPa) pressure, lift the try lever on the safety valve to the wide open position and allow steam to be discharged for 5 sec to 10 sec. Release the try lever and allow the spring to snap the disk to the closed position. If the valve simmers, operate the try lever two or three times to allow the disk to seat properly. If the valve continues to simmer, it must be replaced or repaired by an authorized representative of the manufacturer. Inspect the valve for evidence of scale or encrustation within the body. Do not disassemble valve or attempt to adjust the spring setting. It is advisable to have a chain attached to the try lever of the valve to facilitate this test and allow it to be conducted in a safe manner from the floor. The date of this test should be entered into the boiler log book.

B. Pop Test. A pop test of a safety valve is conducted to determine that the valve will open under boiler pressure within the allowable tolerances. It should be conducted annually, preferably at the beginning of the heating season if the boiler is used only for space heating purposes. Hydrostatic testing (using water) is not to be considered as an acceptable test to check safety valve opening pressure. A recommended procedure is as follows.

(a) Establish necessary trial conditions at the particular location. Where necessary, provide adequately supported temporary piping from the valve discharge to a safe location outside the boiler room. In some installations temporary ventilation may dispose of the steam vapor satisfactorily. Review preparation for test with personnel involved. All such tests should have at least two people present.

(b) Install temporary calibrated test pressure gage to check accuracy of boiler gage.

(c) Isolate the boiler by shutting the stop valves in the steam supply and condensate return piping.

(d) Temporarily place jumper leads across the appropriate terminals on the operating control to demonstrate the ability of the high-limit pressure control to function properly. After this has been checked, also place another set of jumper leads across the high-limit pressure control terminals to permit continuous operation of the burner.

(e) The safety valve should pop open at an acceptable pressure, i.e., 15 psi (100 kPa) ±2 psi (±14 kPa). A simmering action will ordinarily be noticed shortly before the valve pops to the open position.

(f) If the valve does not open in the 13 psi (90 kPa) to 17 psi (117 kPa) range, it should be replaced. It is not necessarily a dangerous situation if the valve opens below 13 psi (90 kPa), but it could indicate a weakening of the spring, improper setting of the spring, etc. If the valve does not open at 17 psi (117 kPa), shut off the burner and dissipate the steam to the system by slowly opening the supply valve.

(g) If the valve pops open at an acceptable pressure, immediately remove the jumper leads from the high-limit pressure control. The burner main flame should cut off as soon as the jumper leads are removed.

(h) The safety valve will stay open until the pressure drops sufficiently in the boiler to allow it to close, usually 2 psi (14 kPa) to 4 psi (28 kPa) below the opening pressure. This pressure drop (blowdown) is usually indicated on the safety valve nameplate.

(i) Relieve the higher pressure steam to the rest of the system by slowly opening the steam supply valve. After the boiler and supply piping pressures have become equalized, open the return valve.

(j) Remove the jumper leads from the operating control and check to make certain that it functions properly. This is best done by allowing it to cycle the burner on and off at least once.

(k) Enter the necessary test data into the boiler log book.

C. Capacity Test.

(a) Capacity tests should be performed on safety valves on all new boiler installations where there is extensive piping on the safety valve discharge. They should also be made on existing boiler installations when any modification is made that affects the steam generating capacity of the boiler such as changing the size of the burner, the rate of fuel flow, or the grade or type of fuel not previously fired, or if firing rate cannot be determined.

(b) All such tests should be made with at least two people present.

(c) Establish necessary general trial conditions at the particular location. Where necessary, provide adequately supported temporary piping from the safety valve discharge to a safe location outside the boiler room. In some installations, temporary ventilation may dispose of the steam vapor satisfactorily. Review preparation for test with personnel involved.

(d) A calibrated test gage shall be temporarily installed to check accuracy of the boiler pressure gage during all phases of these tests.

(e) Isolate the boiler by shutting the stop valves in the supply and return piping for this boiler. The water feeder should be able to operate if it is necessary to do so during the test. It may be necessary to manually feed 1 in. (25 mm) or 2 in. (50 mm) of water to the boiler to prevent the low-water fuel cutoff from shutting down the burner.

(f) Set burner to operate at its maximum capacity, making sure that combustion is complete with proper overfire draft.

