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IDENTIFIERS Military Curriculum Project; *Steam Heating

ABSTRACT

This fourth course in a four-course series on heating and ventilating for the secondary/postsecondary level is one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. The four lessons in the course cover these topics: (1) Feed-Water, Condensate, and Pump Systems; (2) Treatment of Boiler Water; (3) Steam Plants; and (4) Steam Distribution. Designed for student self-study and evaluation, the course materials consist of a text and a student workbook. The text contains the reading assignments. Materials found in the workbook are lesson objectives, text assignments, lesson review exercises, answers to the exercises, and a discussion of those answers. A course examination is provided, but no answer key is included. The course may be used for remedial or independent study. (YLB)

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

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Military Curriculum Materials
WRITE OR CALL
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
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THE NATIONAL CENTER FOR RESEARCH IN VOCATIONAL EDUCATION

Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
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217/782-0759

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HEATING AND VENTILATING IV

Table of Contents

Developed by:

United States Army

Development and Review Dates

Unknown

Occupational Area:

Heating and Air Conditioning

Cost:

Print Pages:

87

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Suggested Background:

Heating and Ventilating I, II, & III (Courses 11-2, 11-3, and 11-4 in this catalog)

Target Audiences:

Grades 10-adult

Organization of Materials:

Student workbook containing objectives, assignments, review exercises, solutions to the exercises, discussion and examination; text

Type of Instruction:

Individualized, self-paced

Type of Materials:			No. of Pages:	Average Completion Time:
Heating and Ventilating IV (Steam Heating)				
Lesson 1	—	Feed-Water, Condensate, and Pump Systems	17	Flexible
Lesson 2	—	Treatment of Boiler Water	12	Flexible
Lesson 3	—	Steam Plants	11	Flexible
Lesson 4	—	Steam Distribution	13	Flexible
Workbook			13	

Supplementary Materials Required:

None

Expires July 1, 1978

Course Description

This is the fourth of four courses on heating and ventilating. The previous courses discussed blueprints, tools, piping, electricity, insulation, principles of heating, heating units, warm-air heating, and hot-water heating. This course discusses the installation, operation, and maintenance of several water feeder systems, with emphasis on the use of chemicals in testing and purifying water. The text also offers instruction on the steam-driven pump systems, the centrifugal pump, injector feeder systems, and water conditioners. External and internal steam distribution systems, with their fittings and accessories, are presented in detail. This subcourse consists of the following four lessons:

Lesson 1 — *Feed-Water, Condensate, and Pump Systems* contains discussions on water feeder, gravity condensate and pump systems. There is information on water feeder systems, gravity condensate return systems, the steam-driven pump system, the centrifugal rotary pump, the injector feeder system, and water conditioners.

Lesson 2 — *Treatment of Boiler Water* covers the characteristics of water, the purpose and types of water treatment, and the control of water treatment.

Lesson 3 — *Steam Plants* contains information regarding the requirements, types, installation, operation, and maintenance of steam boilers, the fittings and accessories for boilers; boiler requirements; and boiler and pipe identification markings.

Lesson 4 — *Steam Distribution* provides information about external and internal steam distribution systems and describes installation, operation, and maintenance of these systems and their components.

The student workbook contains lesson objectives, text assignments, lesson review exercises, the answers to the exercises, and a discussion of those answers. The text contains the reading assignments. A subcourse examination is also provided, but no answers are available. The course was designed for student self-study and evaluation and can be used for independent remedial work or advanced study.

ENGINEER
SUBCOURSE 567

HEATING AND VENTILATING IV

(STEAM HEATING)

CORRESPONDENCE COURSE PROGRAM

U. S. ARMY ENGINEER SCHOOL

FORT BELVOIR, VIRGINIA

MOS: 51J20

NRI 204

INTRODUCTION

This is the last of the four subcourses on Heating and Ventilating in the MOS 51-J career field. It discusses the installation, operation, and maintenance of several water feeder systems, with emphasis on the use of chemicals in testing and purifying water. The text also offers instruction on the steam-driven pump systems, the centrifugal pump, the injector feeder systems, and water conditioners. External and internal steam distribution systems, with their fittings and accessories, are presented in detail.

This subcourse consists of four lessons and an examination as follows:

Lesson 1. Feed-Water, Condensate, and Pump Systems.

2. Treatment of Boiler Water.

3. Steam Plants.

4. Steam Distribution.

Examination.

Twelve credit hours are allowed for this subcourse. You will not be limited as to the number of hours that you spend on the subcourse, any lesson, or the examination. For statistical purposes, you are required to enter in the proper space on each answer sheet the number of hours spent in studying the text and solving the exercises.

Text furnished: Memorandum 567. The text need not be returned.

To facilitate removal, answer sheets are bound in reverse order at the end of this booklet. Make sure that the number on the answer sheet is the same as the lesson that you are working on.

Each exercise has four choices with only one BEST answer. Select the choice that you believe is best. Then turn to the answer sheet and mark an X through the letter representing that choice.

The examination will be sent to you when you have successfully completed all the lessons.

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LESSON 1

FEED-WATER, CONDENSATE, AND PUMP SYSTEMS

CREDIT HOURS	3
TEXT ASSIGNMENT	Chapter 1, Memorandum 567.
LESSON OBJECTIVE	To teach you the use of several water feeder systems, the functioning of the centrifugal rotary pump, and the effective use of standard water conditioners.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. How many inches must the water be above the top row of tubes when a fire-tube boiler is ready to light off?

a. 1 c. 3

b. 2 d. 4

2. Which of the following boilers must be provided with at least two ways of feeding water?

a. those that have 300 square feet of heating surface

b. those that have 500 square feet of heating surface

c. those operating below 15 psig

d. low pressure units

3. Makeup water is needed for an operating boiler because of

a. incoming-water pressure

b. change in boiler temperature

c. too much condensate

d. insufficient condensate

4. You are using an automatic water-level control in connection with an electric-driven feed-water pump. When the float rises sufficiently, the pump

a. starts

b. doubles its speed

c. runs slowly

d. shuts off

5. The standard automatic feed-water control is

a. an injector c. a float

b. a valve d. a trap

6. Which of the following returns the condensate to the boiler by means of gravity?

a. automatic feed

b. centrifugal pump

c. Hartford loop

d. manual feeder

7. You are operating a duplex steam reciprocating pump that has a normal speed of 40 strokes per minute. The speed suddenly increases to 80 strokes per minute. What is the most probable cause?

a. loss of water pressure

b. feed water is too hot

c. steam pressure doubled

d. feed water is too cold

8. Leaks around the packing glands of a steam pump cause

a. pump to increase its speed

b. loss of condensate

c. pump to stop

d. increase of condensate

9. The regulating valve of a thermohydraulic feed-water regulator is opened by

a. steam pressure in closed system

b. electrical contacts

c. float-operated switch

d. expansion of thermostat

10. A turbine-type centrifugal pump is suitable as a feed-water pump because of its

a. high-discharge pressure

b. low-discharge pressure

c. high-temperature balance

d. high-suction force

11. The stop valves on the suction and discharge sides of a boiler with an electric motor permit repair or replacement of the pump without interrupting operation of the

a. boiler

b. motor

c. impeller

d. condensate receiver

12. Before starting a new pump or one that has been idle for a long period of time, you should turn the pump shaft by hand in order to verify that the

a. impeller is locked

b. impeller is free

c. valves are closed

d. air discharge tube is clear

13. A check valve is installed between the boiler and the pump discharge in order to prevent hot water or steam from traveling from the

a. pump to packing glands

b. strainer to the pump

c. boiler to the pump

d. pump to the injector

14. An injector is correctly installed on a boiler with enough water and steam pressure available, but the injector will not feed water. What is the most likely trouble?

a. injector is not primed

b. mineral coatings in injector

c. injector holes are plugged

d. water is very hot.

15. For the injector to operate, the water should have a maximum temperature of

a. 100° F

b. 110° F

c. 115° F

d. 120° F

16. Why is feed water preheated?

a. eliminates oxygen from water

b. changes boiler water chemically

c. increases efficiency of boiler operation

d. reduces temperature of makeup water

17. You use exhaust steam to heat a feed-water heater and thereby raise the feed-water temperature from 60° F to 160° F. By what percent have you increased the efficiency of the boiler plant?

a. 6
b. 10
c. 12
d. 15

18. If steam is generated when a downward-flow economizer-type heater is used, the cause is

a. improper circulation through the unit
b. the water is too cold
c. the tubes are incorrectly pitched
d. soot has accumulated in tubes

19. Which of the following would you use to precipitate the hardness salts of calcium and magnesium from the water?

a. sodium zeolite
b. hydrogen zeolite
c. soda ash
d. lime soda

20. What function does a float assembly perform in a tray-type deaerator?

a. decreases nozzle pressure
b. opens spray valves
c. increases steam condensation
d. controls water level

LESSON 2

TREATMENT OF BOILER WATER

CREDIT HOURS ---------------------- 2

TEXT ASSIGNMENT ------------------ Chapter 2, Memorandum 567.

LESSON OBJECTIVE ------------------ To teach you the methods of water treatment, the maintenance of water boilers, and the use of chemicals in testing and purifying water supply.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. What does the symbol CO_2 stand for?

a. 1 part calcium and 2 parts oxygen

b. 1 part coal and 2 parts oil

c. carbon dioxide

d. carbonic oxygen

2. A high-pressure steam steel boiler is rated at how many horsepower?

a. 85-90 c. 95-100

b. 90 d. 100 or more

3. How many pounds of disodium phosphate do you use in boiling out a boiler that holds 10,000 pounds of water?

a. 3 c. 30

b. 15 d. 45

4. The chemically treated water that is used to cleanse a scaled and corroded boiler is raised to 200° F. For how many hours is this temperature maintained?

a. 5 to 10 c. 20 to 30

b. 15 to 20 d. 24 to 48

5. You are using the dry method of storing a 3000-gallon boiler. How many pounds of quicklime do you use?

a. 2 c. 5

b. 3 d. 6

6. You are using the wet method to store a boiler that contains 5000 pounds of water. How many pounds of sodium sulfite should you use?

a. 5 c. 25

b. 6.25 d. 50

7. You are checking condensate return lines of a water boiler and you notice that CO_2 is causing corrosion. You can partially neutralize this by treating the condensate with

a. bicarbonate c. amines

b. carbon d. quicklime

8. The makeup rate of feed water for a central heating plant is equal to what percent of the steam produced?

a. 5 to 10
b. 5 to 15
c. 10 to 15
d. 15 to 20

9. Blowdown is given to a boiler primarily to

a. control solids in boiler water
b. increase heat transmission
c. increase oxygen in the water
d. prevent scales on boiler piping

10. You find a high concentration of calcium salt in the makeup water entering a water boiler. Which of the following would you add to this water in order to control the formation of calcium scale in the boiler?

a. antifoam
b. phosphate
c. sodium sulfite
d. caustic soda

11. You are conducting a pH test of boiler water and find that this water has a pH of 4.5. Which of the following would you add to the water to control the acid content?

a. sodium sulfate
b. calcium salts
c. sodium phosphate
d. caustic soda

12. How many pounds of sodium sulfite would you combine with 5 pounds of oxygen to form sodium sulfate?

a. 10
b. 20
c. 30
d. 40

13. An antifoam compound decreases the foaming in a boiler by changing the

a. feed-water makeup rate
b. rate of condensation
c. surface tension of the water
d. pH reading

14. Which of the following would you select as the best place to mix chemicals for use in a boiler?

a. floor level
b. low bench
c. high table
d. dirt hole

15. You must feed chemicals to five boilers. You would arrange the piping and feeders so that the chemicals are added

a. to all boilers at same time
b. to two boilers from same chemical feeder
c. to three boilers at same time, and two individually
d. directly to each boiler

16. How often would you check the water in a 30-horsepower boiler?

a. daily
b. semi-weekly
c. weekly
d. monthly

17. How often would you check the water in a 15-horsepower boiler?

a. daily
b. twice a week
c. weekly
d. monthly

18. If you used 19 milliliters of causticity reagent No. 2 during a causticity test, how many ppm of causticity would you find in the sample?

a. 220
b. 365
c. 437
d. 450

19. You use 1/4 teaspoon of decolorizing carbon in making a boiler water test. What test are you making?

a. causticity
b. tannin
c. sodium sulfite
d. phosphate

20. You are using a conductivity solo-bridge in making the total dissolved solids test. You get a reading of 2000 micromhos. How many ppm of total dissolved solids do you have?

a. 500
b. 1000
c. 1800
d. 2000

LESSON 3

STEAM PLANTS

CREDIT HOURS ______________________ 2

TEXT ASSIGNMENT ____________________ Chapter 3, Memorandum 567.

LESSON OBJECTIVE ___________________ To teach you the construction, installation, operation, and maintenance of steam boilers, including the functioning of their accessories.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. The sea-level temperature of water cannot be increased beyond

a. 200° F c. 220° F
b. 212° F d. 230° F

2. You want to provide 49 psig from your water boiler. What temperature would you make the water in order to provide this pressure?

a. 49° F c. 270° F
b. 119° F d. 296° F

3. Standard practice requires that a qualified boiler inspector should inspect a steam boiler at least once a

a. day c. month
b. week d. year

4. All boilers are constructed to incorporate a furnace or firebox for

a. storing the fuel
b. burning the fuel
c. holding the gases
d. preventing boiler-surface heat

5. In most cases, baffles are provided in the boiler to

a. guide the gases
b. prevent exit of gases
c. prevent formation of gases
d. reduce heat absorption by boiler water

6. The access door of a boiler permits the cleaning of the tubes and the boiler sides. Which of the following would you use to seal this door between boiler cleanings?

a. asbestos rope
b. rivets
c. cement powder
d. bolts

7. How are the sections of low-pressure sectional steel boilers usually joined together?

a. bolted
b. riveted
c. welded
d. hooked

8. As a rule, the maximum design pressure requirement for which you would use a fire-tube boiler is

a. 150 psi
b. 175 psi
c. 200 psi
d. 225 psi

9. What kind of boiler has its combustion chamber incorporated as an integral part of the boiler?

a. marine
b. locomotive
c. crown
d. firebox

10. Which boiler has all four sides of its firebox surrounded by water?

a. fire tube
b. locomotive
c. tubular
d. Scotch marine

11. In an HRT boiler, the gases are directed upward to the tubes by means of a

a. blowdown line
b. refractory
c. refractory baffle
d. fusible plug

12. Which of the following boilers is a complete, self-contained unit?

a. Scotch marine
b. HRT
c. locomotive
d. bent tube

13. Which of the following do you consider a disadvantage of the Scotch marine boiler?

a. all tubes are same size
b. two-pass arrangement of tubes
c. corrugated sheet-metal firebox
d. large amount of reinforcing is necessary

14. Boilers having tubes less than 2 inches in diameter are small tube boilers. They are commonly called what type of boiler?

a. express
b. firebox
c. bent tube
d. water tube

15. The purpose of the steam-drum baffle in the sectional cross-header type of water boiler is to

a. maintain a continuous flow of water
b. help separate the water from the steam
c. mix water and steam proportionally
d. change the feed water to steam

16. Which of the following are distinguishing features of the sectional header cross-drum boiler?

a. baffles
b. hand holes
c. headers
d. tubes

17. You must check the pressure gage on a boiler that has its safety valve pressure set at 100 psi. This test dial that you use for this check is graduated to read at least

a. 50
b. 100
c. 150
d. 200

18. You are operating a boiler with a cut-in pressure of 100 psi and a differential pressure of 10 psi. What is the psi cut-out pressure?

a. 90
b. 100
c. 105
d. 110

19. How many water-gage glasses would you provide on a boiler that is operating at 500 psi?

a. 1
b. 2
c. 3
d. 4

20. You have a boiler with 700 square feet of heating surface. What is the minimum number of safety valves that you would install?

a. 1
b. 2
c. 3
d. 4

LESSON 4

STEAM DISTRIBUTION

CREDIT HOURS ---------------------------3

TEXT ASSIGNMENT ---------------------Chapter 4, Memorandum 567.

LESSON OBJECTIVE --------------------To teach you the installation, operation, and maintenance of external and internal distribution systems, and the functioning of their components.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. The exterior steam distribution system is divided into which two categories?

a. conduit and utilidor

b. utilidor and overhead

c. aboveground and utilidor

d. underground and aboveground

2. The underground steam distribution system is divided into which of the following two categories?

a. conduit and utilidor

b. gravity and air vent

c. one-pipe and utilidor

d. one-pipe and two-pipe vapor

3. The aboveground steam distribution system is divided into which of the following two categories?

a. conduit and utilidor

b. internal and gravity

c. vapor and exterior

d. overhead and surface

4. In a surface steam distribution system, you find that the pipe at one place has been shaped into a large loop. The most likely reason for this is to

a. provide for pipe expansion

b. keep out water

c. reduce rate of water flow

d. control steam pressure

5. In the gravity one-pipe, air-vent system, the return of condensate depends upon the

a. hydrostatic head

b. air valve

c. radiator shut-off valve

d. inlet valve

6. In which distribution system does the condensate and the steam flow in opposite directions within the same pipe?

a. two-pipe gravity reverse

b. two-pipe vapor

c. gravity, one-pipe, air vent

d. one-pipe, external vapor

7. You are installing a gravity, air-vent, one-pipe distribution system. What pitch would you give a 40-foot line in order to obtain proper drainage?

a. ¼ inch
b. ½ inch
c. ¾ inch
d. 1 inch

8. You are starting to heat up a cold heating system. You open the main steam stop valve only very little in order to

a. allow a gradual entry of air to system

b. avoid thermal shock to lines and fittings

c. build up condensate in distribution lines

d. maintain an unchanging boiler-water level

9. In the one-pipe steam distribution system, a partially open radiator valve will interfere with the

a. pitch of the distribution lines

b. proper drainage of the radiator

c. functioning of water-return trap

d. rate of condensate return to boiler

10. When a radiator fails to heat or when water-hammer occurs, which of the following is a probable cause?

a. failure of air vent to function

b. a fluctuating boiler-water line

c. valve is completely open

d. valve is completely closed

11. You are installing a return trap in a two-pipe vapor system. How many inches above the boiler water line do you set the bottom of this trap?

a. 14
b. 16
c. 18
d. 20

12. What component of a two-pipe vapor system would you find at the bottom of the opposite end of the radiator?

a. air vent

b. radiator valve

c. thermostatic trap

d. flow-control valve

13. If you operate a boiler at an altitude at which water boils at 190° F, the liquid in the bellows of its automatic radiator air vent would boil at

a. 180° F
b. 190° F
c. 200° F
d. 212° F

14. You are inspecting a float trap that does not operate. You shake the trap and hear sloshing of water in the float, which does not rise. You would

a. drain the trap

b. enlarge the seat

c. replace the trap

d. replace the float

15. What steam trap operates on the principle that a portion of hot water under pressure will flash into steam when its pressure is reduced?

a. throttling

b. thermodynamic

c. bucket

d. impulse

16. The impulse trap of a steam distribution system has an inlet pres-

sure of 100 psi. The psi pressure on the discharge side should not be more than

a. 10
b. 15
c. 20
d. 25

17. Which of the following steam traps contains only one moving part?

a. thermostatic
b. thermodynamic
c. bimetallic-element
d. impulse

18. How many times its volume does water expand when it changes to steam?

a. 1500
b. 1628
c. 1728
d. 1850

19. Which of the following metals are commonly used in making the bimetallic strip in a bimetallic trap?

a. invar and copper
b. invar and steel
c. steel and magnesium
d. steel and copper

20. The temperature of the steam to which a slip-type expansion joint may be subjected is determined by the

a. temperature valve
b. water pressure in line
c. type of anchor on the joint
d. kind of packing

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CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 567 ________________________Heating and Ventilating IV.

LESSON 1 ____________________________Feed-Water, Condensate, and Pump Systems.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 567.

1. *b* (para 1-1)
2. *b* (para 1-2)
3. *d* (para 1-3)
4. *d* (para 1-4)
5. *c* (para 1-4)
6. *c* (para 2-2)
7. *b* (para 3-3)
8. *b* (para 3-7)
9. *a* (para 3-12)
10. *a* (para 4-7)
11. *a* (para 4-10)
12. *b* (para 4-11)
13. *c* (para 4-11)
14. *d* (para 5-1)
15. *d* (para 5-5)
16. *c* (para 6-1)
17. *b* (para 6-2)
18. *a* (para 6-5)
19. *d* (para 7-9)
20. *d* (para 7-15)

For further explanation, see Discussion.

All concerned will be careful that neither this solution nor information concerning the same comes into the possession of students or prospective students who have not completed the work to which it pertains.

DISCUSSION

Exercise:

1. The water level for fire-tube boilers must be maintained at least 2 (b) inches above the top row of tubes.

2. **Boilers having 500 or more square feet of heating surface** (b), as well as all high-pressure boilers (those operating above 15 psig), must have at least two different ways of providing feed water.

3. Generally, the **condensate is not of sufficient quantity** (d) to make up for all the water that a boiler requires. The fresh water that is added to the boiler water is usually called make-up water.

4. The feed water is pumped into the boiler, raising the boiler water to the correct level. When this happens, the rising float causes the electrical contacts to open and **shut off** (d) the pump.

5. Modern feed-water installations have automatic controls. The standard automatic feed-water control is a **float** (c).

6. To make possible the return of condensate by gravity, the pressure in the return system must be equal to that in the boiler. One method of balancing these return water and steam pressures is the **Hartford loop** (c), illustrated in figure 3.

7. When the **feed water is too hot** (b) (212° F or higher), the pump will not operate properly and will exceed its normal speed, which is 5 to 50 strokes per minute.

8. Leaks around the packing glands of a steam pump cause the **loss of condensate** (b) and create the hazard of burning the operator. These leaks can be stopped in most instances by tightening the packing-gland nuts.

9. Heat from the steam in the inside tube is transferred to water in the outside tube, and this changes the water to steam. The **steam creates pressure in the closed system** (a) of the outside tube. This increased pressure acts on the bellows of the regulating valve and opens the valve.

10. Different types of pumps employ the centrifugal rotary principle. Of these, the turbine design is very suitable for use as a feed-water pump because of its **high-discharge pressure** (a).

11. By closing the valves, you can repair or replace the pump without interrupting the operation of the **boiler** (a).

12. You should turn the pump shaft by hand to see that the **impeller is free** (b). Also be sure that all valves in the feed line between pump discharge and the boiler are open.

13. The nonreturn or check valve installed between the boiler and the pump discharge prevents hot water or steam from traveling from the **boiler to the pump** (c) and causing damage to the pump parts.

14. One drawback to using the injector is that it will not feed water when the water is very **hot (d).**

15. The water supply should not be hotter than **120° F (d)** for the injector to operate. If several unsuccessful attempts are made to operate the injector, it becomes very hot and will not prime.

16. A feed-water heater is used to **increase the efficiency of boiler operation (c)** by heating the feed water. This preheating often results in economy.

17. The use of the heat from exhaust steam that would otherwise be lost increases boiler plant efficiency 1 percent for each 10° increase in feed-water temperature. $(160° - 60° \div 10 \times 1\% = 10\%$ **(b)**)

18. When a downward-flow economizer is used and some steam is generated, there is **improper circulation through the unit (a).**

19. The **lime-soda (d)** softener is used to precipitate the hardness salts of calcium and magnesium from the water. A typical lime-soda water softener is shown in figure 21.

20. A float assembly, similar to the ones shown in figures 21 and 23, that actuate the water-control valves, **controls the water level (d)** in the tray-type deaerating heater.

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 567 ----------------------------Heating and Ventilating IV.

LESSON 2 ----------------------------------Treatment of Boiler Water.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 567.

1. *c* (para 8-2)
2. *d* (para 10-3)
3. *c* (para 10-7)
4. *d* (para 10-10)
5. *d* (para 11-3)
6. *b* (para 11-5)
7. *c* (para 12-2)
8. *a* (para 12-3)
9. *a* (para 12-4)
10. *b* (para 13-1)
11. *d* (para 13-1 and 14-1)
12. *d* (para 15-5)
13. *c* (para 15-6)
14. *a* (para 16-3)
15. *d* (para 17-9)
16. *a* (para 18-2)
17. *b* (para 18-3)
18. *c* (para 18-19)
19. *d* (para 18-21)
20. *c* (para 18-31)

For further explanation, see Discussion.

All concerned will be careful that neither this solution nor information concerning the same comes into the possession of students or prospective students who have not completed the work to which it pertains.

DISCUSSION

Exercise:

1. Natural water usually contains some impurities such as acids, scale-forming calcium and magnesium, dissolved and suspended oxygen, and **carbon dioxide (c)** **(CO_2)**.

2. Steam steel boilers are classified as high horsepower, rated at **100 or more (d)** horsepower, and low horsepower rated at 100 or less.

3. After brushing, the boiler should be filled with water. Then 3 pounds of caustic soda, 3 pounds of disodium phosphate, and 1 pound of sodium nitrate should be added for each 1000 pounds of water capacity.

$$(10{,}000 \div 1000 \times 3 = \mathbf{30\ (c)}\ \text{pounds})$$

4. You maintain the temperature from **24 to 48 (d)** hours. You also add makeup water as required during this period to keep the boiler filled to base of the safety valve.

5. Two pounds of quicklime per 100 gallons of water capacity are placed in the boiler.

$$(2 \times \frac{3000}{1000} = \mathbf{6\ (d)})$$

6. Approximately 2 ounces of sodium sulfite to 100 pounds of water are placed in the boiler. No airspaces should be left in the boiler.

$$(\frac{50 \times 2\ \text{oz.}}{16\ (\text{ounces to pound})} = \mathbf{6.25\ (b)}\ \text{pounds})$$

7. The corrosive effect of CO_2 is partially neutralized by chemical treatment of the condensate with **amines (c)**, derivatives of ammonia.

8. The makeup rate of feed water for central heating plants is equal to **5 to 10 (a)** percent of the steam produced.

9. Blowdown should be given a boiler primarily to **control solids in the boiler water (a)** within specified limits.

10. **Phosphate (b)** is used to control the calcium scale.

11. According to para 14-1 and the scale in figure 26, a pH reading of 4.5 indicates that the water is acid. **Caustic soda (d)** is used to control the acid content of the water.

12. It takes about 8 pounds of sodium sulfite to combine with 1 pound of oxygen to form sodium sulfate, a noncorroding agent.

$$(8 \times 5 = \mathbf{40\ (d)})$$

13. The tendency to foam can be decreased by changing the **surface tension of the water (c)** in the boiler with an antifoam compound.

14. The mixing should be done at **floor level (a)** to prevent injury to your eyes and face. You should use protective equipment when you are mixing chemicals.

15. When a steam heating plant includes three or more boilers, the treatment chemicals can be distributed effectively if the chemicals are individually added **directly to each boiler (d).**

16. The water in high-horsepower plants is tested **daily (a).** When more than one boiler is in operation in a boiler plant, the water in the boilers is tested alternately.

17. The water in low-horsepower plants is tested **twice a week (b).** When more than one boiler is in operation, the boilers are tested alternately.

18. To determine the ppm, multiply the milliliters of the reagent (No. 2) by the constant number 23.

(19 × 23 = **437 (c)**)

19. The use of decolorizing carbon is the first step in making the **phosphate (d)** test, which is conducted to determine the amount of soluble phosphate in the boiler water.

20. To convert this micromhos reading on the solo-bridge to ppm, you multiply the reading by standard number factor of 0.9.

(2000 × 0.9 = **1800 (c)**)

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 567 ______________________ Heating and Ventilating IV.

LESSON 3 ___________________________ Steam Plants.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 567.

1. *b* (para 20-3)
2. *d* (para 20-6)
3. *d* (para 20-7)
4. *b* (para 20-10)
5. *a* (para 20-11)
6. *a* (para 20-11)
7. *c* (para 20-12)
8. *a* (para 20-14)
9. *d* (para 20-15)
10. *b* (para 20-17)
11. *c* (para 20-20)
12. *a* (para 20-21)
13. *d* (para 20-24)
14. *a* (para 20-28)
15. *b* (para 20-31)
16. *c* (para 20-32)
17. *c* (para 20-42)
18. *d* (para 20-43)
19. *b* (para 20-46)
20. *b* (para 20-53)

For further explanation, see Discussion.

All concerned will be careful that neither this solution nor information concerning the same comes into the possession of students or prospective students who have not completed the work to which it pertains.

DISCUSSION

Exercise:

1. The sea-level temperature of water will not increase beyond the boiling point, 212° F (b). Even if you add more heat after the water starts to boil, the water will not get any hotter as long as it remains at the same pressure.

2. It is relatively simple to determine the temperature of the water when you know the steam pressure: take square root of the steam pressure, multiply this by 14, and then add the constant 198.

$$(\sqrt{49} \times 14 + 198 = 296° \text{ F (d)})$$

3. The ASME Boiler Construction Code that has been adopted by governmental agencies recommends operating and inspecting procedures. Standard practice requires that a qualified boiler inspector make an inspection at least once a year (d).

4. All boilers are constructed to incorporate a furnace or firebox for **burning the fuel (b).**

5. In most cases, baffles are provided in the boiler to **guide the gases** (a) over the most effective route. The baffles also prolong the exit of the gases so that maximum amount of heat can be absorbed by the water.

6. Access doors are usually sealed or made airtight by the installation of **asbestos rope** (a) or webbing around the door.

7. The common practice is for low-pressure boilers to be electrically **welded** (c) and the high-pressure boilers to be riveted.

8. There is a definite limitation in the size and pressure of fire-tube boilers. They are seldom used when requirements are above **150 psi** (a) design pressure.

9. This type boiler is usually referred to as a **firebox** (d) boiler. It requires no masonry setting, except perhaps an ashpit or floor for the combustion chamber.

10. The **locomotive** (b) boiler, figure 31, has a steel firebox consisting of inner and outer sheets held together with stay bolts. All four sides of the firebox are surrounded by water.

11. The gas flow in the HRT boiler is from the firebox toward the rear of the boiler, where gases are directed upward to the tubes by means of a **refractory baffle** (c).

12. The **Scotch marine** (a) boiler is a portable or package unit. It is a complete, self-contained unit which includes automatic controls, steel boiler, and burner equipment.

13. The Scotch marine boiler has a few disadvantages. For example, its shell is from 6 to 8 feet in diameter and **a large amount of reinforcing is necessary** (d).

14. Boilers having tubes less than 2 inches in diameter are small tube boilers, and are commonly called express (a) type. Practically all of the modern steam boilers are the express type.

15. The steam-water mixture returns to the steam drum through the circulating tubes and is discharged in front of the steam-drum baffle. This baffle helps to separate the water from the steam (b).

16. Headers (c) are distinguishing features of the sectional-header cross-drum boiler. They are usually made of forged steel and are connected to the drums by the tubes. The headers are connected at right angles to the tubes, as shown in figure 35.

17. The gage dial is usually graduated to read approximately twice the pressure at which the safety valve is set; it is never graduated to read less than 1½ times this safety valve pressure.

(100 psi × 1½ = 150 psig (c))

18. To find the cut-out point, add the differential pressure to the cut-in pressure.

(100 psi + 10 psi = 110 psi (d))

19. Each boiler must have at least one water-gage glass. If the operating pressure is 400 psi or more, 2 gage glasses (b) must be provided.

20. Each boiler must have a least one safety valve. If the boiler has more than 500 square feet of heating surface, there must be 2 (b) or more safety values installed.

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 567 ---------------------------Heating and Ventilating IV.

LESSON 4 ---------------------------Steam Distribution.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 567.

1. *d* (para 21-1)
2. *a* (para 21-2)
3. *d* (para 21-7)
4. a (para 21-9)
5. *a* (para 22-3)
6. *c* (para 22-3)
7. *d* (para 22-5)
8. *b* (para 22-8)
9. *b* (para 22-9)
10. *a* (para 22-11)
11. *c* (para 22-15)
12. *c* (para 22-32)
13. *a* (para 23-6)
14. *d* (para 23-11)
15. *d* (para 23-20)
16. *d* (para 23-21)
17. *b* (para 23-22)
18. *c* (para 23-22)
19. *a* (para 23-27)
20. *d* (para 23-44)

For further explanation, see Discussion.

All concerned will be careful that neither this solution nor information concerning the same comes into the possession of students or prospective students who have not completed the work to which it pertains.

DISCUSSION

Exercise:

1. Steam distribution systems are grouped under two classifications: exterior and interior. The exterior distribution system is further divided into **underground and aboveground (d).**

2. The major underground systems are the **conduit and utilidor (a).** These systems are normally installed only in permanent heating installations because of their high cost of installation.

3. Aboveground distribution systems are divided into **overhead and surface (d)** systems.

4. Sometimes an expansion loop, formed by a loop in the pipe, is used instead of an expansion joint to **provide for pipe expansion (a).**

5. The return of condensate depends upon the **hydrostatic head (a).**

6. In the **gravity, one-pipe, air-vent system (c),** the condensate is drained from the radiators through the same pipe that supplies the steam. The condensate and the steam flow in opposite directions in the same pipe.

7. The necessary internal drainage can be obtained by sloping the lines down (in direction of condensate flow) at least ¼ inch for every 10 feet of pipe.

$$\left(\frac{40'}{10'} \times \frac{1}{4}'' = 1 \text{ inch (d)}\right)$$

8. The reason for doing this (opening the main steam stop valve very little) is to allow the system to warm up slowly and **avoid any thermal shock to the lines and fittings (b).**

9. Partial opening of the valves will interfere with the **proper drainage of water from the radiators (b).** The radiator valves in the one-pipe steam distribution should be completely open or completely closed.

10. When a radiator fails to heat or water hammer occurs, there are several probable causes. One is the **failure of the air vent to function (a),** thereby causing the radiator to become airbound.

11. The bottom of the trap should be approximately **18 (c)** inches above the boiler water line to provide a sufficient hydrostatic head to overcome friction in the return piping to the boiler.

12. The steam is supplied at the top of the radiator, and the air and condensate discharged through a **thermostatic trap (c)** from the bottom of the opposite end of the radiator.

13. The bellows contains a volatile liquid which has a boiling point that is 10 degrees lower than that of water.

$$(190^\circ - 10^\circ = 180^\circ \text{ (a)})$$

14. A common difficulty is that water gets into the float and it does not rise. In this case, **the float must be replaced (d).**

15. The operation of the **impulse (d)** trap is based on the principle that a portion of hot water under pressure will flash into steam when its pressure is reduced.

16. The pressure on the discharge side of the trap should not be over 25% of the inlet pressure if the trap is to function properly.

(100 psi × 25% = **25 psi (d)**)

17. The **thermodynamic (b)** trap contains only one moving part — a disc. This disc is operated by changes in steam pressure.

18. Water expands to as much as **1728 (c)** times its volume when it changes to steam.

19. The metals contained in the bimetallic strip are generally **invar and copper (a)**. The copper expands very rapidly when heated, but invar expands very little.

20. The joint is held tight by the packing, which permits expansion. The **kind of packing (d)** used determines the temperature to which the joint can be subjected.

EXAMINATION

ARMY CORRESPONDENCE COURSE • ENGINEER SUBCOURSE 567

HEATING AND VENTILATING IV

CREDIT HOURS ---------------------- 2
TEXT ASSIGNMENT ------------------ Review previous assignments.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. Generally, the return condensate cannot produce all the water that a boiler requires. What must be done?

a. add fresh water

b. raise steam temperature

c. add extra inlet pump

d. use manual feeder

2. Steam plants that use pumps for both the regular feed system and the standby system must have at least one of the pumps

a. with gravity return

b. steam driven

c. with separate cylinders

d. with steam-driven injector

3. The outside tube of the thermo-hydraulic regulator has exterior fins. What effect do these have on the tube?

a. decrease cooling rate

b. increase cooling rate

c. maintain pitch

d. control rate of rotation

4. Which of the following would you use to remove lime deposits from the injector of a feeder system?

a. hot water

b. cold water

c. muriatic acid

d. steam

5. One reason why water conditioners are added to feed water before it reaches the boiler is to

a. remove minerals that cause hardness

b. eliminate hydrogen

c. increase magnesium content

d. increase calcium content

6. A sodium-zeolite softener has a capacity of 250 kilograms. The water to be softened has 20 grains of hardness per gallon. How many gallons of this raw water can the sodium-zeolite unit soften?

a. 11,000

b. 11,500

c. 12,000

d. 12,500

7. You want to reduce the alkalinity of the boiler water and to soften it at the same time. Which of the following do you use?

a. sodium-zeolite

b. lime soda

c. brining

d. hydrogen-zeolite

8. You are cleaning out a water boiler with a mixture of disodium phosphate and sodium nitrate. How many hours would you allow this treated water to boil before draining the boiler?

a. 5 to 10 c. 20 to 40

b. 10 to 20 d. 24 to 48

9. You are storing a 200-horsepower boiler by the dry boiler method. How many pounds of quicklime do you use?

a. 25 c. 40

b. 35 d. 45

10. You would use the wet boiler method when it was necessary to store a boiler for periods up to

a. 30 days c. 2 months

b. 50 days d. 3 months

11. You are using the wet boiler method to store a boiler containing 2000 pounds of water. How much caustic soda do you add to this water?

a. 1¼ pounds c. 30 ounces

b. 25 ounces d. 2 pounds

12. Which of the following chemicals would you use to control sludge fluidity in the boiler?

a. antifoam

b. tannin

c. sodium sulfite

d. phosphate

13. Several methods are used to place water-treatment chemicals into the boiler water. Which of the following statements do you accept as a correct procedure?

a. dissolve tannin in cold water

b. add chemicals to water, not water to chemicals

c. dissolve caustic soda in hot water

d. mix sodium sulfite in hot water

14. In a phosphate test, the boiler water is considered satisfactory if the water sample comes between what two standards in the comparator?

a. 20 to 50 ppm

b. 25 to 55 ppm

c. 30 to 60 ppm

d. 35 to 65 ppm

15. You should prevent the impurities in the water from collecting on the boiler heating surface because they

a. slow water current

b. cool boiler metal

c. cause hot spots

d. complicate boiler cleaning

16. How are the sections of high-pressure steel sectional boilers usually joined together?

a. bolted c. hooked

b. welded d. riveted

17. Which of the following boilers would you install for low-pressure and low-capacity purposes?

a. box-header cross drum

b. box-header longitudinal

c. bent-tube

d. fire-tube

18. Which of the following boilers has its firebox constructed separately of firebrick?

a. HRT

b. firebox

c. water tube

d. Scotch marine

19. You have received a heating requirement to provide 700,000 pounds of steam per hour. What type boiler do you select for this task?

a. locomotive

b. water tube

c. Scotch marine

d. fire tube

20. The water column that is connected to the boiler helps prevent fluctuation of the water level in the

a. boiler feed tubes

b. gage glass valves

c. gage glass

d. gage cocks

21. The following give the square feet of heating surface of 4 boilers. On which boiler would you install two or more safety valves?

a. 300

b. 400

c. 500

d. 600

22. A fusible plug in a boiler should be replaced every

a. week

b. month

c. quarter

d. 12 months

23. The boiler feed-water control unit maintains a fixed water level. When the water in the boiler becomes dangerously high or low, this water control unit provides for.

a. a safety valve to open

b. a fusible plug to blow out

c. ringing a bell

d. a low-water cut-off to shut off boiler

24. You are installing two blowdown lines on a 150-psi stationary boiler. How many valves would you install on each blowdown pipe?

a. 1

b. 2

c. 3

d. 4

25. How would you install the steampipe of a conduit type distribution system?

a. inside a conduit in the ground below frostline

b. in covered steel container on ground

c. in each tunnel just above frostline

d. elevated aboveground in asbestos container

26. While inspecting a two-pipe vapor system with a condensate pump, you find that one radiator will not heat. Which of the following is the most likely cause?

a. too much condensate

b. defective condensate pump

c. too much steam pressure

d. inoperative steam trap

27. In what distribution system is the cast iron radiator generally used?

a. two-pipe gravity

b. two-pipe vapor

c. one-pipe

d. one-pipe vapor

28. In the storage-type hot water tank, the stored water temperature should not exceed

a. 170° F

b. 180° F

c. 185° F

d. 200° F

29. In your maintenance of expansion joints, how often would you lubricate the slip-type joint?

a. monthly

b. every 3 months

c. every 6 months

d. yearly

30. How often would you check the bellows-type expansion joint?

a. monthly

b. quarterly

c. semiannually

d. annually

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MEMORANDUM 567

HEATING AND VENTILATING IV

(STEAM HEATING)

11-5

U. S. ARMY ENGINEER SCHOOL

FORT BELVOIR, VIRGINIA

MOS: 51J20 NRI 204

PREFACE

THIS MEMORANDUM is written for personnel in the Army whose duties require them to have a knowledge of steam heating.

The discussions in four chapters of this volume are directed toward steam heating. In the first chapter there are discussions about feed-water, condensate, and pump systems. There is information on water feeder systems, gravity condensate return systems, the steam-driven pump system, the centrifugal rotary pump, the injector feeder system, and water conditioners.

The second chapter covers the characteristics of water, the purpose and types of water treatment, and the control of water treatment. The third chapter contains information regarding the requirements, types, installation, operation, and maintenance of steam boilers; also the fittings and accessories for boilers. The third chapter also contains information regarding boiler requirements and boiler and pipe identification markings. The fourth chapter provides information about the external and internal steam distribution systems. The discussions describe various types of distribution systems and tell about installing, operating, and maintaining the systems and their components.

Keep this memorandum for your use.

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CONTENTS

35

Feed-Water, Condensate, and Pump Systems

SURELY YOU HAVE attempted to inflate an automobile innertube by lung power, and you found that you could not fully inflate the tube. This was true because you were unable to force in any more air above the maximum pressure you were able to build up in the tube with your lungs.

2. If you have visited some steam-heating plants, you probably noticed that the boilers operated at high pressures. Then you, no doubt, wondered how water was fed into these boilers against those pressures. From your experience with the innertube, you know that the water must be placed under greater pressure than the pressure existing inside the boiler before it can be forced into the boiler. For this reason, dependable and efficient systems are designed to feed water under pressure into boilers at frequent intervals as the steam is used. Feed-water systems now vary from the simple type of water-main supply and gravity-return system to the complex pumping system used in a high-pressure multiple-boiler installation.

3. During your career you may have the opportunity of working with all types of feed-water, condensate, and pump systems. You should be ready to help do the jobs when the time comes. In this chapter we are going to start you off with discussions regarding the basic principles related to the operation of these systems and the construction of system components.

4. The discussions will tell you about the construction and operation of feed-water supply systems, gravity-condensate return systems, steam-driven pump systems, centrifugal rotary pumps, injector feeder systems, feed-water heaters, and water conditioners.

5. Water must be fed into a steam boiler at frequent intervals to replace water lost by the heating system during operation. The subsystem designed to replace this boiler water with feed water is called the feed-water system and will be discussed first.

1. Feed-Water Systems

1. Steam boilers must be filled with the correct amount of water before the heat is applied. The water level for fire-tube boilers must be maintained at least 2 inches above the top row of tubes. At the time the boiler is fired, the feed-water system must be ready for operation.

2. The simplest method of feeding water into a boiler is that of using the pressure in the water-main system. This can be done either manually or automatically. Most military steam boiler plants have automatic devices for controlling both the boiler water level in the boiler and the feeding of water into the boiler. The position of the control and its relationship to the water level for the system is shown in figure 1. Boilers having 500 square feet of heating surface or more, as well as all high pressure boilers (those operating at above 15 psig are considered high pressure), must have at least two different ways of providing feed water. These ways consist of various combinations using steam pumps, electric-driven pumps, water-main pressure, and injectors.