(g) When the operating control has shut off the burner, place jumper leads across its terminals to switch control to the high-pressure cutout.

(h) When this has demonstrated its ability to shut off the burner, place another set of jumper leads across its terminals, reset it if it has this feature, and allow the burner to continue running without control.

(i) The safety valve should pop open at the set pressure [15 psi (103 kPa)] ±2 psi (±14 kPa) or within the range of 13 psi (90 kPa) to 17 psi (117 kPa). If it opens below 13 psi (90 kPa) or does not open at 17 psi (117 kPa), it should be replaced.

(j) If the safety valve opens within this range, continue running the burner. If the pressure continues to rise, allow it to reach a maximum and hold it for a minimum of 30 sec. The maximum reached should not exceed 20 psi (140 kPa).

(k) If the pressure continues to rise above 20 psi (137 kPa), the burner should be stopped by removing the jumper leads from the high-pressure cutout. The safety valve should be replaced by one that demonstrates its ability to maintain a pressure of not more than 20 psi in the boiler.

(l) If the safety valve does maintain a maximum pressure of 20 psi (140 kPa) or below, the burner should be stopped by removing the test leads from the high-pressure cutout. Observe the pressure at which the safety valve closes. Replace the valve if it does not close within 2 psi (14 kPa) to 4 psi (28 kPa) of opening pressure.

(m) Remove the jumper leads from the operating control and let the burner cycle once to determine that it is functioning properly.

(n) Enter all pertinent data in boiler room log: date, time, personnel present, opening pressure, maximum pressure, closing pressure, and any other pertinent data or information.

V. SAFETY RELIEF VALVE TEST (WATER BOILERS)

A. Try Lever Test.

(a) Frequency. A try lever test of the safety relief valve should be conducted every 30 days during the heating season, after any prolonged period of inactivity, and prior to the annual safety relief valve test.

(b) Procedure

(1) Check the safety relief valve discharge piping to determine that it is properly installed and supported.

(2) Check and log the system operating pressure and temperature.

(3) Lift the try lever on the safety relief valve to the full open position and hold it for at least 5 sec or until clean water is discharged.

(4) Release the try lever and allow the spring to snap to the closed position. If the valve leaks, operate the try lever two or three times to clear the seat of any foreign matter that is preventing proper seating. As safety relief valves are normally piped to the floor or near a floor drain, it may take some time to determine if the valve has shut completely.

(5) If the safety relief valve continues to leak, it must be replaced before the boiler is returned to operation.

(6) Check that system operating pressure and temperature have returned to normal.

(7) Check again to assure the safety relief valve has closed completely and is not leaking.

B. Safety Relief Valve Test.

(a) Frequency. A safety relief valve test should be conducted every twelve months.

(b) Procedure. The following test should be conducted with at least two people present. The personnel conducting this test should review the test procedures and determine if any special conditions exist.

(1) Check that safety relief valve discharge piping is properly installed and supported.

(2) With the circulating equipment in operation, turn the fuel burning equipment off and allow the boiler water to reach a temperature approximately 80% to 85% of its normal operating temperature. Normally this will be between 140°F (60°C) and 150°F (66°C).

(3) After the boiler water temperature has been reduced, turn off the water circulating equipment. On some boilers, it may be necessary to jumper out the circulating pump flow switch to allow the burner to come on during the test.

CAUTION: On boilers requiring water flow to prevent damage to the boiler, *do not* jumper out the flow switch. It may be necessary to isolate the boiler and hydrostatically test the safety relief valve or have the safety relief valve removed and sent to a nationally recognized testing agency for testing.

(4) Turn off the system supply and return valves, and isolate the expansion tank from the boiler.

(5) Install a calibrated test gage.

(6) After assuring that all personnel are clear of the safety relief valve discharge piping, turn on the fuel burning equipment.

CAUTION: On boilers with small water storage capacity, very little heat will be required to raise the pressure to the opening pressure of the safety relief valve.

(7) If the temperature at the start of the test is below the normal operating temperature, as recommended in (b), it will not be necessary to change or jumper out the operating or high limit temperature controls. If the water temperature is at normal operating temperature, it may be necessary to readjust these limits upward to allow the burner to remain on long enough to reach the opening pressure of the safety relief valve.