3. The water that is fed into a boiler is normally a combination of fresh makeup water, taken from the base water main, and return condensate. Most installations include pipe that returns condensate water from the distribution system to the boiler. The pipe used is extra strong steel pipe or wrought iron pipe. The return is done either by means of gravity or by pumping. You ask what is condensate? Condensate is the water that accumulates in the distribution system as the steam cools and condenses. Generally, the condensate is not of sufficient quantity to make up for all the water that a boiler requires. Therefore, some provision is made to add fresh water to the boiler water. The fresh water provided is usually called *makeup* water.

4. **Automatic Feed.** Modern feed-water installations have automatic controls. The standard automatic feed-water control is a float. It is installed at the normal water-level mark, shown on the boiler, so that it will maintain the water at the

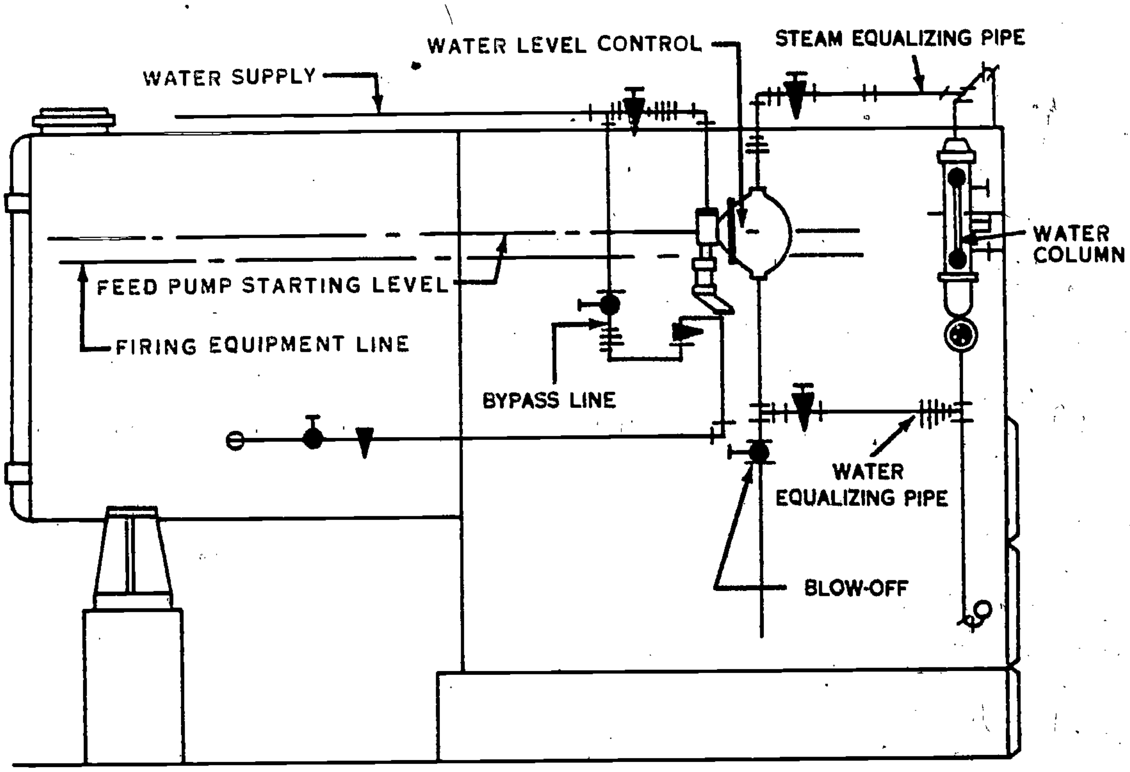

Figure 1. A typical water-level control installation.

normal boiler water level. When boiler water is changed to steam, the boiler water level in the boiler and the control both drop. The float drops until it reaches a predetermined point. Then, a pair of electrical contacts, attached by linkage to the float, make contact with each other. This action starts the feed-water pump. The feed water is pumped into the boiler, raising the boiler water to the correct level. When this happens, the rising float causes the electrical contacts to open and shut off the pump.

5. When the pump cannot pump sufficient water into the boiler because of excess load or other reasons and the water level continues to drop, the float reaches another predetermined point and another set of electrical contacts closes the circuit to set off an alarm bell. Still another set of contacts opens to break a different circuit, thus stopping the operation of the fuel-burning equipment. A typical feed-water piping arrangement is shown in figure 1.

6. **Manual Feeder.** In the event that the automatic control becomes inoperative, there is normally a bypass piping arrangement installed to provide makeup water to the boiler manually. A commonly used bypass piping hookup is shown in figure 2. When the automatic control fails to operate and you must feed the water manually through the bypass system, close the hand-operated valves for cutting out the automatic regulator and open the hand bypass valves. You watch the water level very closely and regulate it by opening or closing the hand bypass valves. Of course, the automatic regulator must be repaired or replaced as soon as possible. The common control that we have just discussed is not the only means of automatically controlling the boiler water level; other methods and devices will be discussed later in this chapter. First however, we are going to discuss some gravity-condensate return systems.

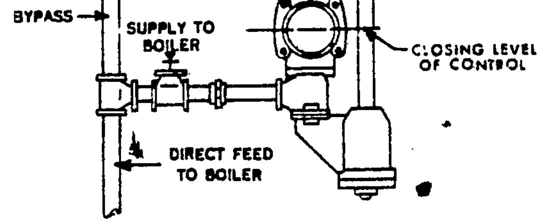

Figure 2. A manual bypass.

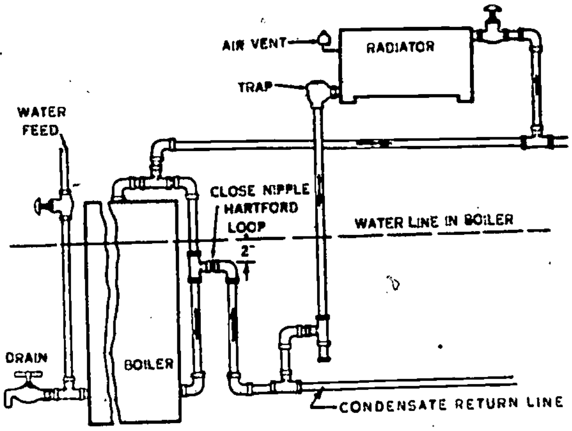

Figure 3. A typical Hartford loop installation.

2. Gravity Condensate Return Systems

1. In many military steam-heating installations, you will find the condensate being returned to the boiler plant by means of pumps, which will be discussed later in this chapter. At this time, however, we are going to discuss returning the condensate to the boiler by means of gravity. Two types of gravity-return systems are the Hartford loop and the mechanical-return trap systems.

2. **Hartford Loop.** The pressure in the return system must be equal to that in the boiler, to make possible the return of condensate by gravity. One method of balancing the return water and steam pressure is the Hartford loop, illustrated in figure 3. This method brings the return line up to the boiler-water level and connects at this point to a steam line that comes down from the top of the boiler. At the junction of the steam line and the return line, a third line drops down to the boiler-return connection. At the junction of the three lines, the steam pressure and return-water pressure are balanced, and the water, being heavier than steam, will return to the boiler.

3. **Mechanical Return Trap.** The mechanical return trap in the steam system, illustrated in figure 4, is another method that is used to balance the pressures and allow the water to return to the boiler by gravity. The trap is vented to the atmosphere and is connected to the steam line and the condensate return line. Two swing-type check valves (one located on each side of the tee connection to the trap) are necessary for the operation of this system.

4. When the boiler pressure is quite low, the condensate returns to the boiler by gravity, but when the boiler pressure exceeds 1 pound, check valve A, shown in figure 4, is held closed and the condensate water backs up into the return trap. When the water level in the trap reaches a predetermined point, the float closes the air vent and opens a pipe leading to the top of the boiler. With the air vent closed and the boiler line opened, the pressure in the trap immediately equalizes with the pressure in the boiler. When this happens, the pressure on each side of check valve A becomes equal and the weight of the water causes

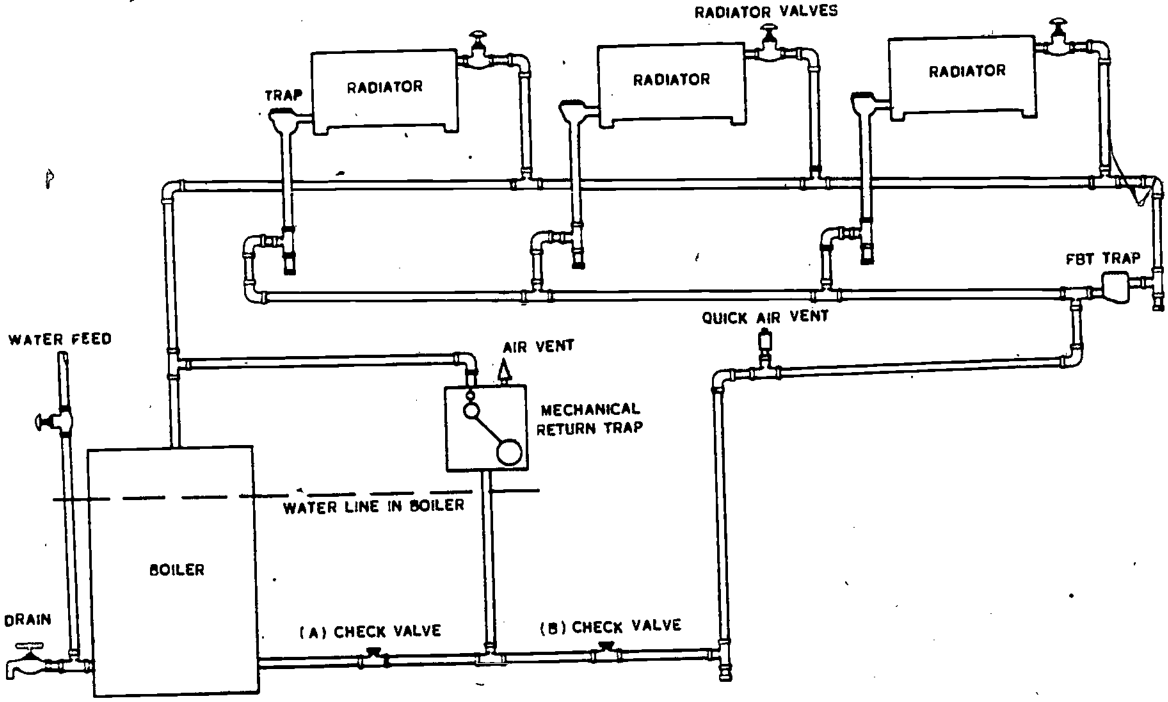

Figure 4. A mechanical return-trap steam system.

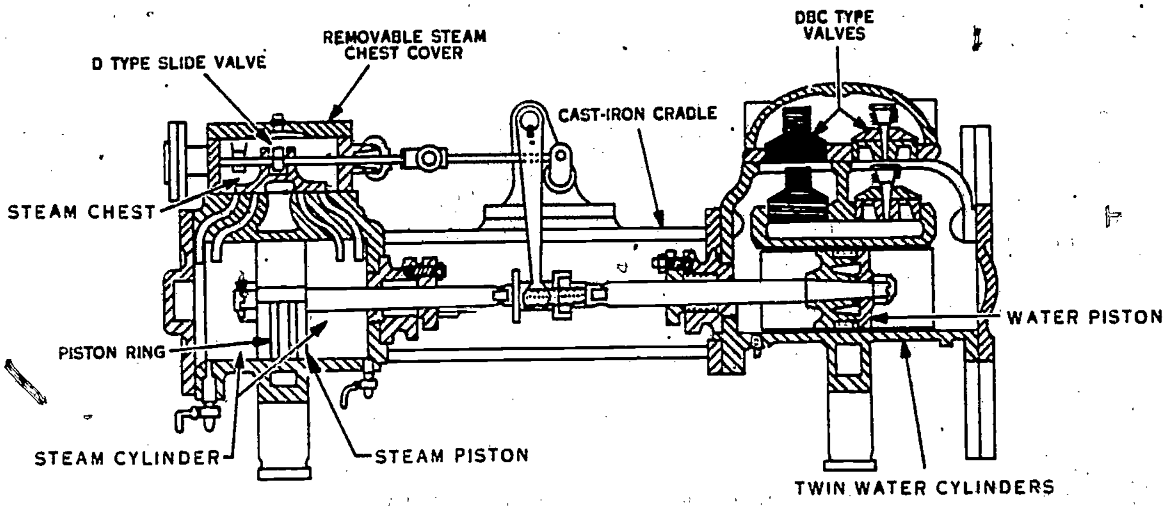

Figure 5. A duplex steam reciprocating pump.

it to swing open and allow the condensate to flow into the boiler. The check valve B, shown in figure 4, prevents the pressure from backing up the water into the return line. When the trap is almost empty, the steam valve closes, the air vent opens, and the trap begins to refill.

5. Although the feed water is supplied to the boiler automatically, it does not relieve the operator from the responsibility of periodically checking the water level by means of the water-glass gage and the gage cocks.

3. Steam-Driven Pump System

1. The water-main feed system with a gravity return for the condensate cannot be used with high-pressure boilers because the pressure in the water main is not great enough to overcome boiler pressures. Consequently, a pumping system must be used. Steamplants that use pumps for both the regular feed system and the standby system must have at least one of the pumps steam driven. Otherwise, a third method such as a steam-driven injector must be installed. Most steam pumps are of the duplex type. The duplex pump, illustrated in figure 5, consists of a piston rod having a steam piston and a cylinder at one end and a water piston and a cylinder at the other end. Both cylinders are cast together as one unit.

2. The steam sections of duplex pumps are normally controlled by slide valves mounted above the cylinders and operated by the piston rods through rocker arms and valve rods. The details of one side of such a pump are shown in figure 6. Each water cylinder has an intake valve and an outlet valve operated by the suction and pressure caused by the movement of the pistons.

3. There are many ways of controlling the flow of steam to a steam-operated pump. The operation of the pump, in one method, is controlled by the water-level control on the boiler. The water-level

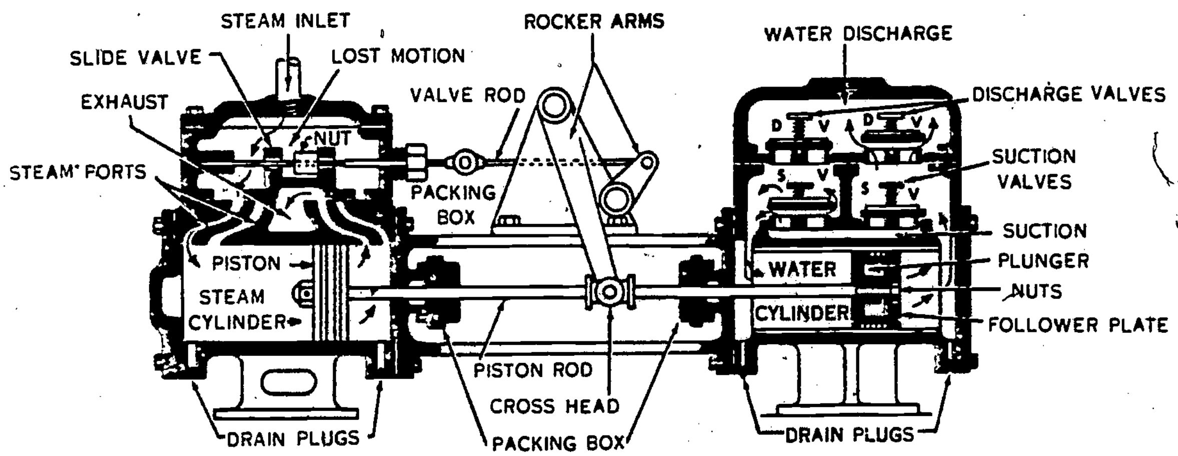

Figure 6. Cutaway view of a duplex steam reciprocating pump.

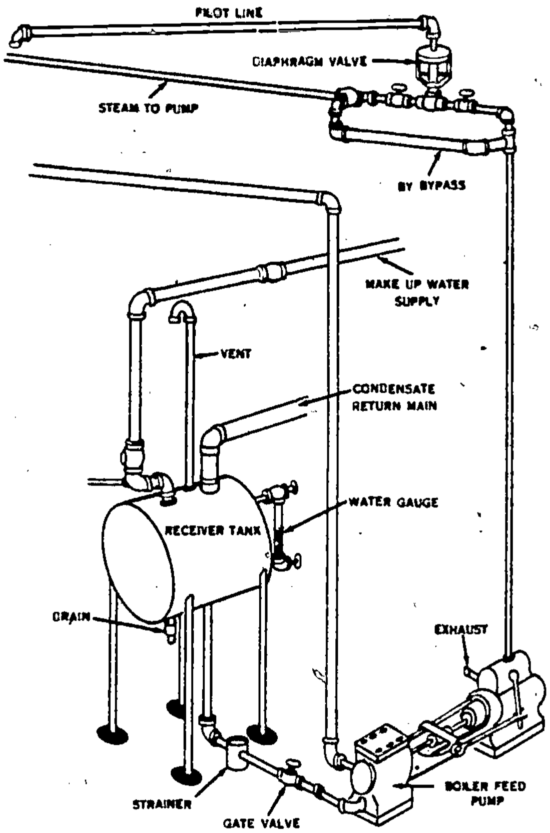

Figure 7. A steam pump controlled by a diaphragm valve.

control operates a steam valve which opens to allow steam to flow to the feed pump when water is needed by the boiler. When the pump has replaced the required amount of water, the steam valve closes and stops the pump. When the feed water is too hot, 212° F. or higher, the pump will not operate properly and will exceed its normal speed, thus causing damage to the pistons and cylinder heads. The normal speed of the pump is from 5 to 50 strokes per minute.

4. Another method has the flow of steam going to the pump controlled by a diaphragm valve located in the steam supply line, as shown in figure 7. The valve is opened by spring pressure applied on the underside of the diaphragm and closed by water pressure applied on the top of the diaphragm. The water pressure for closing the valve is supplied by a pilot line running from the boiler feed line or pump discharge. When the boiler water-level control calls for water, a valve in the feed line opens and allows the pressure in the pilot line to drop. The spring then opens the diaphragm valve and allows steam to flow to the pump. The pump now starts, and it supplies feed water to the boiler. When the boiler requirements are satisfied, the water-level control closes the feed valve. The closing of this feed valve creates an increase in pressure in the feed line. This increase in pressure is transmitted to the diaphragm through the pilot line and closes the valve. This action shuts off the steam supply to the pump and the pump stops.

5. The water piping between the boiler and the steam pump is similar to that of the water-main supply system. The supply of water to the steam pump is taken from a condensate receiving tank. The water piping between the boiler and the steam pump is shown in figure 7.

6. **Steam-Pump Maintenance.** The steam pump will give years of satisfactory service if it is properly maintained. Give particular attention to the lubrication of the pump. Lubricate all external moving parts frequently with mineral oil. If the pump is equipped with a lubricator, you keep the lubricator filled with the type of oil recommended by the manufacturer. In most cases the manufacturer furnishes complete maintenance instructions with the pump; however, there are some things you should inspect whether or not these instructions are furnished by the manufacturer.

7. These inspections should include examining for leaks around the packing glands, which cause the loss of condensate and create the hazard of burning the operator. The leaks can be stopped, in most instances, by tightening the packing-gland nuts. You should use extreme caution when you tighten these nuts. If they are drawn down unequally or excessively, the packing will score or scratch the shaft. This condition causes the leak to become even worse than before.

8. When a packing gland continues to leak water or steam after the packing-gland nuts have been tightened, it is best to let it leak until the pump can be shut down and the gland repacked or the shaft refinished as necessary. Again, we remind you that for the most efficient results these repairs and adjustments should be made in accordance with the manufacturer's recommendations. These instructions generally vary with each different type of pump.

9. **Thermo-Expansion Water-Level Control.** In some big steam feed-water systems you will find two large water-level controls, which are commonly referred to as feed-water regulators. One of these controls is the thermoexpansion type, as shown in figure 8. It has an expansion generator called a "thermostat," which consists of a metal tube mounted on a rigid frame. The tube is connected to the boiler at about the normal water level much the same as a water column or gage glass. The tube is fastened at one end and is free to move at the other end. Linkage connects the free end of the tube to a valve bellcrank, which, in turn, opens and closes the regulating valve. The

bellcrank has its fulcrum point attached to the valve.

10. When the water level in the boiler drops, more steam is allowed to enter the tube and heat it. More steam causes the thermostat to expand and operate the linkage that opens the valve. This allows more feed water to be forced into the boiler. As the water level in the boiler rises, less steam is admitted to the tube of the thermostat; consequently, the tube cools and contracts. The operation of the linkage and bellcrank this time closes the regulating valve.

11. **Thermohydraulic Water-Level Control.** Another water-level control is the thermohydraulic type, also commonly called a *regulator.* This unit is made up of a generator and a regulating valve, as shown in figure 9. The generator consists of an outside tube and an inside tube. The outside tube is filled with water, except for some space left for the generation of steam. This outside tube also has fins on the exterior to increase its cooling rate. The outside tube is connected by other tubing to a bellows in the regulating valve. This makes it a closed system. The inside tube is connected to the boiler shell in much the same way as a water column or a gage glass. The regulator is mounted at the boiler water line; therefore, the inside tube contains both steam and water.

12. The regulating valve is opened or closed by the water in the closed system of the outside tube, which actuates the bellows in the regulating valve. Thus, the valve controls the flow of water to the boiler. When the water level in the boiler drops, more steam is allowed to enter the inside tube. The heat from the steam in the inside tube is then transferred to the water in the outside tube. This causes the water to change to steam. The steam, in turn, creates pressure in the closed system of the outside tube. This increased pressure acts on the bellows of the regulating valve and opens the valve. This allows water to flow into the boiler.

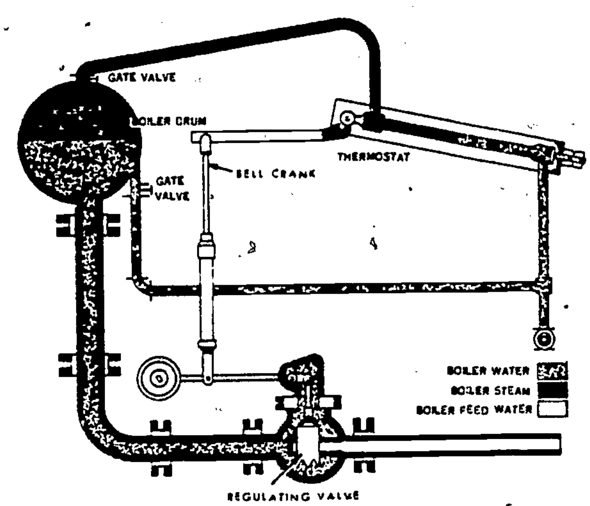

Figure 8. Thermoexpansion water-level control.

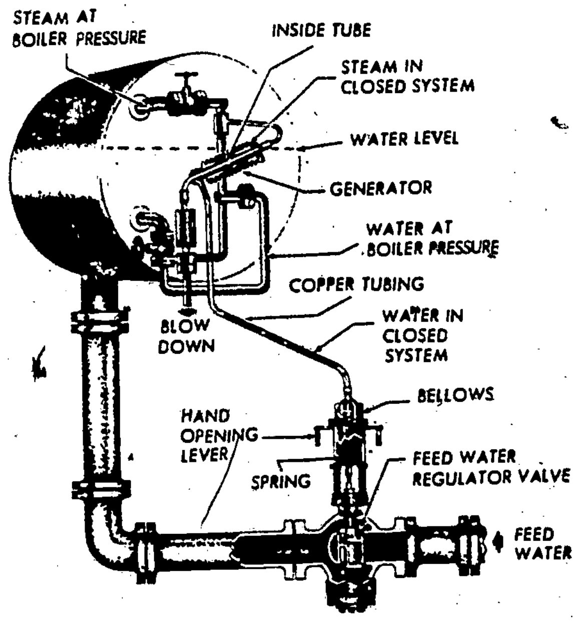

Figure 9. Thermohydraulic water-level control.

13. When the water level rises, less steam goes into the inside tube. The tube then cools and less heat is transferred to the outside tube. The steam in the outside tube cools and condenses from steam to water, thus relieving the pressure on the bellows in the regulating valve. When the pressure on the bellows is removed, the regulating valve closes. This shuts off the water to the boiler. The closing of the valve is accomplished by the spring located in the valve body, which is shown in figure 9.

4. Centrifugal Rotary Pump

1. Many boilerplants use some type of centrifugal rotary pump to feed water into a boiler. The centrifugal pump construction varies slightly with different manufacturers. In general, however, the centrifugal pump is simple in construction. It discharges water at a uniform rate of flow and pressure. In most cases, the pumps do not contain valves or pistons. Centrifugal pumps generally operate at high speeds and can handle water even though it contains some small particles of foreign matter. To illustrate centrifugal force let us imagine that a man is whirling a bucket of water rapidly around and around in a circle. The outward pull, or centrifugal force, developed by this whirling action holds the water against the bottom of the bucket without spilling—even when the bucket is upside down.

2. To apply the principle of the whirling bucket to centrifugal pumps, suppose you have

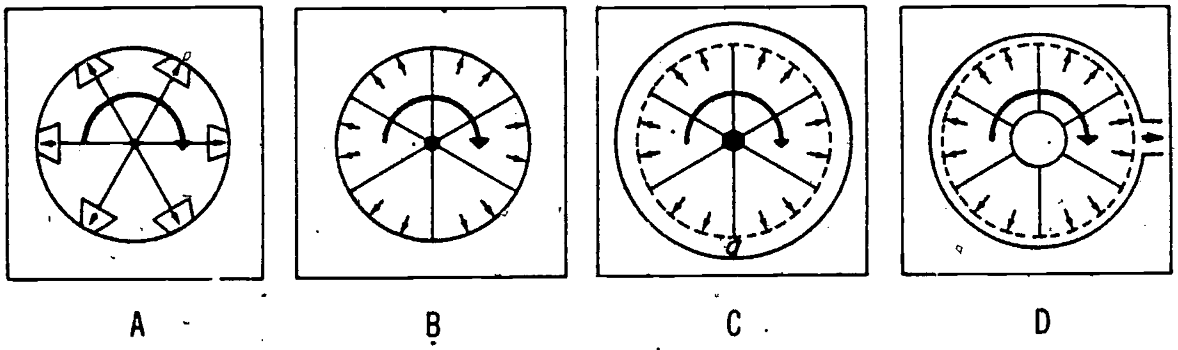

Figure 10. The principle of the centrifugal pump.

a number of bottomless buckets rotating about a center, as shown in detail A, figure 10. The drum wall against which these buckets rotate forms a continuous bottom. As the buckets rotate, the water is held against this continuous bottom by centrifugal force.

3. Now, suppose that the buckets are arranged in pie-shaped fashion as illustrated in detail B, figure 10. When the buckets rotate, they produce the same effect as a paddle wheel revolving in a drum-shaped container. Because of centrifugal force, there is a continuous liquid pressure all over the circumference of the container.

4. Let us further suppose that we have increased the diameter of the container, as indicated in detail C, figure 10. The purpose is to provide a space (a, detail C) for liquid between the ends of the paddles and the drum. The wedge-shaped buckets now have a liquid bottom, but the action remains the same as before. The rotation of the liquid in the buckets, because of centrifugal force, pushes outward against the liquid bottom, thus producing pressure on the liquid in space (a).

5. If an opening were made in the drum, this pressure would cause the liquid in the space (a) to be discharged. Now, let us go a step further and suppose that we provide a central opening in the container whereby the buckets will be continuously filled with liquid; also, let us provide a source of power to rotate the paddles. These additions make possible a continuous flow, as illustrated in detail D, figure 10.

6. The centrifugal pump has two major disadvantages: (1) It has a comparatively low efficiency and (2) it is unable to discharge air or vapor. However, its advantages more than offset its lower efficiency. The inability of the pump to discharge air can be overcome by correct piping installation and proper operation practices. In some cases you will find that the pump has not been correctly installed to provide for air elimi-

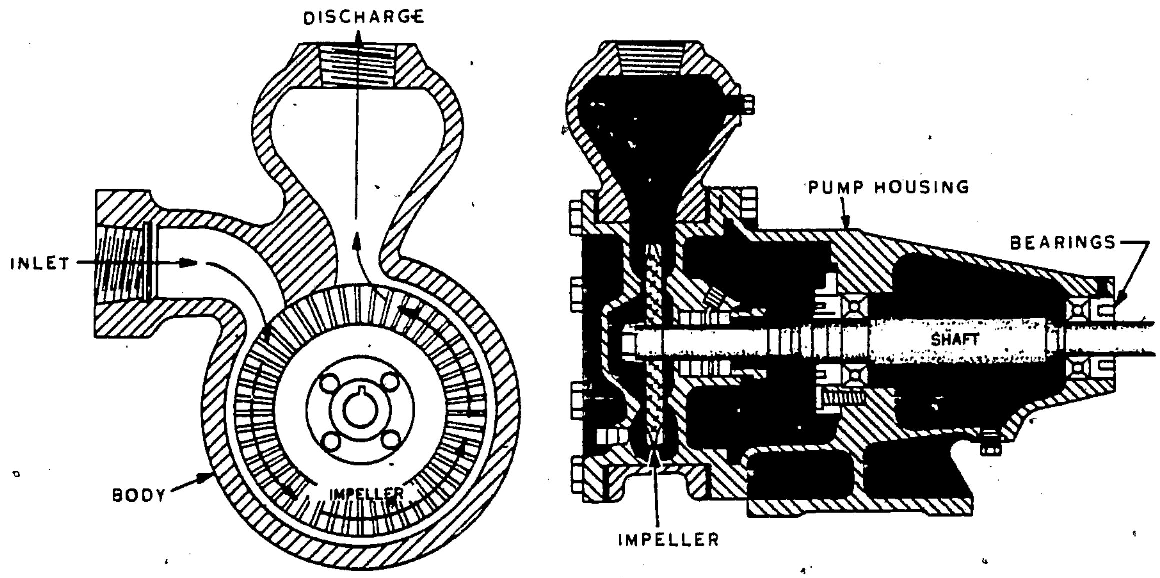

Figure 11. A centrifugal pump.

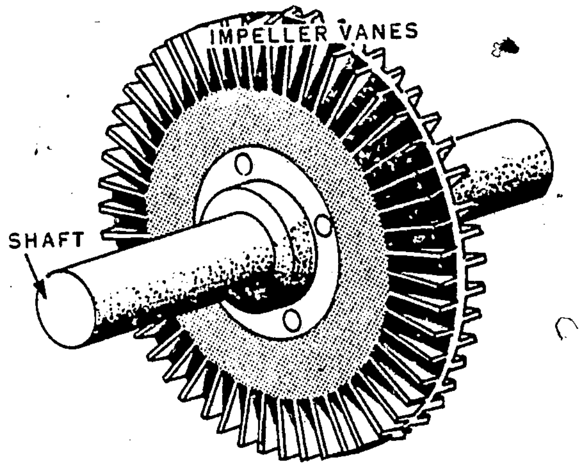

Figure 12. An impeller.

nation, nor has it always been properly operated. Therefore, you will frequently be required to bleed the pump. Otherwise, the piping and the operating practices will have to be changed to prevent air from entering the pump.

7. There are many different types of pumps that employ the centrifugal rotary principle. Of these, the turbine design is very suitable for use as a feed-water pump because of its high-discharge pressure. The discharge pressure must be sufficiently high to overcome the boiler operating pressure. The pump consists of an impeller shaft and housing with bearings, as shown in figure 11. The liquid enters the pump and is carried around the inside by the blades of the impeller and forced out through the discharge opening which connects with the boiler feed line.

8. The impeller, illustrated in figure 12, consists of a number of small vanes mounted around a hub. The vanes act as pockets with

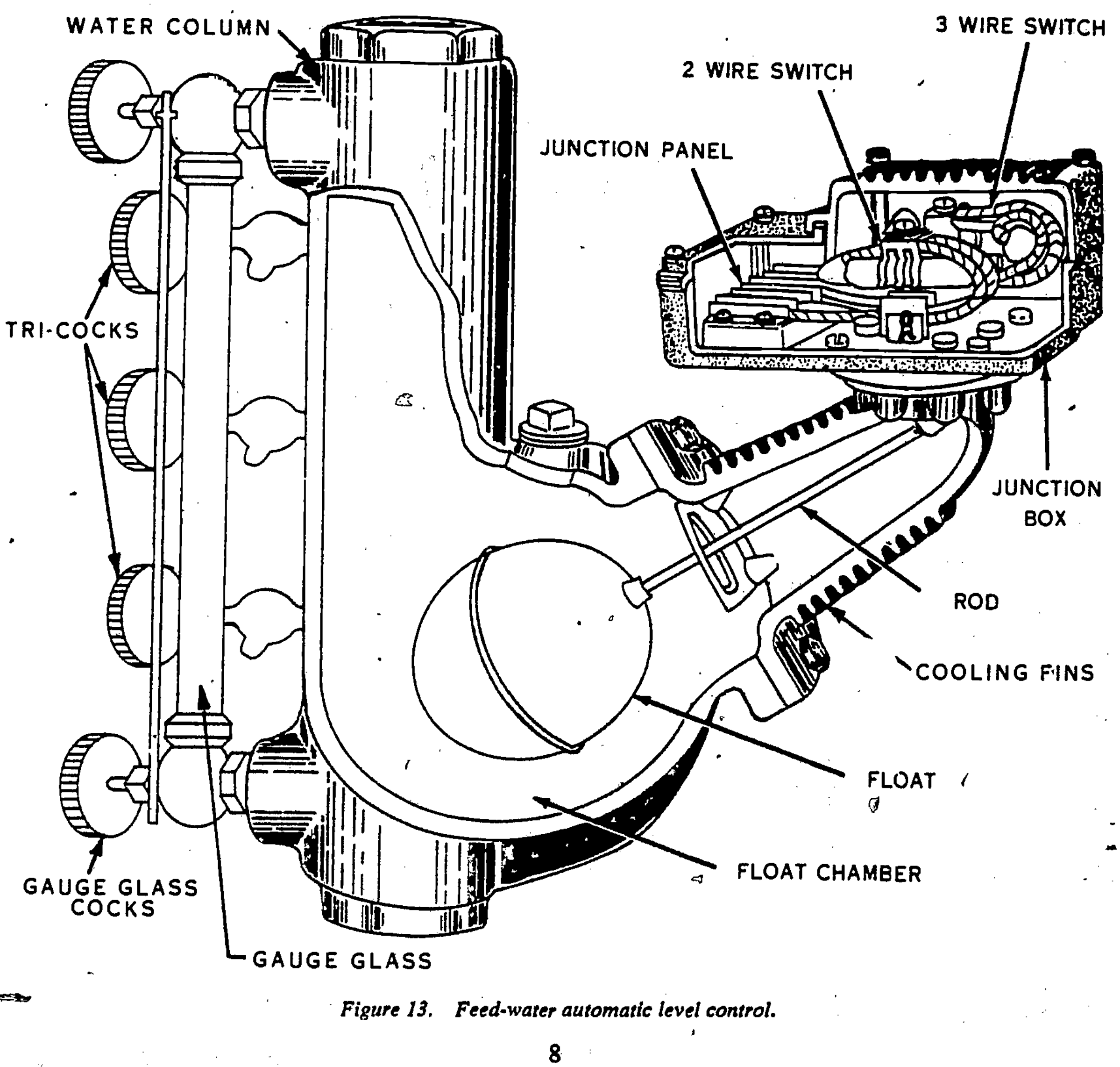

Figure 13. Feed-water automatic level control.

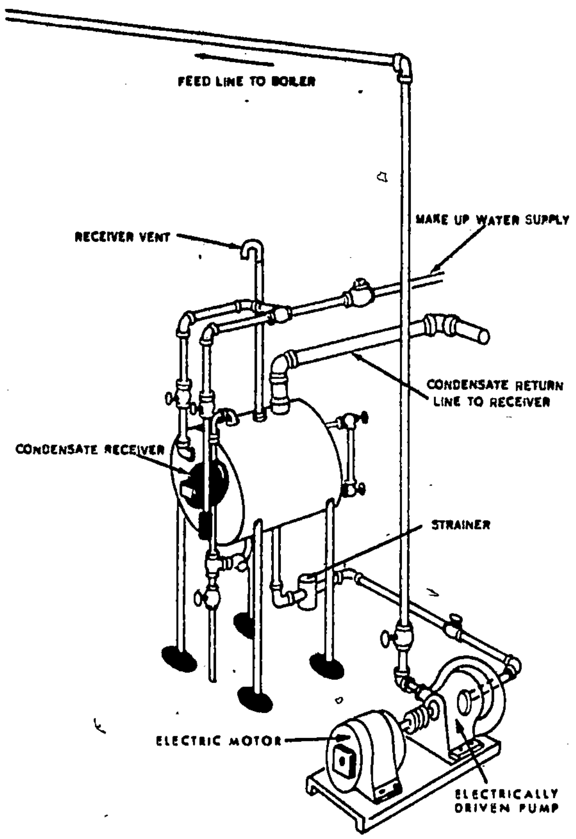

Figure 14. Piping arrangement for an electrically-driven feed-water pump.

which to pick up the liquid and carry it to the discharge outlet. The pump is usually equipped with factory-sealed ball bearings which do not require any lubrication.

9. Feed-water pumps can be adapted to an automatic control by operating them with electric motors. The feed-water control, shown in figure 13, attached to the boiler operates an electrical switch by means of a float, in accordance with the water level in the boiler. The switch closes and energizes an electric circuit which starts the operation of an electric motor when the boiler requires water. After the boiler is filled to the correct level, reverse action takes place, causing the electric motor to stop.

10. The piping arrangement for a boiler with an electric feed-water pump is illustrated in figure 14. This piping arrangement is provided with a valve installed in the piping between the condensate receiver and the pump, and still another valve between the pump and the boiler. By closing these valves, you can repair or replace the pump without interrupting the operation of the boiler. However, when this pump is taken out of service, the standby feed-water system must be placed in operation. The standby feed-water system usually is a boiler steam injector.

11. Before starting a new pump or one that has been idle for a long period of time, you should turn the pump shaft by hand to see that the impeller is free. Also, be sure that all valves in the feed line between the pump discharge and the boiler are open. Your failure to do these things can result in damage to the pump and the motor. Before putting this type of pump into operation, you should insure that the mounting bolts are tight and that the motor and pump are properly aligned. Improper alignment can cause damage to the couplings and bearings, and result in a bent pump shaft. If the water supply inlet is lower than the pump, it may be necessary to prime the pump. This is done by removing the priming plug, shown in figure 15, and pouring water into the pipe until the pump will start pumping water. There should always be a nonreturn or check valve installed between the boiler and the pump discharge. This prevents hot water or steam from traveling from the boiler to the pump and causing damage to the pump parts.

12. Operator's maintenance of the electrically driven feed pump consists mostly of cleaning the pump and motor. However, the pump motor is lubricated according to the manufacturer's specifications. Remember that not using enough lubricant can result in the bearings running dry or seizing on the motor shaft. But, too much lubricant causes the motor to become dirty, and it can result in the motor windings becoming saturated with oil and burning out.

13. However, when a water leak develops around the pump shaft, it is necessary to tighten the packing-gland nuts or repack the stuffing box as necessary. The strainer installed between the pump and the condensate receiver should be kept clean to avoid any restriction of the flow of water to the pump.

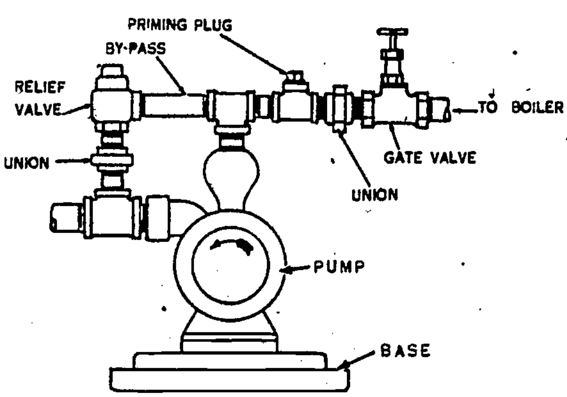

Figure 15. The location of the priming pump.

5. Injector Feeder System

1. The injector is best known as the locomotive boiler feeder, but it is also used to some extent by the military in boiler plants as an emergency reserve or standby feed unit. It is used when pumps or other means of feeding water fail. One drawback to using the injector is that it will not feed water when the water is very hot. Under the best conditions, the injector will lift 120° F. water approximately 14 feet.

2. The installation of an injector is comparatively simple; it is mounted on the side of the boiler. Four line connections are made to the injector: the steam supply line from the boiler, the water supply line from a reservoir, the discharge line to the boiler feed-water inlet, and the water overflow line.

3. The controls for an injector consist of a steam supply valve, a water supply valve, a discharge valve to the boiler, and a check valve in the discharge line. A typical installation of an injector and the piping is shown in figure 16. The injector shown in figure 17 consists of a steam nozzle, combining tube, delivery tube, ring valve, overflow valve, and injector body.

4. Some degree of skill is required to start an injector, but once it is operating, it will continue to operate until the operator manually shuts it down. To start the injector, the operator first opens the water supply valve about one full turn.

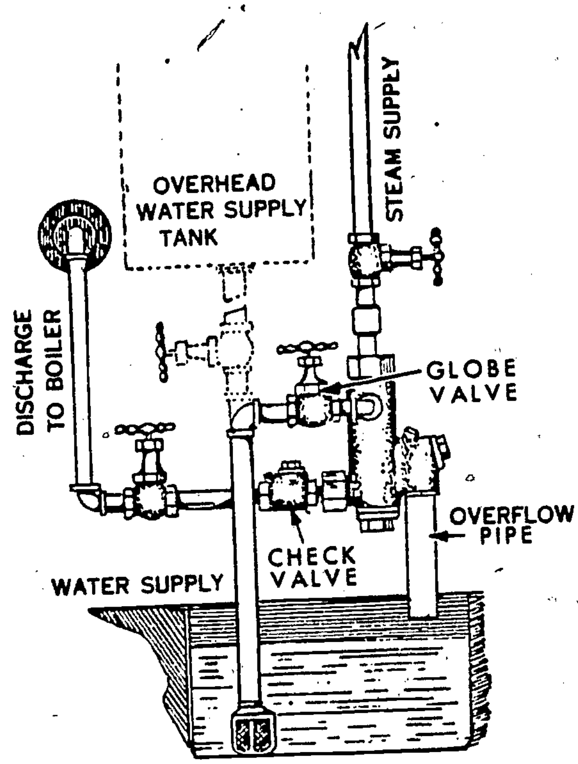

Figure 16. A typical injector installation.

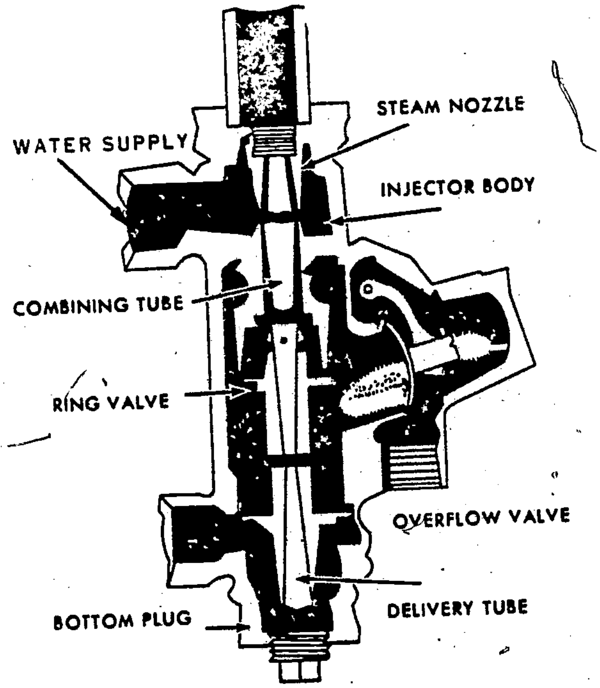

Figure 17. A cutaway of a steam injector.