(8) The safety relief valve should open[4] within an acceptable range above or below the set point. This range is ±3 psi (±20.6 kPa) for valves set to open at or below 60 psig (400 kPa), and ±5% of set pressure for pressures above 60 psig (400 kPa).

(9) There will be a discernible point when the valve opens and provides water flow with no significant rise in pressure. At this point log the pressure and turn off the fuel burning equipment.

(10) If the safety relief valve does not open at the set pressure plus the allowable tolerance, shut off the fuel burning equipment and do not operate the boiler until the safety relief valve has been replaced.

(11) If the safety relief valve opens at a pressure below the allowable tolerance, this is not necessarily a dangerous condition but it can indicate a deteriorating condition or improper spring setting. The valve should be replaced.

(12) After the safety relief valve has closed, open the valve to the expansion tank, the system return line, and the supply line to allow the boiler to return to its normal operating pressure.

(13) If applicable, remove the flow switch jumper and return the operating and high limit temperature controls to normal.

(14) Start the water circulating equipment.

(15) Start the fuel burning equipment. Observe the pressure and temperature until the system returns to normal operating conditions and the operating control has cycled the burner on and off at least once.

(16) Check again to assure that the safety relief valve is not leaking.

(13)

MANDATORY APPENDIX II
SUBMITTAL OF TECHNICAL INQUIRIES TO THE BOILER AND PRESSURE VESSEL COMMITTEE

DELETED

MANDATORY APPENDIX III
STANDARD UNITS FOR USE IN EQUATIONS

Table III-1
Standard Units for Use in Equations

Quantity	U.S. Customary Units	SI Units
Linear dimensions (e.g., length, height, thickness, radius, diameter)	inches (in.)	millimeters (mm)
Area	square inches (in.^{2})	square millimeters (mm^2)
Volume	cubic inches (in.^{3})	cubic millimeters (mm^3)
Section modulus	cubic inches (in.^{3})	cubic millimeters (mm^3)
Moment of inertia of section	inches^4 (in.^{4})	millimeters^4 (mm^4)
Mass (weight)	pounds mass (lbm)	kilograms (kg)
Force (load)	pounds force (lbf)	newtons (N)
Bending moment	inch-pounds (in.-lb)	newton-millimeters (N·mm)
Pressure, stress, stress intensity, and modulus of elasticity	pounds per square inch (psi)	megapascals (MPa)
Energy (e.g., Charpy impact values)	foot-pounds (ft-lb)	joules (J)
Temperature	degrees Fahrenheit (°F)	degrees Celsius (°C)
Absolute temperature	Rankine (R)	kelvin (K)
Fracture toughness	ksi square root inches ($\text{ksi}\sqrt{\text{in.}}$)	MPa square root meters ($\text{MPa}\sqrt{\text{m}}$)
Angle	degrees or radians	degrees or radians
Boiler capacity	Btu/hr	watts (W)

NONMANDATORY APPENDIX A GUIDANCE FOR THE USE OF U.S. CUSTOMARY AND SI UNITS IN THE ASME BOILER AND PRESSURE VESSEL CODE

A-1 USE OF UNITS IN EQUATIONS

The equations in this Nonmandatory Appendix are suitable for use with either the U.S. Customary or the SI units provided in Mandatory Appendix III, or with the units provided in the nomenclature associated with that equation. It is the responsibility of the individual and organization performing the calculations to ensure that appropriate units are used. Either U.S. Customary or SI units may be used as a consistent set. When necessary to convert from one system of units to another, the units shall be converted to at least three significant figures for use in calculations and other aspects of construction.

A-2 GUIDELINES USED TO DEVELOP SI EQUIVALENTS

The following guidelines were used to develop SI equivalents:

(a) SI units are placed in parentheses after the U.S. Customary units in the text.

(b) In general, separate SI tables are provided if interpolation is expected. The table designation (e.g., table number) is the same for both the U.S. Customary and SI tables, with the addition of suffix "M" to the designator for the SI table, if a separate table is provided. In the text, references to a table use only the primary table number (i.e., without the "M"). For some small tables, where interpolation is not required, SI units are placed in parentheses after the U.S. Customary unit.

(c) Separate SI versions of graphical information (charts) are provided, except that if both axes are dimensionless, a single figure (chart) is used.