Then, he quickly turns the steam supply valve all the way open. Steam rushes into the combining tube of the injector; and as it speeds past the water supply opening, it creates a suction that draws water through the opening into the combining tube. Water and steam are then mixed together inside the injector and the steam pressure opens a valve that leads to the boiler. In the meantime, there is an excess of water in the injector which is discharged through an overflow valve. Next, the operator slowly turns the water supply valve toward the closed position until the overflow stops. The overflow valve has closed and all of the water being picked up from the supply line is going into the boiler.

5. The water supply should not be hotter than 120° F. for the injector to operate. If several unsuccessful attempts are made to operate the injector, it becomes very hot and will not prime. It is necessary to pour cold water over the injector until it is cool enough to draw water from the supply when the steam valve is opened.

6. Injectors require very little maintenance. After a period of time, it will be necessary to reseat the overflow and ring valve. Lime deposits from the water also can reduce the operation by closing down the size of the combining and delivery tubes. Placing the injector in a container of muriatic acid for several hours will remove the lime deposits.

7. It is necessary to remove the bottom plug, shown in figure 17, to clean the injector. The

delivery tube and ring valve will drop out. After cleaning the passages and holes, the delivery tube and the ring valve are replaced by setting them in the plug (which acts as a guide) and screwing it tightly in place.

6. Feed-Water Heaters

1. A feed-water heater is used to increase the efficiency of boiler operation by heating the feed water. The hotter the feed water is, the less is the amount of fuel required to bring the water to the boiling point. This preheating often results in economy.

2. Feed-water heaters raise the temperature of the makeup water by using the exhaust steam from boilers or the hot flue gases from smokestacks. Heated water liberates the oxygen and other gases carried in the water. The liberation of these gases, in turn, decreases oxidation in the boiler and the steam distribution system. The use of the heat from exhaust steam that would otherwise be lost increases boilerplant efficiency 1 percent for each 10° increase in feed-water temperature. There are several types and designs of feed-water heaters available, and each unit differs according to the manufacturer. In general, however, feed-water heaters may be divided into three types: open, closed, and economizers.

3. **Open-Type Heater.** The open-type feed-water heaters, illustrated in figure 18, heats water by direct contact with the steam. These heaters are usually cylindrical in shape and have an air vent located at the top. Steam enters the side of the heater through an oil separator. The water to be heated, usually from the condensate return, enters at the top and is distributed over the trays in rainfall fashion. The steam comes in direct contact with the water and is condensed as the water is heated. Oxygen and other gases are liberated to the atmosphere through the vent. Such heaters are provided with a sight glass that indicates the water level (not shown), a drain valve for draining the solid materials which settle to the bottom, and a regulating float valve in the supply line. Some heaters have provisions for skimming any foreign matter that collects on the surface of the water in the heater.

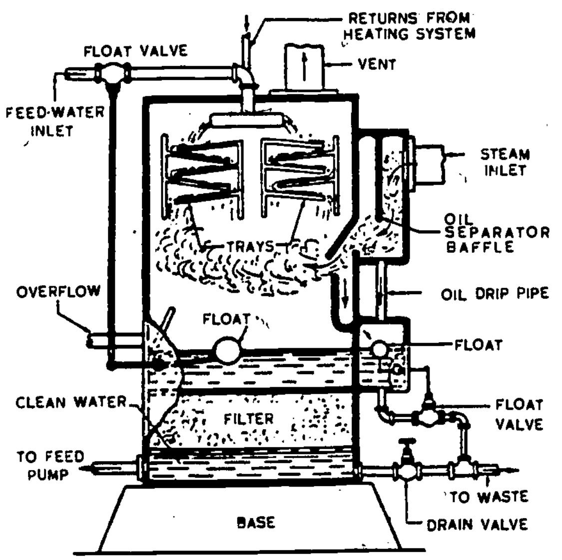

Figure 18. Open-type feed-water heater.

4. **Closed-Type Heater. The closed-type feed-water heater is constructed so that the steam which heats the water and the water do not come into direct contact. They are separated from each other by metal surfaces such as tubes. The tank of the heater is supplied with steam, and the water passes through tubes heated by the steam. Figure 19 illustrates a typical closed-type feed-water heater. The closed-type feed-water heaters are not very common on military installations; however, some posts have them installed.**

5. **Economizer-Type Heater.** The economizer is another unit used to heat feed water. Economizers have horizontal tubes that are arranged in staggered, closely spaced rows. The tubes are placed in the path of the hot flue gases, and the water flows inside the tubes. As the hot flue gases pass around the tube, the water inside is heated. The water can flow either upward or downward through the economizer. However, the upward flow is preferred when there is a possibility of steam being generated in the tubes. When a downward-flow economizer is used and some steam is generated, there is improper circulation through the unit.

6. The maintenance of feed-water heaters and economizers normally includes removing the solid matter that accumulates in the unit; stopping steam and water leaks; and repairing inoperative traps, floats, valves, pumps, and other such associated equipment.

7. Now that you have finished your study of the discussions regarding the methods of heating feed water, we believe you will be interested to know about water conditioners.

7. Water Conditioners

1. Water conditioners are used to soften and otherwise condition the feed water before it is fed into the boiler. This work is accomplished by removing the minerals that cause hardness, oxygen, and foreign matter from the water.

2. **Water Softeners. The first group of these water conditioners that we have selected to discuss is the water softener. Military installations normally use three processes for water softening: the sodium-zeolite, the lime-soda, and the hydrogen-zeolite.**

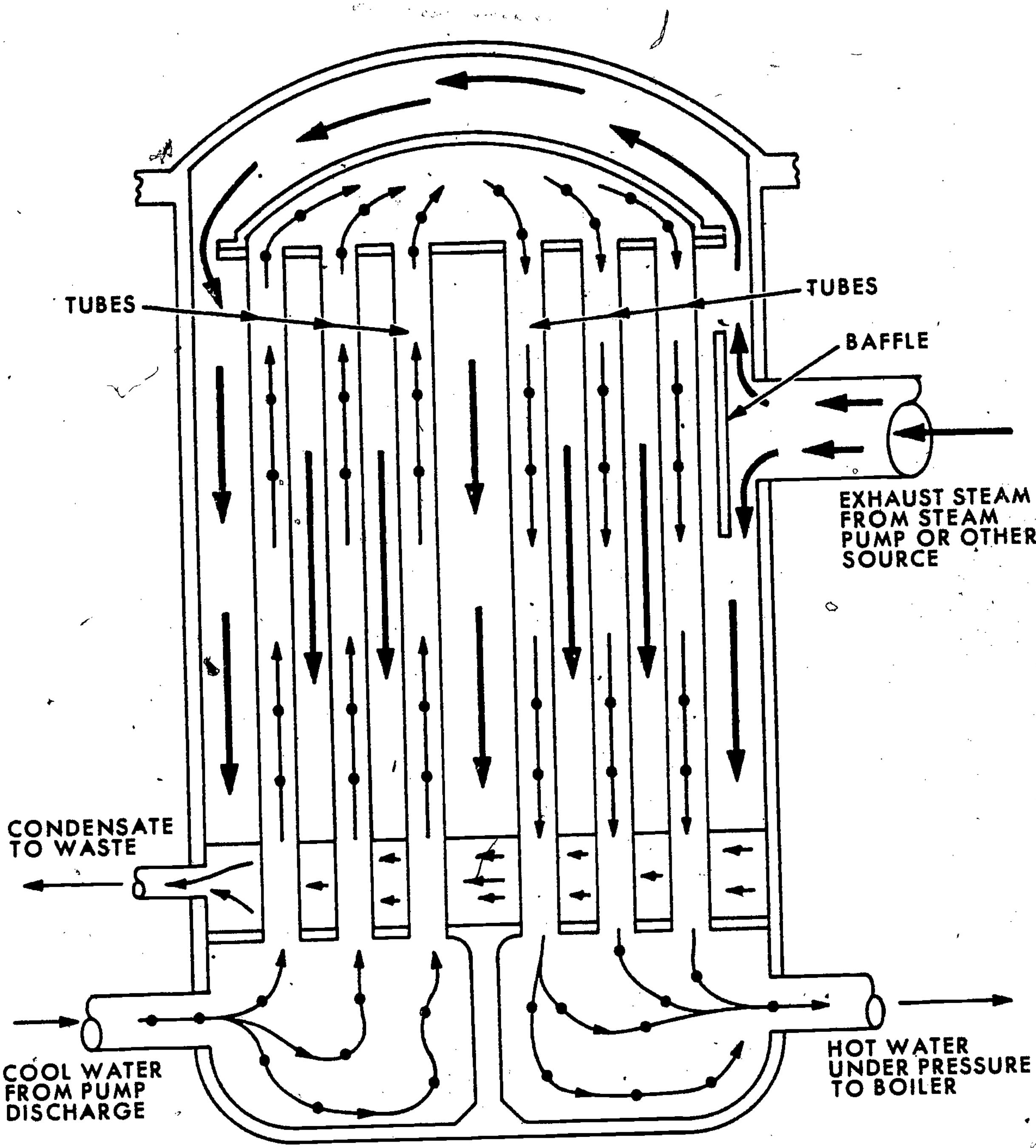

Figure 19. Closed-type feed-water heater.

3. *Sodium-zeolite.* The pressure-type sodium-zeolite softener consists of a steel shell which contains a bed of zeolite supported by several layers of graded gravel. These softeners may be operated either manually or automatically. A manually operated water softener is shown in figure 20.

4. The water is admitted to the upper portion of the shell and passes over the zeolite bed. There the ions of calcium and magnesium, which cause the hardness in water, are attached to the zeolite and replace the ions of soluble sodium salt. This action is called *ion exchange*. Then, the water that has passed through the bed of zeolite passes on through the gravel bed and collects in an underdrain system. The accumulated soft water is discharged to the feed-water system and goes to the boiler as required.

5. You will find the capacity of most water softeners stamped on a plate mounted on the unit. Now, you are perhaps wondering what happens when the softener reaches its rated capacity? Or,

you would like to know why sodium salts are placed in the softener to be exchanged for the calcium and magnesium ions.

6. When a water softener reaches its capacity, as determined by a soap test, the softener is put through a process called *brining*. The brining process is done to regenerate the zeolite. A predetermined volume of saturated brine is admitted into the softener, and the soluble sodium salt ions replace the ions of calcium and magnesium. The directions for mixing the brine are usually furnished by the softener manufacturer. The brine is usually a mixture of rock salt and water.

7. When the brining process is finished, the softener must be rinsed with a predetermined amount of clean water. During the rinsing, the water is allowed to flow over the zeolite from top to bottom. This washes the chlorides of calcium, magnesium, and excess salt into the drain. After this, the softening cycle may start all over again.

8. When you know the capacity of a water softener, you can check its performance efficiency. For example, if a sodium-zeolite unit has an exchange capacity of 250 kilograins [1 kilograin (kgr) is equal to 1000 grains (g)] and the raw, unsoftened water has 10 g of hardness per gallon, the unit can soften 25,000 gallons (250 kgr × 1000 g ÷ 10 g = 25,000 gal) of water between regenerations. Should the unit show the need for regeneration after processing only 20,000 gallons of the same 10-grain hardness of water, then the efficiency of the unit is 80 percent ($\frac{20,000 \text{ gal}}{25,000 \text{ gal}}$ × 100 percent = 80 percent). You should often check the efficiency of the water softener. If it shows a marked decrease in efficiency, you should determine whether the hardness of the raw water has changed or if the change is due to other factors.

9. *Lime-soda.* The lime-soda softener is used to precipitate the hardness salts of calcium and magnesium from the water. A typical lime-soda water softener is shown in figure 21. When using this hot process lime-soda water softener you should strictly follow the manufacturer's instructions.

10. The hard water is heated to 212° F., or higher, by using live steam or exhaust steam in a jet, tray, or deaerating heater. The high operating temperature develops maximum treatment efficiency. A mixture of lime and soda ash is added to the hot water causing the hardness salts to precipitate. The soft water settles to the bottom of the tank, then rises through the uptake cylinder, and flows to the filter. The softening process takes from 1 to 2 hours. The filter removes the remaining precipitate and leaves the water clear. The heater element must be thoroughly vented at all

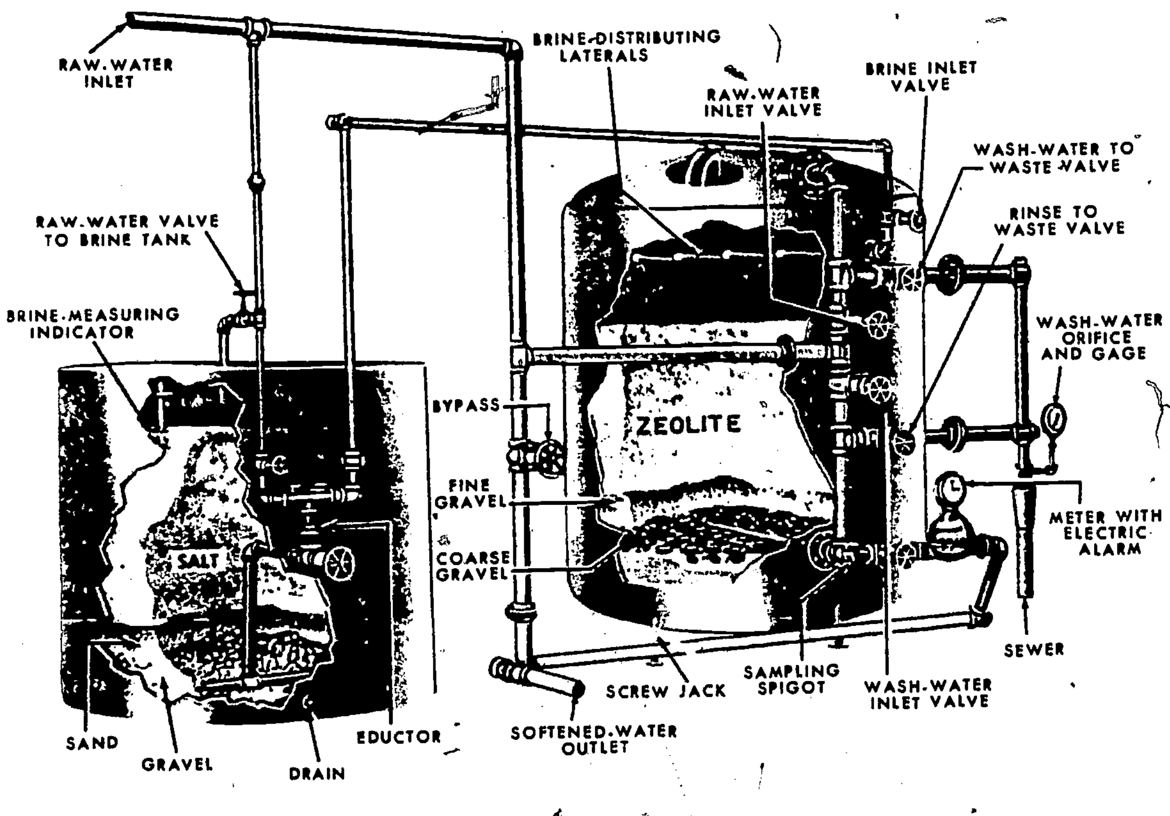

Figure 20. Sodium-zeolite softener.

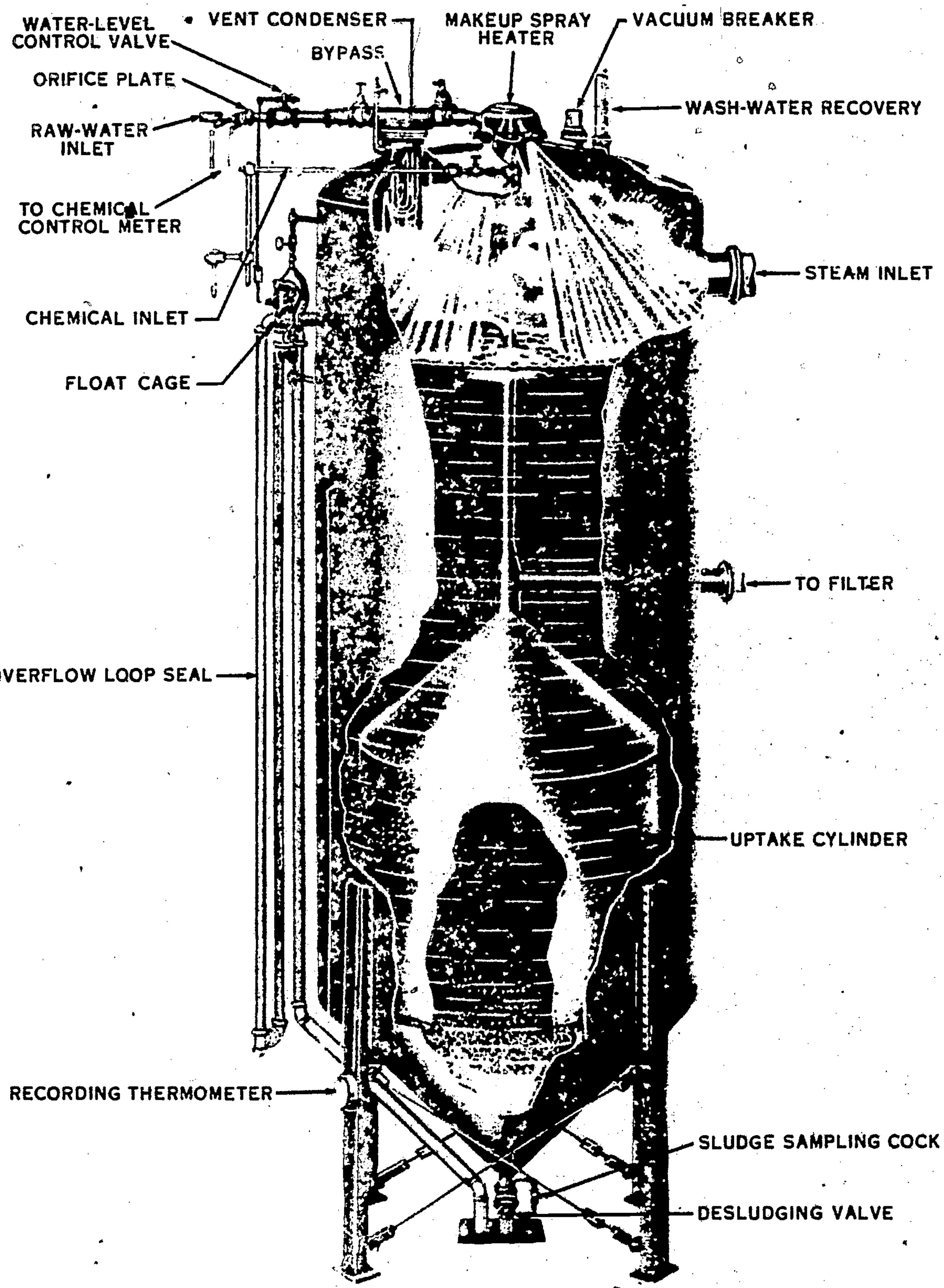

Figure 21. Lime-soda softener.

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times so that the dissolved gases will be removed. The softener should be regenerated in accordance with the manufacturer's instructions.

11. Lime-soda softening equipment requires special maintenance to insure the efficient operation of heaters, filters, and chemical feed pumps. All equipment including pumps, meters, valves, motors, and the like, must be inspected periodically and adjusted according to the manufacturer's instructions in order to get proper service from the unit.

12. *Hydrogen-zeolite.* The hydrogen-zeolite acid cycle softener is used when it is necessary to reduce alkalinity and soften the water at the same time. Consequently, these softeners are not widely used in the military. This type of water softener is used only where special water problems are involved. The softeners themselves can present quite a problem when they are not properly operated. When you are adding acid to the water, you can very easily develop acid corrosion in the system.

13. The proper operation and maintenance procedures are normally furnished with the softener by its manufacturer. Hydrogen-zeolite softeners vary considerably with each unit; therefore, we will not attempt to discuss the differences in each of these units.

14. **Deaerators.** Deaerators and deaerating heaters are of the tray type and the spray type, depending upon the method used to break up the water. Figure 22 illustrates a tray-type deaerating heater. During operation, the water passes through the vent condenser, enters the spray distributor, and is sprayed upward. The water breaks into small droplets and is forced into intimate contact with the steam. Most of the noncondensable gases are eliminated and the water is heated almost to a steaming temperature. When the water reaches the temperature of saturated steam, corresponding to the pressure in the deaerator, the gases are completely liberated. The deaerated water then goes from the tray section into the storage reservoir.

15. A float assembly (not shown) similar to the ones shown in figures 21 and 23, that actuate the water-control valves, controls the water level in the tray-type deaerating heater. The steam enters through a nozzle in the side of the shell and flows through perforations in the top plate of the tray section. Here it meets the water sprayed upwards from the distributor. Most of the steam is condensed by the time it passes through the tray stack. The remaining steam and any noncondensable gases enter the vent condenser. There the gases are discharged into the atmosphere, but the last of the steam is condensed and the water drains back into the unit.

16. In the spray-type deaerating heater the water is broken up by spray valves instead of being allowed to cascade through a tray stack. Figure 23 illustrates a spray deaerating heater. The water is heated to the saturation temperature. Other than the difference in which the water is broken up, the spray deaerating heater works in much the same way as the tray-type.

17. **Demineralizers.** Demineralization is the process of removing mineral salts from the water by ion exchange. With most water supplies it is possible to remove salts to an equal or even greater extent than would be possible by distillation. Demineralization involves two ion exchange reactions. First, the cations, such as calcium, magnesium, and sodium, are removed in a hydrogen cation exchanger. This is the same process as the hydrogen-zeolite cycle you have just previously studied. In a sense you might even consider water softeners as types of demineralizers. Second, the anions, such as sulfate and chloride, are removed in an anion exchanger, which is usually regenerated with caustic soda.

18. The demineralization process is expensive and, therefore, is limited to applications where severe operating conditions occur.

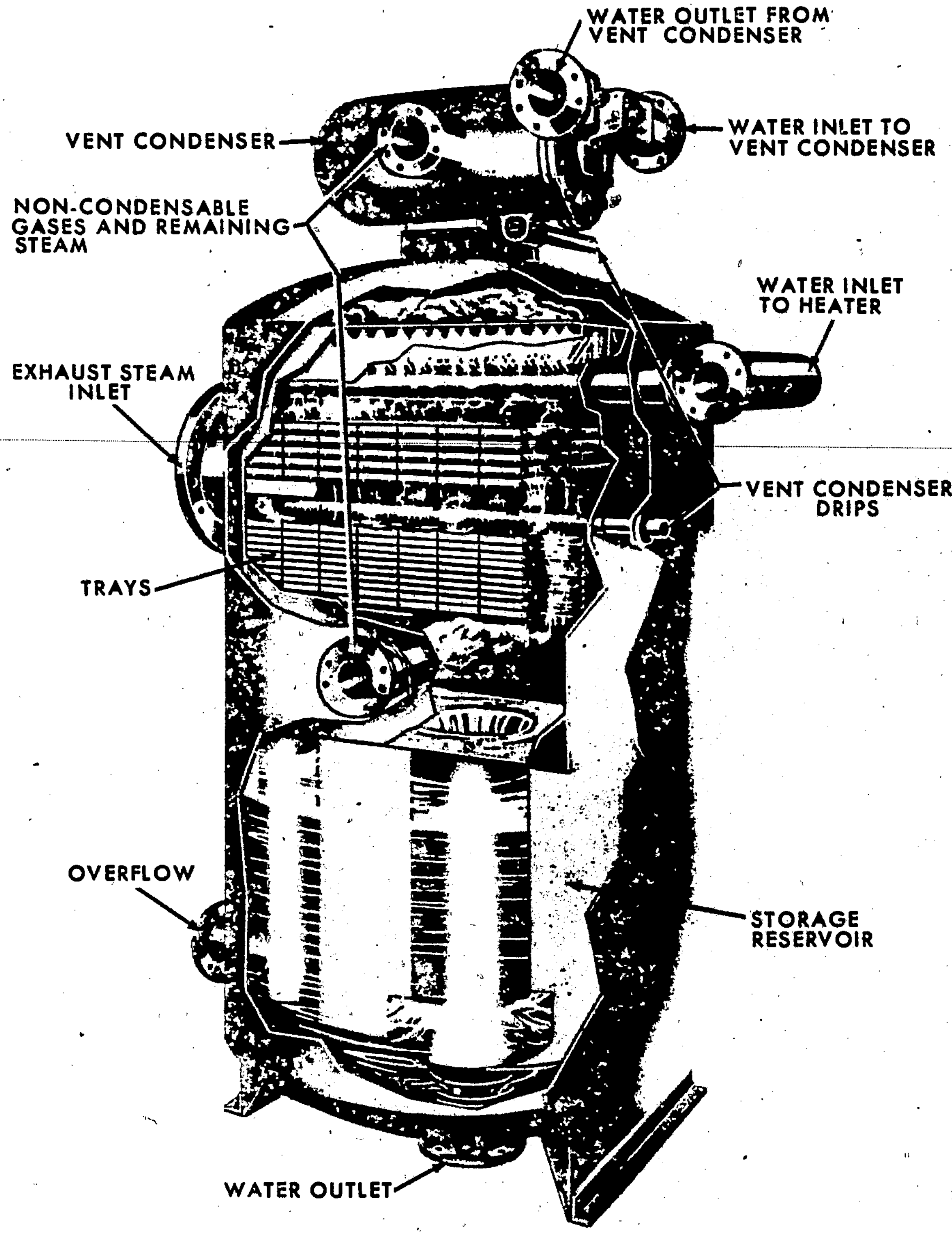

Figure 22. Tray-type deaerating heater.

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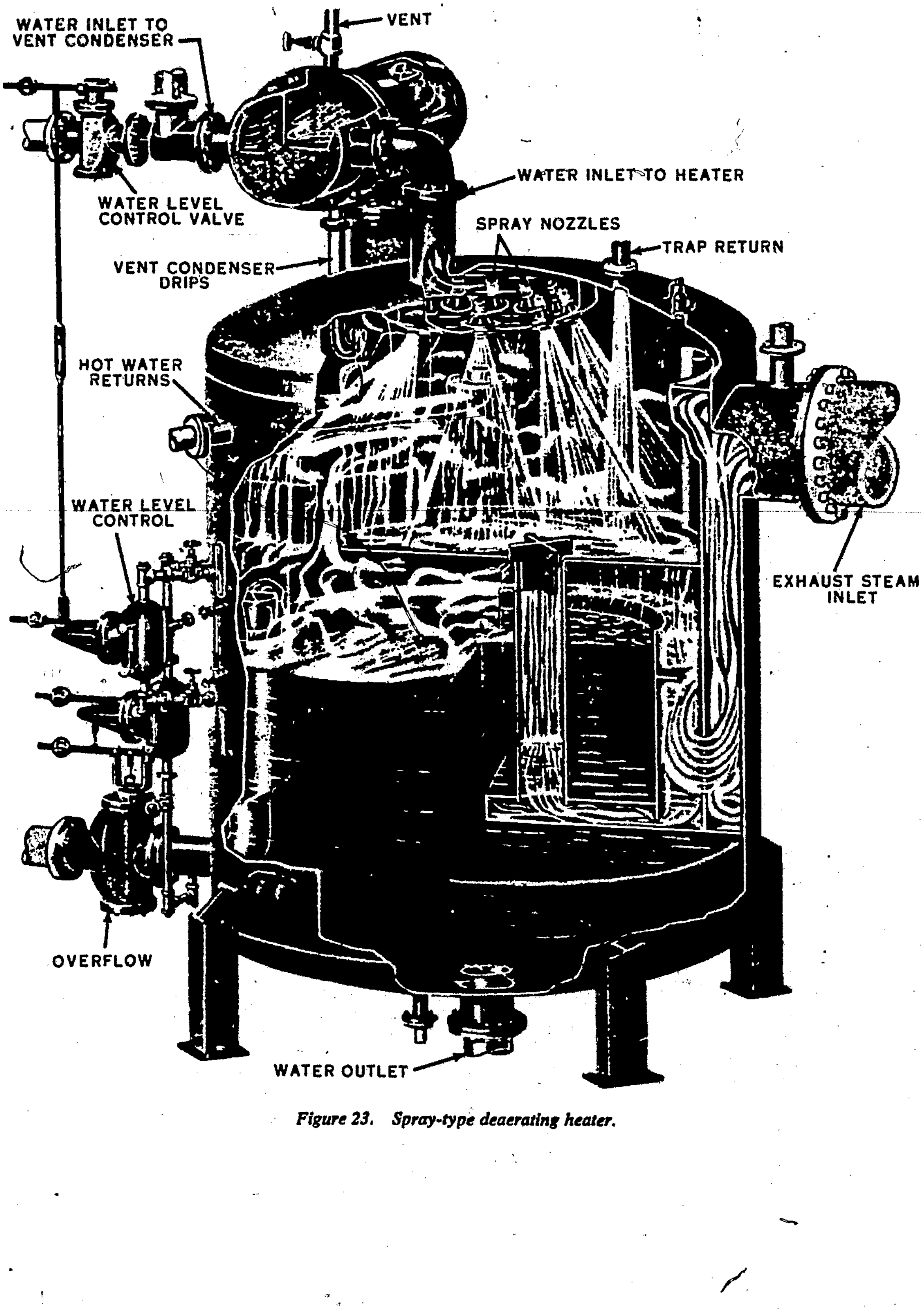

Figure 23. Spray-type deaerating heater.

Treatment of Boiler Water

FOR MANY YEARS man has been boiling water for various reasons. One important reason is for the purpose of heating his home — later his place of business. It was only a comparatively few years ago, however, when he discovered that just any kind of water should not be used in boilers. Up to this time the boiler operator accepted a dirty boiler as a necessary evil. The only treatment used at that time to combat the dirty-boiler condition was an annual cleaning. In recent years great strides have been made in the chemical development of feed-water treatment to protect the boiler. Today the different feed-water tests and treatments have been made so simple that the operator no longer has to be a chemist. The major requirements of a good boiler operator are an interest in his job and the proper background to give him a good understanding of his job. With these qualifications and the proper equipment, almost anyone can become a "boiler-room chemist."

2. The chemical treatment of boiler water has helped to increase efficiency and minimize damage to the boiler. It cuts down the scale formation that formerly collected on the internal surfaces of the boiler and reduces the deterioration of the boiler metal caused by corrosion.

3. In this chapter you will have the opportunity of studying discussions that contain knowledges needed when you are assigned the responsibility of treating boiler water. We will discuss the characteristics of water, reasons for water treatment and water-treatment requirements, care of idle boilers, condensate return and return lines, function of chemicals, standard high-pressure treatment, special treatments and chemicals procurement, mixing chemicals, admission of chemicals to the boiler, testing boiler water, and the control of boiler water treatment.

4. As you study about the treatment of boiler water, you should keep in mind the reason for treating raw makeup water and boiler water.

8. Characteristics of Water

1. Natural water can be divided into two categories: surface water and ground water. Surface water comes from such sources as lakes, rivers, streams, and reservoirs. Ground water is taken from such sources as wells, springs, and underground rivers.

2. Natural water usually contains some impurities such as acids, scale-forming calcium and magnesium, dissolved and suspended oxygen, and carbon dioxide (CO_2). Raw water may also contain particles of soil and organic matter. Water sources in or close to industrial areas may contain factory wastes. Factory wastes often contain acids, alkalis, or other materials that are harmful to a boiler. The acids and alkalis, when not properly controlled or eliminated, can cause metal brittleness and the corrosion that results in pits and holes in the boiler metal.

9. Purpose of Water Treatment

1. The major objectives of water treatment are to prevent boiler scale formation and corrosion. Successful water treatment permits ready removal, by blowdown, of most of the sludge, formed by the treatment, in the boiler water. It provides corrosion control, prevents boiler water from making the boiler metal brittle, eliminates the possibility of the boiler water foaming and priming from the boiler into the distribution lines. Water treatment also keeps the concentration of dissolved solids below the point which requires excessive blowdown.

2. You notice we have mentioned the word "blowdown." This is the word used by people in the heating field to describe the removal of foreign matter from the bottom of the boiler by draining the water from the boiler under pressure. Water treatment must also provide protection for other equipment in the system as well as steam and condensate return lines. It prevents corrosion or deposition in boiler feed lines and feed-water heaters. At this point we will discuss some types of feed-water treatment.

3. **Types of Treatment.** Many of the objectives of water treatment are best achieved mechanically with deaerators, softeners, and demineralizers. These devices were discussed in Chapter 1 of this memorandum. In this chapter, however, we

are primarily concerned with the chemical treatment of water.

4. The chemical treatment of makeup water and boiler water falls into two distinct types of treatment — external and internal — which are discussed next.

5. *External.* The external treatment of water entails the pretreatment of makeup water to control its alkalinity and to remove scale-forming materials and gases before the water enters the boiler. External treatment is subdivided into two general classifications. The first is the ion-exchange method which converts the scale-forming compounds of calcium and magnesium ions to non-scale-forming compounds of sodium and hydrogen ions. The second is the precipitation method which provides for sedimentation of the scale-forming materials from the boiler feed water before the water enters the boiler. An example of the first is the zeolite treatment, and an example of the second is the lime-soda process; both methods were discussed in detail in Chapter 1.

6. *Internal.* Many methods of internal boiler water treatments are used. Most of these treatments use carefully controlled boiler water alkalinity, an alkaline phosphate, and an organic tannin. The organic tannin is designed to absorb oxygen, to keep the boiler steel from becoming brittle, and to diffuse the solids in the boiler water. Because of the economy of treatment costs and the simplicity of chemical concentration control, the alkaline phosphate-tannin method of internal treatment is preferred for military boilers. When properly applied and controlled, this treatment prevents the formation of scale on the internal boiler tubes and the shell.

7. The chemical treatment of boilers is recorded on water testing and treatment logs which are forwarded to higher headquarters for monitoring. The instructions for maintaining these logs are usually contained on the back of the log sheet; however, in most cases you will not be required to maintain the logs without supervision until you reach a high skill level.

8. **Technical Assistance.** Technical assistance is available to all military headquarters for training personnel in the control of chemical treatment, including testing procedures and related problems, such as return-line corrosion, feed-water heater operation, problems pertaining to the treatment of steam, condensate boiler feed water, and boiler water.

9. Water samples that are to be shipped to either the Bureau of Mines or a major command for technical assistance testing are prepared for shipment in accordance with instructions that will be furnished by these organizations prior to shipment of the sample.

10. Water Treatment Requirements

1. The basic requirements for the treatment of boiler water vary according to the materials used in the construction of steam-distribution and feed-water systems. The operating pressure, the capacity of the boiler, and the condition of the water available are also factors to be considered in treating the water to be used in the boiler.

2. **Methods of Boiler Water Treatment.** Since the type of chemical treatment, method of control, and application vary with the type of boiler, the following information can only be a guide to water treatment.

3. Steam steel boilers are operated at either high pressure or low pressure and are consequently classified as high horsepower, rated at 100 horsepower or more, and low horsepower, rated at less than 100 horsepower. The water used in high-pressure steam steel boilers (operating at pressure above 15 psi) is treated with caustic soda in combination with sodium metaphosphate and tannin. Boilers under 10 horsepower are exempt, unless local conditions warrant such treatment. The water used in low-pressure steam steel-type boilers (operating at 15 psi or less) is treated with caustic soda if corrosion is noticed. When the formation of scale is observed, these boilers are treated with caustic soda in combination with sodium metaphosphate and tannin. The treatment is controlled as with high-pressure boilers.

4. The water used in low-pressure cast-iron boilers is not treated unless the formation of scale is observed. When such treatment is necessary, caustic soda in combination with sodium metaphosphate and tannin are used as with high-pressure boilers.

5. **Methods of Cleaning Boilers.** Before a boiler is placed in operation, attention should be given to the chemical treatment of the boiler water. New boilers may have oil and other foreign materials present in the steam and water spaces. Used boilers often have some scale and corrosion present. A complete boiler inspection, by an approved agency, should be made prior to the initial operation of the boiler.

6. *New boilers.* After a new boiler has been installed, it is usually necessary to remove solid foreign materials left in the steam and water spaces during boiler fabrication. Many times oil is on the metal surfaces of new boilers and must be removed. The removal of the foreign materials and oil generally cannot be done by using only hot water. In most cases it is necessary to use chemicals in the hot water to change the form of the materials in order to remove them.

7. All of the loose foreign materials possible should be taken from the boiler by hand. Also, the surfaces that can be reached by hand should be scrubbed with a wire brush. After the brushing, the boiler should be filled with water. Then 3 pounds of caustic soda, 3 pounds of disodium phosphate, and 1 pound of sodium nitrate should be added for each 1000 pounds of water capacity. This water should be boiled in the boiler for 24 to 48 hours. You should maintain about one-half of the normal operating pressure in high-pressure boilers.

8. The steam generated during the boiling-out process should not be used because it is usually contaminated. After the boilout has been completed, you should drain the boiler and flush it thoroughly with hot water. You should make sure that none of the chemicals used in the boilout remain in the boiler. Even after the boilout, some oil residue may remain in the boiler. The oil can cause foaming of the boiler water and contamination of the steam; therefore, adequate blowdown of the new boiler should be provided during its first week of operation.

9. *Scaled and corroded boilers.* Many used boilers contain scale and corrosion at the time they are being reinstalled. Other boilers in their present installation are in this condition because of the lack of proper water treatment. When you are confronted with boilers in this condition, you should thoroughly inspect them to determine the extent of scaling and corrosion. If the corrosion appears to be serious, an immediate boiler inspection should be made by your command headquarters or by an approved boiler inspection agency. The scale will probably be removed during the inspection. The inspector will usually direct that your organization clean out all of the loose scale and manually remove as much of the scale adhering to the boiler as possible by brushing and scraping. Then, the boiler should be closed and have the same amount of chemicals added for each 1000 pounds of water as for new boilers. The chemicals are added to the boiler at the same time water is fed into the boiler. The boiler should be filled to the normal water level. The vent openings must be left open so that the gases from the treated water can escape as the water is heated.

10. The water is usually heated by building a small wood fire in the furnace of the boiler and raising the temperature of the water to approximately 200° F. You maintain this temperature from 24 to 48 hours. You also add makeup water, as required, during this period to keep the boiler filled to the base of the safety valve. The reason for filling the boiler to the bottom of the safety valve is to make sure that all of the boiler surfaces contacted by boiler water will be treated.

11. The treated water is tested during this boilout period. Also, enough caustic soda and sodium metaphosphate are added to maintain concentrations of 300 ppm to 500 ppm (parts of chemicals per million parts of water) of causticity (caustic soda) and 100 ppm to 150 ppm of phosphate. At the end of the boilout period, you should open the boiler and remove any loose sludge or scale. Particularly, care should be taken to insure that all of this sludge is removed from the boiler. If the remaining scale and sludge are not removed and the boiler is operated, the residual scale can cause faulty operation and the sludge formation can cause damage to the boiler. Sludge is formed from disintegrated scale and the boiler should be taken out of service at frequent intervals to remove this matter.

11. Care of Idle Boilers

1. Serious corrosion can take place in a sound boiler while the boiler is idle. The corrosion is caused by oxygen dissolved in the water. If oxygen is permitted to dissolve in small pools of water in the boiler, concentrated, localized corrosion will occur. It is not always possible to eliminate air, which contains oxygen, from the boiler. It is possible, however, to dry the boiler and follow procedures which will insure that moisture will not again form upon exposed metal surfaces. Out-of-service boilers may often be required to resume operation in 4 to 6 hours. Under these conditions, it is not practical to drain the water from the boiler. Unless the boiler is sealed and contains water, there will not be time to meet the steam demand. For this situation an alternate method of boiler layup is recommended which protects the boiler metal and maintains the boiler in a standby condition. The following information will help you protect boiler metal against corrosion during an out-of-service period.

2. **Dry Boiler Method (Quicklime).** The dry method of boiler storing, sometimes called *lay up,* is normally used when it is necessary to store the boiler for long periods of time—usually over 30 days. If it becomes necessary for you to store a boiler by the dry method, you should first take the boiler out of service and then drain all loose rust, scale, and sludge that you can. You should do this with a stiff wire brush. All the internal surfaces of the boiler that you can reach should be cleaned. You should break the boiler feed-water and steam connections to keep out the moisture. Also, close off the end of the line with either a blank flange or a cap, depending upon the type of connection. Figure 24 shows a typical four-hole blank flange and a 3-inch pipe cap.

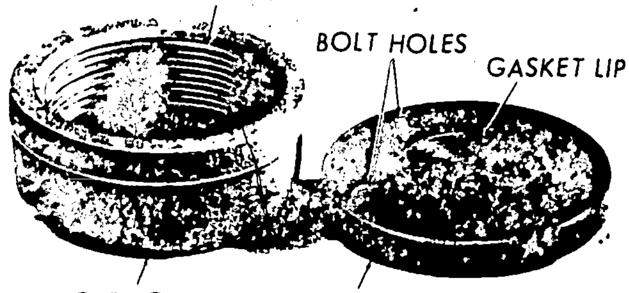

Figure 24. Typical four-hole flange and 3-inch pipe cap.

3. Next, you build a small wood fire in the furnace of the boiler. You maintain the fire for at least 2 hours, or until an inspection shows that there is no moisture on the internal sections of the boiler. Then, place one or more wood or plastic trays of quicklime in the boiler at the rate of 20 pounds of quicklime per 100 boiler horsepower, or 2 pounds per 1000 gallons of water capacity. The lime absorbs any moisture that might get into the boiler. It is important that the quicklime does not contact the metal surface of the boiler. The lime will attack metal when it becomes moist. To prevent this, you should place the trays on wood blocks. Now, you seal the boiler tightly. You should make periodic inspections of the lime containers to determine if the lime is still dry. If the quicklime becomes moist, it must be replaced, the boiler dried out, and the openings resealed.

4. **Wet Boiler Method.** When it is necessary to store boilers for short periods (up to 30 days), you will find that the wet method is usually the best, especially if the boilerplant is currently on standby service. When storing a boiler by the wet method, you should drain and clean the scale, rust, and other foreign material out of the boiler. After this has been done, you should clean all of the internal surfaces that you can reach with a stiff wire brush and then flush the boiler with hot water. The openings of the boiler should then be closed again.

5. If the boilerplant is equipped with a feed-water heater, you fill the boiler with water which has been boiled in the heater. If feed water from a heater is not available, you use either the return condensate or raw water in the boiler. No airspaces should be left in the boiler. Approximately 1 ounce of caustic soda and 2 ounces of sodium sulfite to 100 pounds of water are placed in the boiler.

6. Next, you build a small wood fire in the furnace of the boiler. Then, remove the safety valve and boil the water inside the boiler under atmospheric pressure for 2 hours to insure the circulation of the chemicals. After the boilout has been completed, you should install the safety valve and seal the boiler.

7. It is necessary to make periodic inspections to insure the maintenance of the proper water level. You must replace all water losses from the boiler. Under these conditions, it may also be necessary to place additional chemicals in the boiler. You can determine this need by using Bureau of Mines test kits. Concentrations of hydroxides, (causticity) (OH) should be maintained at approximately 200 ppm. When the water in the boiler has cooled, you tightly close all of the vents and seal the boiler from the atmosphere.

8. Before regular operation is resumed, you drain the boiler water to the proper level. Then, make the chemical tests for causticity, phosphate, tannin, and total dissolved solids. You blow down the boiler and feed in chemicals according to the test results. Prior to lighting the boiler, you should make a thorough check of it and the auxiliary equipment to make sure everything is in proper operating condition.