(d) In most cases, conversions of units in the text were done using hard SI conversion practices, with some soft conversions on a case-by-case basis, as appropriate. This was implemented by rounding the SI values to the number of significant figures of implied precision in the existing U.S. Customary units. For example, 3,000 psi has an implied precision of one significant figure. Therefore, the conversion to SI units would typically be to 20 000 kPa. This is a difference of about 3% from the "exact" or soft conversion of 20 684.27 kPa. However, the precision of the conversion was determined by the Committee on a case-by-case basis. More significant digits were included in the SI equivalent if there was any question. The values of allowable stress in Section II, Part D generally include three significant figures.

(e) Minimum thickness and radius values that are expressed in fractions of an inch were generally converted according to the following table:

Fraction, in.	Proposed SI Conversion, mm	Difference, %
1/32	0.8	−0.8
3/64	1.2	−0.8
1/16	1.5	5.5
3/32	2.5	−5.0
1/8	3	5.5
5/32	4	−0.8
3/16	5	−5.0
7/32	5.5	1.0
1/4	6	5.5
5/16	8	−0.8
3/8	10	−5.0
7/16	11	1.0
1/2	13	−2.4
9/16	14	2.0
5/8	16	−0.8
11/16	17	2.6
3/4	19	0.3
7/8	22	1.0
1	25	1.6

(f) For nominal sizes that are in even increments of inches, even multiples of 25 mm were generally used. Intermediate values were interpolated rather than converting and rounding to the nearest mm. See examples in the following table. [Note that this table does not apply to nominal pipe sizes (NPS), which are covered below.]

Size, in.	Size, mm
1	25
1 1/8	29
1 1/4	32
1 1/2	38
2	50
2 1/4	57
2 1/2	64
3	75
3 1/2	89
4	100
4 1/2	114
5	125
6	150
8	200

Table continued

Size, in.	Size, mm
12	300
18	450
24	600
36	900
40	1 000
54	1 350
60	1 500
72	1 800

Size or Length, ft	Size or Length, m
3	1
5	1.5
200	60

(g) For nominal pipe sizes, the following relationships were used:

U.S. Customary Practice	SI Practice	U.S. Customary Practice	SI Practice
NPS 1/8	DN 6	NPS 20	DN 500
NPS 1/4	DN 8	NPS 22	DN 550
NPS 3/8	DN 10	NPS 24	DN 600
NPS 1/2	DN 15	NPS 26	DN 650
NPS 3/4	DN 20	NPS 28	DN 700
NPS 1	DN 25	NPS 30	DN 750
NPS 1 1/4	DN 32	NPS 32	DN 800
NPS 1 1/2	DN 40	NPS 34	DN 850
NPS 2	DN 50	NPS 36	DN 900
NPS 2 1/2	DN 65	NPS 38	DN 950
NPS 3	DN 80	NPS 40	DN 1000
NPS 3 1/2	DN 90	NPS 42	DN 1050
NPS 4	DN 100	NPS 44	DN 1100
NPS 5	DN 125	NPS 46	DN 1150
NPS 6	DN 150	NPS 48	DN 1200
NPS 8	DN 200	NPS 50	DN 1250
NPS 10	DN 250	NPS 52	DN 1300
NPS 12	DN 300	NPS 54	DN 1350
NPS 14	DN 350	NPS 56	DN 1400
NPS 16	DN 400	NPS 58	DN 1450
NPS 18	DN 450	NPS 60	DN 1500

(h) Areas in square inches (in.^{2}) were converted to square mm (mm^2) and areas in square feet (ft^2) were converted to square meters (m^2). See examples in the following table:

Area (U.S. Customary)	Area (SI)
1 in.^{2}	650 mm^2
6 in.^{2}	4 000 mm^2
10 in.^{2}	6 500 mm^2
5 ft^2	0.5 m^2

(i) Volumes in cubic inches (in.^{3}) were converted to cubic mm (mm^3) and volumes in cubic feet (ft^3) were converted to cubic meters (m^3). See examples in the following table:

Volume (U.S. Customary)	Volume (SI)
1 in.^{3}	16 000 mm^3
6 in.^{3}	100 000 mm^3
10 in.^{3}	160 000 mm^3
5 ft^3	0.14 m^3

(j) Although the pressure should always be in MPa for calculations, there are cases where other units are used in the text. For example, kPa is used for small pressures. Also, rounding was to one significant figure (two at the most) in most cases. See examples in the following table. (Note that 14.7 psi converts to 101 kPa, while 15 psi converts to 100 kPa. While this may seem at first glance to be an anomaly, it is consistent with the rounding philosophy.)