12. Condensate Return and Lines

1. The corrosion of condensate return lines is a serious maintenance and operating problem. Cause of this corrosion appears to be related to the carbon dioxide (CO_2) content of the return condensate. When the CO_2 concentration of return condensate is high, the corrosion of return lines and the nipples following traps is pronounced. When the CO_2 concentration is low, corrosion occurs to a lesser degree. This type of corrosion cannot be controlled with equal success in all installations because some makeup waters contain more bicarbonate than do others. The bicarbonate breaks down as a result of temperatures in the boiler and liberates CO_2 into the steam in the boiler. The CO_2 is not active while it is in the steam, but it does become active to form carbonic acid when condensed with the steam as condensate.

2. The corrosion of return lines is minimized by admitting less bicarbonate (concentrated in makeup water) to the boiler system. This entails the reduction of water losses in the steam-generating and return systems. Bicarbonate may be removed from the boiler feed water before its entry to the boiler by preheating and deaerating makeup water. The corrosive effect of CO_2 is partially neutralized by chemical treatment of the condensate with amines (derivatives of ammonia).

3. **Feed-Water Makeup Rates.** The percentage of makeup water used in a boiler is an index that can be used to evaluate maintenance effectiveness and indicate the degree of operating efficiency. The following percentages indicate the maximum quantities of feed water that may be expected

with properly operated and maintained systems to provide steam to the facilities indicated. The makeup rate of feed water for central heating plants is equal to 5 to 10 percent of the steam produced; laundries, 5 to 15 percent; hospitals (winter), 5 to 10 percent; and hospitals (summer), 15 to 25 percent.

4. **Excessive Boiler Blowdown.** Blowdown should be given a boiler primarily to control solids in the boiler water within specified limits. Any additional blowdown results in heat waste and necessitates the replacement of the water blown from the boiler with a raw makeup water.

5. **Feed-Water Heater Operation.** If a feed-water heater is operated at a temperature corresponding to the operating temperature of the boiler, then oxygen is removed from the feed water. The bicarbonate contained in the raw water is also partially broken down by the temperature within the heater, and a large part of the CO_2 formed as a result of this breakdown is eliminated through the heater vent. Any free CO_2 contained in the raw water is also eliminated. You will recall that we discussed feed-water heaters in Chapter 1.

6. **Chemical Treatment of Condensate.** When all possible losses of water and steam from a boiler plant are eliminated, chemical treatment of the condensate is instituted to remove the CO_2. Unless such losses are reduced to a minimum, the cost of this chemical treatment is excessive and corrosion cannot be inhibited. Figure 25 shows sections of return lines that have not been properly treated to prevent corrosion. The chemicals used for this purpose are alkaline amines. These alkaline amines are introduced directly into the boiler water and vaporize with the steam. The alkaline

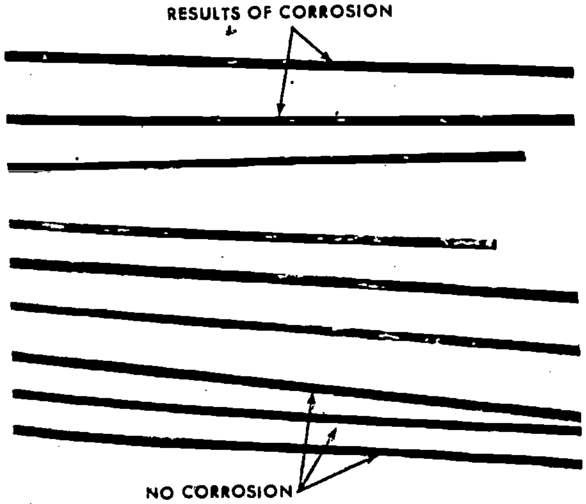

Figure 25. Comparison of corroded lines and lines not corroded.

amine is carried in the steam and combines with CO_2 in the condensate and makes the CO_2 inactive. The combined CO_2 and amine is then reintroduced into the boiler in the feed water where the alkaline amine vaporizes again. Amine treatment is instituted only after a careful survey of corrosion conditions and then only with the permission of the command headquarters.

7. When the steam is to be used for sterilizing materials in hospitals or in direct contact cooking in dining halls, amines should not be used unless a special type of amine which will not cause sickness and endanger the health of personnel is procured.

13. Function of Chemicals

1. The chemicals used in the treatment of boiler water have the definite function of preventing the formation of scale and corrosion of the boiler metal. When tannin, caustic soda, amines, sodium phosphate, sodium sulfite, and antifoam are included in the boiler water, each chemical has a specific purpose. For example, sodium sulfite is used to control the oxygen in boiler water, and caustic soda is used to control the acid content. Tannin is used to control sludge fluidity, and phosphate is used to control the calcium scale. Antifoam, of course, is used to prevent the foaming of the water in the boiler.

14. Standard High-Pressure Treatment

1. The standard high-pressure treatment of water consists of introducing the proper amounts of caustic soda, sodium sulfite, phosphate, and tannin into the boiler. Caustic soda provides alkalinity in the form of free hydroxide to neutralize the acid materials in the water. Alkalinity in the water is necessary to prevent corrosion. The relationships between acidity and alkalinity are determined by pH readings, such as those given in the pH scale shown in figure 26. You will see on the scale that when the pH reading is below 7, the water is acid; when the scale reading is above 7, the water is alkaline. You will also note that when the reading is exactly 7, the water is neutral—neither alkaline nor acid.

2. The sodium phosphate combines with some of the free hydroxide, formed by caustic soda, to form trisodium phosphate. Trisodium phosphate combines with calcium salts to form tricalcium phosphate, a soft, nonadhering, finely divided sludge which can be easily removed from the boiler by blowdown. A pH scale reading above 9.5 is therefore maintained to cause the calcium to precipitate (settle out).

3. Tannin is an oxygen absorber and acts as a dispersing agent of the insoluble solids contained in boiler water, and it prevents excess accumulations of sludge in the lower parts of the boiler.

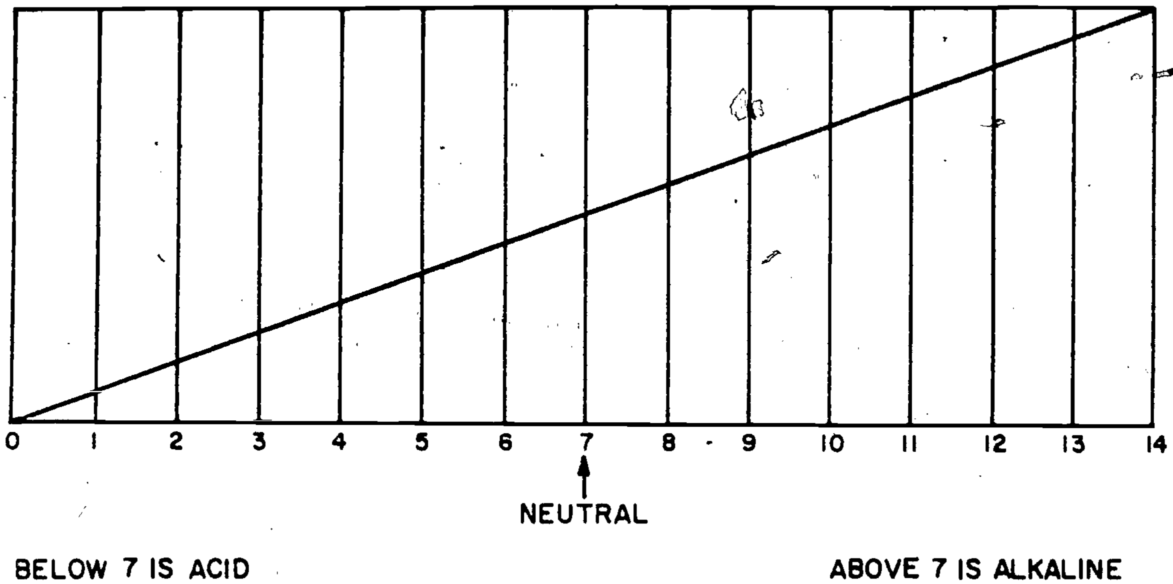

Figure 26. The pH scale.

This makes possible the effective removal of solids by properly applied boiler breakdown. Sodium sulfite, an oxygen scavenger, is used to eliminate oxygen from the water and is used in addition to tannin.

15. Special Treatment and Procurement of Chemicals

1. There are many ways of treating the water used for various purposes on an Army post. However, you are mainly interested here in the special treatments required for boiler water. You should take note at this point that your major command must be contacted for approval before any of the chemicals are used. The approval will also direct the chemicals to be used and tell how they should be used. Special treatments of the water used in the steam boiler and the procurement of the chemicals used in these treatments are discussed in the paragraphs that follow.

2. **Caustic Soda.** Caustic soda can normally be procured locally and can be purchased in 100-pound steel drums if desired. You should specify flake or granular caustic soda containing not less than 76 percent NA_2O.

3. **Sodium Phosphate.** Sodium phosphate can be procured locally and is usually shipped in 100-pound bags.

4. **Tannin.** Tannin generally can be procured locally and is shipped in the form of brown crystals in 100-pound bags.

5. **Sodium Sulfite.** Sodium sulfite can generally be procured locally. However, you should specify anhydrous sodium sulfite, not less than 90-percent pure, for the treatment of boiler feed water. Sodium sulfite removes oxygen from the feed water and boiler water. It takes about 8 pounds of sodium sulfite to combine with 1 pound of oxygen to form sodium sulfate, a noncorroding agent.

6. **Antifoam.** Some raw waters contain excessive amounts of soluble salts and foaming is encountered unless excessive blowdown is used. There are many compounds available that suppress boiler water foaming. Therefore, the tendency to foam can be decreased by changing the surface tension of the water in the boiler with an antifoam compound.

16. Mixing Chemicals

1. Most of the chemicals used for treating boiler water are dry when they are received and are mixed with water just before they are used to prevent caking in pumps and lines. These chemicals must be properly stored to prevent contamination and the absorption of water. If foreign matter is allowed to contaminate the chemicals, the foreign matter will probably be fed into the boiler along with the chemicals. It is virtually impossible to remove some types of foreign materials from the chemicals once they have become contaminated. When water is allowed to get into the chemicals, many of them will react prematurely and lose their strength. If only a small amount of moisture comes in contact with the chemicals, they will become caked and be difficult to mix with the water.

2. **Methods of Mixing.** The methods of mixing chemicals may vary greatly with various installations. However, there are some general rules that should be used. The chemicals should not be mixed in advance of the immediate requirements.

Mixing the chemicals too long before they are to be used defeats the purpose of the water treatment and complicates controlling the individual chemicals in the boiler water.

3. You should wear protective equipment when you are mixing chemicals. The mixing should be done at floor level to prevent injury to your eyes and face. Also, you should never add the water to the chemicals, but rather add the chemicals to the water to prevent splashing.

4. *Solution of chemicals.* Tannin is dissolved in hot water at approximately 160° F. to 180° F. in a clean container. Stir the solution until the tannin is completely dissolved. You mix the phosphate separately in water at approximately 200° F. in a clean metal container, and stir the solution until all of the phosphate is dissolved. Mix the two solutions before placing them into a chemical feeding device.

5. *Apparatus for mixing.* Placing a small steam jet in the bottom of the dissolving vessel will facilitate chemical mixing. Phosphate and tannin are dissolved easily by placing the chemical in a fine-mesh wire basket and suspending the basket just beneath the water surface in the mixing container, as shown in figure 27.

6. *Solution of caustic soda.* You must not use hot water when mixing the solution of caustic soda, because splashing and serious injury can result. You wear goggles, rubber gloves, and a rubber apron when mixing this chemical. You are not to pour the cold water on the caustic soda, but add the caustic soda gradually, with constant stirring, to an adequate quantity of cold water. The chemical action causes the solution container to become hot; therefore, be careful when handling it.

7. *Solution of sodium sulfite.* You should also mix a sodium sulfite solution in cold water just before it is to be used. If it is mixed and exposed to the air for long, the chemical becomes useless

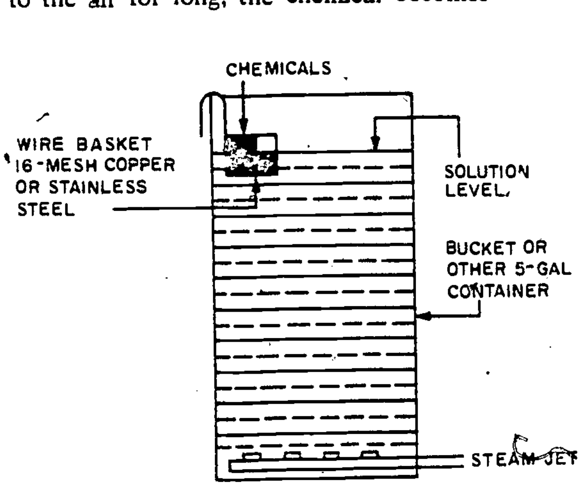

Figure 27. The apparatus for mixing chemicals.

for boiler water treatment. This is caused by air from the surrounding area combining with the sodium sulfite and neutralizing it.

8. **Makeup of Chemical Dosage.** Individual chemicals rather than ready-mixed chemical compounds are used in boiler water treatment to better control the concentrations of the individual chemicals. Improper chemical concentrations are not effective in protecting the internal water-contacted surfaces of the boiler against scale and corrosion and can cause damage. A chemical analysis of the boiler water should be made so that the chemical demands of the water can be determined.

17. Admission of Chemicals to the Boiler

1. Several methods are used to admit water treatment chemicals into the boiler. The method of admission used depends on the design of the boilerplant and the chemical requirements of the boiler water. You are going to study some of these methods of feeding in chemicals, which are discussed next.

2. **Phosphate Feeding.** Phosphate combines with the calcium and magnesium salts in raw water and precipitates (settles out) in the insoluble materials. If the phosphate solution is not fed into the boiler almost immediately after being mixed, some of its strength is lost. Consequently, the loss of strength can be appreciably decreased by feeding the chemical as quickly and directly as possible into the boiler.

3. **Pressure-Pot Feeder.** A simple chemical feeder can be fabricated with a piece of 6- to 8-inch pipe 18 to 24 inches long, as shown in figure 28. Both ends of the pipe are sealed either by capping or welding. The fabrication should allow for the application of boiler pressure to the feeder. Suitable valving and a funnel for admission and discharge should also be installed. This type of feeder permits the rapid-shot feed of chemicals to the point of admission.

4. Pressure-pot feeders are normally installed in the bypass located on the discharge side of the feed-water pump so that pump pressure can be used to force the chemicals into the boiler. These feeders should not be constructed of galvanized pipe because of the adverse chemical reaction to the galvanizing material.

5. **Chemical Feed Pump.** The most satisfactory method of chemical admission for large boiler plants is a properly designed chemical-feed pump, either the continuous or shot-feed type. Chemical-feed can be controlled manually or by automatic devices. To obtain closely controlled continuous feeding, the chemical feed can be proportioned to the flow of the feed water. This can be done by connecting either the chemical pump or the chemical-feed pump so that it is actuated by the boiler-feed pump.

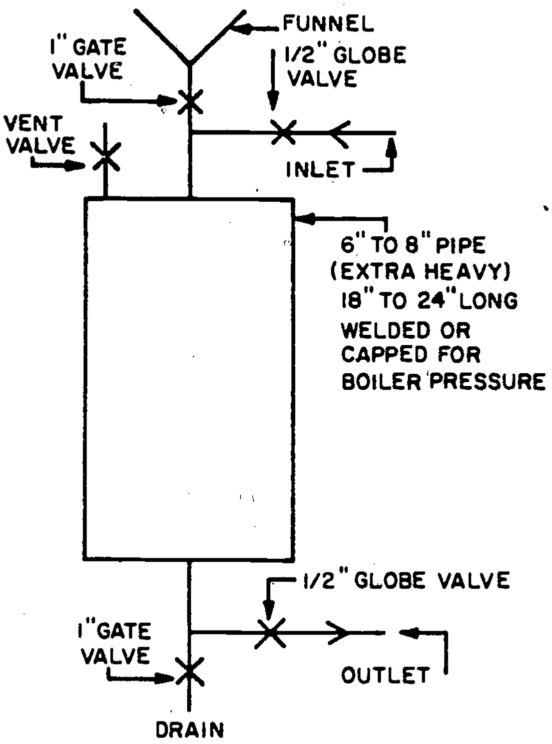

Figure 28. A pot-type chemical feeder.

6. **Points of Admission.** The point of chemical admission varies with the individual boilerplant and with the operating conditions. Therefore, each installation presents an individual problem.

7. *Boiler-feed suction.* The chemical-feed chamber for small boiler plants can be installed at the boiler-feed pump suction connection. However, this is not desirable in all cases, because the chemicals in some cases will cause the packing in the pump to deteriorate and leak.

8. *Boiler-feed discharge.* Some feed-chambers are installed on the discharge side of the boiler-feed pump. This type of installation eliminates the possibility of damage to the pump and packing that might be caused by chemical action.

9. *Direct admission.* When a steam heating plant includes three or more boilers, the treatment chemicals can be distributed effectively if the chemicals are individually added directly to each boiler. Individual feeders are installed so that the chemicals are admitted into the feed line beyond the feed-water regulator or into the boiler proper.

10. *Precautions.* You should never place dry chemicals in a chemical feeder or pump. This practice plugs the chemical feed lines in a short time. Make sure all piping and valves installed with chemical feeders or pumps are designed to withstand boiler pressure. Also, drain the feeder before introducing the chemicals. When draining a feeder, you should close all pressure connections to the feeder before opening the drain valve. This prevents injury to the operator by hot water or chemicals.

18. Testing Boiler Water

1. Boiler water should be tested at stated intervals to control boiler water treatment. The frequency and extent of these tests depend on the size and nature of the steam plant and on the extent of water control required. Your command headquarters can specify other tests, and the testing discussed here is onlv the minimum required.

2. The water in high-pressure boilers (over 15 pounds pressure) is tested for causticity, phosphate, tannin, and total dissolved solids. The water in high-horsepower plants is tested daily. When more than one boiler is in operation in a boiler plant, the water in the boilers is tested alternately.

3. The water in low-horsepower plants is tested twice a week. When more than one boiler is in operation, the boilers are tested alternately.

4. When treated for corrosion, the water in low-pressure steam steel boilers (15 pounds pressure and less) is tested for pH at frequent intervals to insure that the pH reading of the boiler water is 10.5 to 11.5.

5. **Procurement of Testing Equipment.** The standard test kit for causticity, tannin, pH, and phosphate determination is obtained through your command headquarters (through channels) from the Boiler Water Service, U.S. Bureau of Mines, College Park, Maryland.

6. With the exception of the pacometer, all reagents and replacement parts for the standard test kits can be obtained upon request, free of charge, from the Boiler Water Service, U.S. Bureau of Mines, College Park, Maryland.

7. **Boiler Water Sampling.** To control the water treatment, it is necessary that the boiler water being tested represent the true condition of the water inside the boiler. It is necessary to blow down all sampling lines and connections to the sampling points to clear the line of stagnant water before the sample is collected.

8. *Location of sampling point.* When the water column connections to the boiler are short and direct, you blow down the water column several times and draw a sample from the water-column blowdown connections. A ¼-inch sampling connection should be provided ahead of the water-column blowdown valve. Take the sample from the water-tube boilers either from the front drum or from the forward part of the upper rear drum. Continuous blowdown connections that are properly located make good sampling

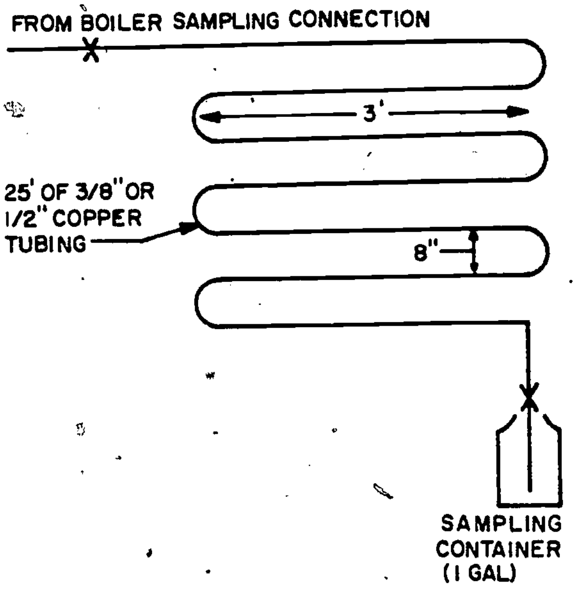

Figure 29. An air-cooled sampling coil.

points. If the rear drum connection is close to the feed-water inlet, you must be sure that the sample is not diluted by feed water. If any doubt exists as to the proper location of the sampling connection, consult the Director of Facilities Office. All sample connections should be piped to the floor level and have a valve near the end of the line for convenience and safety.

9. *Flash samples.* It is necessary to blow down sampling lines several times to flush out any stagnant water. At the sampling connection, you attach a piece of rubber tubing which is long enough to reach the bottom of the sampling container. Then, adjust the flow to permit the collection of a 2-quart sample in 5 minutes. Avoid excessive flashing and the use of too much time in collecting the sample.

10. **Sampling Coils.** A sample of boiler water is best drawn through a cooling unit that prevents flashing the water into steam and burning the operator. There are several types of cooling coils that can be fabricated locally for this purpose.

11. *Atmospherically cooled coil.* About 25 feet of ⅜- or ½-inch copper tubing that has been bent into the shape of a large helix and suspended in air (fig. 29) works well as an air-cooled sampling coil when the sample is not drawn too rapidly.

12. *Water-cooled coil.* Good results are obtained by using 15 to 25 feet of ¼-inch copper tubing to form a coil approximately 6 inches in diameter and about 10 inches high to make a water-cooled sampling coil such as that shown in figure 30. The coil is immersed in a bucket of cold water when a sample is being drawn. The coil can also be fitted with detachable fittings to permit its use at several locations.