Pressure (U.S. Customary)	Pressure (SI)
0.5 psi	3 kPa
2 psi	15 kPa
3 psi	20 kPa
10 psi	70 kPa
14.7 psi	101 kPa
15 psi	100 kPa
30 psi	200 kPa
50 psi	350 kPa
100 psi	700 kPa
150 psi	1 MPa
200 psi	1.5 MPa
250 psi	1.7 MPa
300 psi	2 MPa
350 psi	2.5 MPa
400 psi	3 MPa
500 psi	3.5 MPa
600 psi	4 MPa
1,200 psi	8 MPa
1,500 psi	10 MPa

(k) Material properties that are expressed in psi or ksi (e.g., allowable stress, yield and tensile strength, elastic modulus) were generally converted to MPa to three significant figures. See example in the following table:

Strength (U.S. Customary)	Strength (SI)
95,000 psi	655 MPa

(l) In most cases, temperatures (e.g., for PWHT) were rounded to the nearest 5°C. Depending on the implied precision of the temperature, some were rounded to the nearest 1°C or 10°C or even 25°C. Temperatures colder than 0°F (negative values) were generally rounded to the nearest 1°C. The examples in the table below were created by rounding to the nearest 5°C, with one exception:

Temperature, °F	Temperature, °C
70	20
100	38
120	50
150	65
200	95
250	120
300	150
350	175
400	205
450	230
500	260
550	290
600	315
650	345
700	370
750	400
800	425
850	455
900	480
925	495
950	510
1,000	540
1,050	565
1,100	595
1,150	620
1,200	650
1,250	675
1,800	980
1,900	1 040
2,000	1 095
2,050	1 120

A-3 SOFT CONVERSION FACTORS

The following table of "soft" conversion factors is provided for convenience. Multiply the U.S. Customary value by the factor given to obtain the SI value. Similarly, divide the SI value by the factor given to obtain the U.S. Customary value. In most cases it is appropriate to round the answer to three significant figures.

U.S. Customary	SI	Factor	Notes
in.	mm	25.4	...
ft	m	0.3048	...
in.^{2}	mm^2	645.16	...
ft^2	m^2	0.09290304	...
in.^{3}	mm^3	16,387.064	...
ft^3	m^3	0.02831685	...
U.S. gal.	m^3	0.003785412	...
U.S. gal.	liters	3.785412	...
psi	MPa (N/mm^2)	0.0068948	Used exclusively in equations
psi	kPa	6.894757	Used only in text and for nameplate
psi	bar	0.06894757	...
ft-lb	J	1.355818	...
°F	°C	$^5/_9$ × (°F −32)	Not for temperature difference
°F	°C	$^5/_9$	For temperature differences only
R	K	$^5/_9$	Absolute temperature
lbm	kg	0.4535924	...
lbf	N	4.448222	...
in-lb	N·mm	112.98484	Use exclusively in equations
ft-lb	N·m	1.3558181	Use only in text
ksi$\sqrt{in.}$	MPa$\sqrt{m}$	1.0988434	...
Btu/hr	W	0.2930711	Use for boiler rating and heat transfer
lb/ft^3	kg/m^3	16.018463	...

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ENDNOTES

1 The top or side of the boiler means the highest practicable part of the boiler proper, but in no case shall the safety valve be located on the boiler below the normal operating level and in no case shall the safety relief valve be located below the lowest permissible water level.

2 Boilers having a capacity of 25 gal (91 L) or less are exempt from the requirements in A, except that they must have a NPS $^{3}/_{4}$ (DN 20) minimum drain valve.

3 A qualified water treatment chemical specialist should be consulted for recommendations regarding appropriate chemical compounds and concentrations that are compatible with local environmental regulations governing disposal of the boilout solutions.

4 In the absence of flow metering equipment, opening of the valve can be considered to have been achieved when a steady fast drip or stream of approximately 40 cc/min is observed at the discharge opening of the valve.

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