13. **Time of Sampling.** All samples must be drawn immediately before the regular blowdown and before the chemicals are added. This is done so that the minimum concentrations of chemicals available in the boiler and the maximum total dissolved solids content of the boiler water can be determined. When feed water is allowed to go into the boiler just prior to drawing a sample, the sample may be diluted and not be representative of the chemical concentrations in the boiler.

14. **Methods of Testing.** The step-by-step methods for testing boiler water can be obtained through channels from the Boiler Water Service, U.S. Department of Interior, U.S. Bureau of Mines, College Park, Maryland. However, we are going to give you some general information so that you may gain a better insight to boiler water testing.

15. *Causticity test.* The causticity test is used to determine the amount of free hydroxide (OH) in the boiler water. The use of caustic soda, or the breakdown and conversion of the natural bicarbonates in raw or any treated water, makes the boiler water caustic.

16. When the boiler water is colored by organic matter such as tannin, fill two test tubes, obtained from the Bureau of Mines test kit, with the proper amount of boiler water from the sample container. When filling the tubes, you should be careful not to get any of the sludge that has settled on the bottom of the sample container into the test tubes. At this time add the first causticity reagent (Nr. 1, barium chloride solution) and mix it with the water in the test tubes. Then allow the tubes to rest undisturbed in the test tube rack

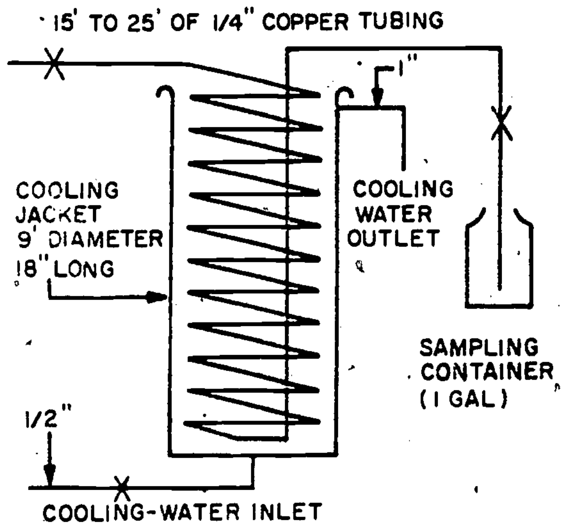

Figure 30. A typical water-cooled sampling coil.

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while precipitate forms and settles to the bottoms of the tubes. The precipitating process takes about 15 minutes.

17. Next, about half of the water from each test tube is transferred to the third test tube, from the kit, which has a long, or 30-ml mark on it. The solution should be pink. When the solution turns pink, there is causticity in the water. If the solution is not pink, add 2 drops of phenolphthalein indicator. If the mixture does not turn pink after the indicator has been added, there is no causticity in the water.

18. To determine the amount of causticity in the pink sample, add the second causticity reagent (Nr. 2, one-thirtieth-strength hydrochloride acid) to the solution, drop-by-drop, while stirring the solution until the pink color disappears. Stop adding this causticity reagent (Nr. 2) as soon as the pink color fades out. The amount of this reagent used is indicated by the marks on the test tube that are above the long mark. Five milliliters of reagent are required to raise the level in the test tube from one mark on the tube to the next mark. Fractional distances can be estimated fairly accurately. For example, if the tube is filled three-fifths of the distance from the long mark to the next mark above it, about 3 milliliters of causticity reagent (Nr. 2) have been used. When the distance filled is past the first mark above the long mark, then 3 milliliters plus 5 milliliters, or 8 milliliters, have been used.

19. After the amount of causticity reagent (Nr. 2) used has been determined, you will need to find the ppm—the number of parts of causticity to a million parts of water. To determine the ppm, you multiply the milliliters of reagent (Nr. 2) used by the constant number 23. For example, if 8 milliliters of reagent (Nr. 2) are used, you would have (8 milliliters $\times$ 23 = 184 parts per million) 184 ppm of causticity. The desired amount of causticity is between 20 ppm and 200 ppm.

20. *Phosphate test.* The phosphate test is conducted to determine the amount of soluble phosphate in the boiler water and thereby to control the amount of phosphate to be added to the water. To make this test, fill two test tubes from the Bureau of Mines test kit about half full of water taken from the boiler water sample container. Be careful not to disturb the sediment in the bottom of the sample container.

21. After the water is in the test tubes, mix one-fourth of a teaspoon of decolorizing carbon into the water in each test tube to remove any organic color existing in the water. Then filter the water-decolorizing carbon solution into the test kit comparator mixing tube. The first mark on the mixing tube is the 5-milliliter (ml) mark. As the water is filtered into this tube, allow the water to accumulate to the first mark.

22. Now, add 10 milliliters of comparator molybdate to the solution in the mixing tube. This fills it to the third, or 15 milliliter, mark. After this has been done, add fresh dilute stannous chloride to bring the level to the 17.5 milliliter mark. Mix the stannous chloride according to the instructions received with the phosphate test kit from the Bureau of Mines.

23. When you have added dilute stannous chloride to the solution of water and comparator molybdate reagent, the solution should turn blue if there is phosphate in the boiler water.

24. Use a comparator to determine the concentration of the phosphate. Place the test tube containing the test solution in the slot provided in the comparator block. If the color comes between the two standards of 30 to 60 ppm in the comparator, the boiler water is satisfactory. However, if the color is lighter than the 30-ppm standard, you should add phosphate to the boiler. If the color is darker than the 60-ppm standard, the phosphate concentration is too high.

25. *Tannin test.* The tannin test is used to visually determine the approximate amount of tannin in the boiler water, but it does not differentiate between oxidized and unoxidized tannins. To make the test, filter a cooled sample of the boiler water into a standard test tube taken from the Bureau of Mines test kit. The reason for filtering the sample is to remove any suspended solid matter that might be in the water. It may be necessary to filter the sample more than once to get out all of the suspended matter and obtain true tannin color.

26. To aid in determining the concentration, place the sample in the tannin comparator block. Once you have placed the sample in the comparator block, move it from standard to standard until it closely matches one of the color standards. These color standards are designated as very light, light, medium, dark, and very dark. The proper concentration should be about medium or the color of dark tea. If the concentration is low, add tannin. If the concentration is high in the boiler, dilute it with water. When you have established the color standard of the sample, give the information to the person who enters such information in the appropriate column of the Boiler Water Treatment Operating Log.

27. *Total dissolved solids test.* The total dissolved solids test is used to determine the concentration of soluble salts in boiler water. In most steamplants this test is made with a conductivity solo-bridge. The solo-bridge test cell normally uses 60-cycle, 110-volt ac electric power. This test indicates the frequency and amount of blowdown required.

28. Rinse a clean 200-mm by 38-mm test tube with some of the boiler water sample and pour 60 milliliters of the sample into the tube without disturbing the settled sludge. You must mark the tube with a file or crayon at the 60-milliliter level. This point is about 5 inches from the top of the tube. (If desirable, you should make a special rack or other support for the test tube.) Now, add 1-milliliter of conductivity neutralizing solution (two ½-milliliter droppers filled to the mark) to the sample.

29. After the test cell has been turned on, thoroughly wash the probe of the tester in distilled water containing 1 milliliter of conductivity neutralizing solution. Then, you must shake the tester until all of the distilled water has evaporated from the probe. The removal of the distilled water from the probe is necessary so that you will not dilute the sample and cause a false reading.

30. Allow the conductivity solo-bridge to warm up for at least 1 minute to get accurate results from the test. Obtain the temperature of the sample with an armored thermometer. Then set the pointer of the solo-bridge temperature scale at the temperature indicated by the thermometer. When the temperature scale on the solo-bridge has been set, place the probe in the sample of boiler water. You move it up and down several times to remove all the air bubbles inside the cell shield.

31. Immerse the cell on the probe in the water sample to the point where the air vents on the cell shield are submerged. Then turn the pointer on the upper dial of the solo-bridge until the dark segment of the electron tube reaches its widest point and take a reading in micromhos. To convert this reading on the solo-bridge to ppm, you multiply the reading by the standard number factor of 0.9. For example, if the dial reading is 4000 micromhos and the standard factor is 0.9, the result is 3600 ppm (4000 micromhos $\times$ $0.9 = 3600$ parts per million).

19. Control of Treatment

1. The most important factor in treating boiler water to prevent scale and corrosion is the proper control of the chemicals used in the treatment. Unless all chemicals are controlled within the specified limits, the treatment is ineffective and steam contamination results.

2. **Specified Limits.** The limits given here will protect the boiler metal against scale and corrosion under average conditions, and they are patterned after industrial practice based on the application of this type of treatment. Under unusual conditions, deviations from these standard limits may be necessary. A study of all the factors involved is required to arrive at the correct chemical concentration limits.

3. *Standard causticity limits.* The limits for causticity concentration are between 20 ppm and 200 ppm, expressed as OH. Otherwise, caustic soda is added to the boiler water to maintain the causticity of it within these limits at all times. When the water supplied to a steam plant is high in natural sodium bicarbonate or when the water is sodium-process zeolite-treated, the use of caustic soda is not always required.

4. *Standard phosphate limits.* The limits for soluble phosphate content of boiler water are between a ¼- and ⅜-inch-diameter spot according to the spot-test method. This corresponds to approximately 30 ppm to 60 ppm phosphate as PO_4. You add sodium phosphate to the boiler water to maintain the phosphate content of the boiler water within these limits at all times.

5. *Standard tannin limit.* The limit for tannin content in boiler water is a medium brown color, as shown by the middle standard in the tannin comparator.

6. *Standard total dissolved solid limits.* The specified limits for boiler water total dissolved solid content are between 1000 ppm and 4000 ppm. The boilers should be blown down sufficiently to maintain these limits at all times.

7. **Samples for Check Analysis.** Part of the procedure for proper treatment of boiler water entails periodic submission of samples to an adequately equipped laboratory for the purpose of check analysis. The Boiler Water Service, U.S. Bureau of Mines, College Park, Maryland, performs a check analysis on samples submitted.

Steam Plants

PROBABLY YOU have heard about steam and steam power most of your life but never realized just how ancient the use of steam really is. The expansive power of steam was tried in various applications as long as the third century A.D. One man, by the name of "Hero," used steam under pressure to operate a simple engine. Even though the use of steam started many centuries ago, it is just as modern as any other heating system today. The type of boiler we have today, however, was not developed until the 19th century. This development of the steam-heating system marked another step forward in the improvement and development of the heating processes, and it has kept pace with the other systems in the heating group. This is true because the steam-heating system also has its special advantages, and it fits in with certain heating requirements.

2. In this chapter you will study about the requirements of the steam boiler, construction of boilers, types of steam boilers, boiler fittings and accessories, code requirement markings, pipe identification markings, installations of steam boilers, operating steam boilers, and maintaining steam boilers.

3. You are interested, we know, in doing your very best as a heating systems specialist. Consequently, you will be very interested in the information contained in this chapter. What you learn here may save your boiler and even your life. What are steam boilers? Our first discussion will tell you what they are.

20. Steam Boilers

1. The word "boiler" is commonly applied to a closed vessel used for generating steam. This steam generation is usually done under pressure. Since most boilers are used to produce steam, all boilers are generally thought of as steam boilers unless they are designated otherwise. In defining a boiler, you could say "a boiler is a closed vessel in which steam is generated as a result of the combustion of fuel." The term "steam generating unit" more accurately describes the present-day equipment. These steam generator units normally include all of the accessories, from fans, feed pumps, and fuel burners to feed-water heaters and economizers.

2. Today central steam plants are used to furnish steam to the hospitals, dining halls, laundries, and other types of facilities on military posts. The term "central steam plant" usually means that the plant serves more than one building. A central heating plant has one or more boilers which burn gas, oil, or coal as fuel. The steam or high-temperature water that is generated is used for cleaning, sterilizing, cooking, and laundering operations. Small heating boilers play an important part in steam production. Frequently they are used to provide steam and hot water for small buildings. Small units can also be used to supply the steam needed to operate mobile emergency power equipment.

3. To acquaint you with some of the fundamentals underlying the process of steam generation, suppose that you set an open pan of water on the stove and turn on the heat. You will find that the heat causes the temperature of the water to increase and, at the same time, to expand in volume. When the temperature reaches the boiling point (212° F. at sea level), a physical change occurs in the water, and it starts vaporizing into steam. The temperature of water will not increase beyond the boiling point. Even if you add more heat after the water starts to boil, the water will not get any hotter as long as it remains at the same pressure. If you hold the temperature at a boiling point long enough, the water will continue to vaporize until the pan is dry.

4. Suppose, however, you place a close-fitting lid on the pan of the boiling water. The lid prevents the steam escaping from the pan, and results in a buildup of pressure inside the container. However, if a small opening is made in the lid, the steam will escape at a uniform rate. As long as any water remains in the vessel, and as long as the pressure remain constant, the temperature of the water and steam will remain constant and equal.

5. The steam boiler operates on the same basic principle as the closed container of boiling water. By way of comparison, it is true with the boiler as with the closed container that the steam formed by boiling tends to push against the water sides of the vessel. Because of this downward pressure on the surface of the water, a temperature in excess of 212° F. is required for boiling. The higher temperature is obtained simply by increasing the supply of heat. Bear in mind, therefore, that an increase in pressure means an increase in boiling point temperature.

6. It is relatively simple to determine the temperature of the water once you know the steam pressure. First, you determine the square root of the steam pressure, then multiply this by 14 and add the constant number of 198. For example, when the steam pressure is 100 pounds per square inch on the gage (psig), the square root is 10. When 10 is applied to the formula, the water temperature is 338° F. ($10 \times 14 + 198 = 338$).

7. **Requirements of a Steam Boiler.** A boiler must meet certain requirements before it is considered to be a satisfactory installation. It must be safe to operate, it must generate clean steam at the desired rate and pressure, and it must be economical to operate. A set of rules for construction of stationary steam boilers, known as the American Society of Mechanical Engineers (ASME) Boiler Construction Code, has been widely adopted by insurance underwriters and governmental agencies. This code contains mandatory provisions for methods of construction and installation, materials used, design features, and recommended operating and inspection procedures. Standard practice requires that a qualified boiler inspector make an inspection at least once a year.

8. A boiler must have certain characteristics to meet the requirements of economical operation and the generation of clean steam at the desired rate and pressure. There must be enough water and steam capacity to prevent any fluctuation in steam pressure or water level. It must have a water surface of sufficient extent for the disengagement of steam from the water to prevent foaming. It must provide constant and thorough circulation of the water throughout the boiler to be free from the strains caused by unequal expansion. If possible, it should avoid having joints exposed to the direct action of the fire. The combustion chamber must be arranged so that the combustion of the gases started in the furnace can be completed before the gases can escape through the chimney. The heating surface should be, as nearly as possible, at right angles to the currents of heated gases to break up the currents and extract the maximum available heat from the gases. All boiler parts should be readily accessible for cleaning and repairs. These last points are of the greatest importance with regard to safety and economy.

9. The boiler must be proportioned for the work to be done and be capable of working to its full rated capacity with the highest economy. The boiler must be equipped with the very best gages, safety valves, and other fixtures. There must be some provision for receiving impurities from the water and removing them from the boiler. The collecting areas should be located where they do not come into direct contact with the fire. This is true because the impurities keep the water away from the heating surfaces and cause hot spots that can damage the boiler.

10. **Construction of Boilers.** Boilers are constructed in many shapes and sizes. Of course, the greater the steam capacity, the larger the boiler. All boilers are constructed to incorporate a furnace or firebox for burning the fuel; also, they have provisions for passing hot gases over the heat-absorbing surfaces. The heat-absorbing surfaces are designed to have the hot gases on one side and the boiler water on the other.

11. In most cases, baffles are provided in the boiler to guide the gases over the most effective route. These baffles also prolong the exit of the gases from the furnace so that the maximum amount of heat can be absorbed by the water. Boilers are equipped with doors and access panels which are used to clean the tubes and firesides of the boilers. Plugs, handholes, and manholes are also provided so that the watersides of the boiler can be reached for cleaning. Access doors are usually sealed or made airtight by the installation of asbestos rope or webbing around the door. Manholes and handholes have gaskets made of asbestos and fiber to seal around these openings. These gaskets usually are replaced when annual maintenance is performed or when a leak occurs at either the manhole or the handhole that cannot be stopped by tightening the holding nut.

12. Many low-pressure boilers are constructed of cast-iron sections which are bolted together. The capacities of these boilers can be increased by adding more sections. Other types of low- and high-pressure boilers are made of good quality sheet steel. These boilers consist of sections of sheet steel formed to the required shape and electrically welded or riveted together. The common practice is for low-pressure boilers to be electrically welded and high-pressure boilers to be riveted.

13. **Types of Steam Boilers.** Steam boilers made of cast iron and others constructed of steel are normally further classified into two general types: fire tube and water tube. Fire-tube boilers were first used many centuries ago, but water-tube boilers were not used until the 18th century.

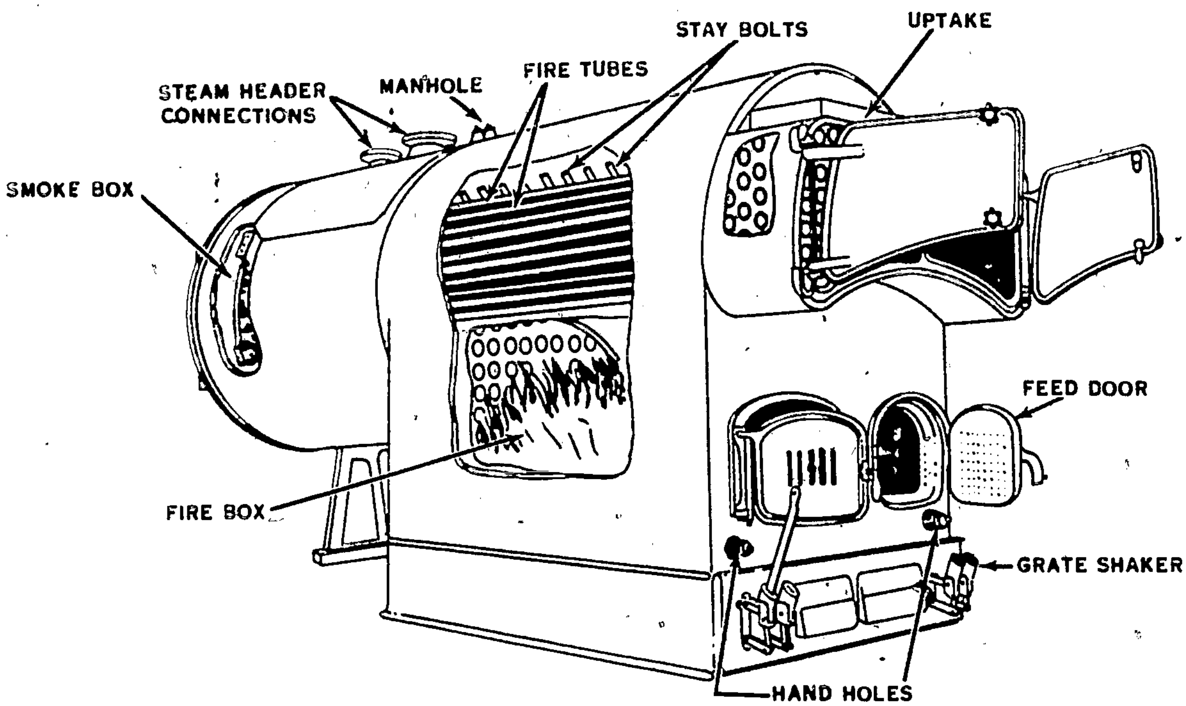

Figure 31. A typical locomotive boiler.

14. *Fire-tube boilers.* Fire-tube boilers are those in which the byproducts of combustion pass through the tubes and the water surrounds the tube. Fire-tube boilers of small and medium size usually have a metal-walled combustion chamber which is integral with the boiler. Because of their ease of installation, fire-tube boilers are the most popular type of steel boiler for low-pressure and low-capacity purposes. Their design and construction, however, are such that there is a definite limitation in the size and pressure for which they can be built. They are seldom used when requirements are above 150 psi design pressure. Their overload is limited, and exit gas temperature rises rapidly with an increased output. One advantage is the large water storage capacity of this boiler. Because of this feature, wide and sudden fluctuations in the steam demand are met with little change in pressure.

15. A boiler that has the combustion chamber incorporated as an integral part of the boiler is usually referred to as a *firebox* boiler. Firebox boilers require no masonry setting, except perhaps an ashpit or floor for the combustion chamber. Combustion gases travel from the firebox through the boiler tubes to a smokebox at the back of the boiler. Then, they return through the second set of boiler tubes to the front of the boiler from which they are discharged to the breaching or the smoke pipe.

16. There are three classes of fire-tube boilers: the locomotive, the tubular, and the Scotch marine. Any of these boilers can be of single- or double-pass construction. There are many versions of these three classes of boilers. Some of the boilers are built to operate in the vertical position instead of in the conventional horizontal position.

17. The locomotive boiler, shown in figure 31, has a steel firebox consisting of inner and outer sheets that are held together with staybolts. The bolts consist of threaded rods that are screwed through threaded holes in the boiler metal sheets and hold them rigid. All four sides of the firebox are surrounded by water. The top metal sheet of the firebox is called the *crown sheet,* and it is supported away from the shell by crown staybolts and crown bolts. These crown sheets should be inspected periodically for leaks, deterioration, and leaking crown staybolts or crown bolts. This type of boiler is very similar in construction to the boiler used on locomotives.

18. The locomotive boiler has water legs that extend down the sides of the firebox. They also serve as collecting places for the sediment that precipitates out of the boiler water. The water legs of the locomotive boiler are connected in the rear to the blowdown lines so that the sediment can be removed from the boiler. This prevents damage to the boiler from hot spots created by the sediment keeping the water away from the heating surfaces of the water legs of the boiler. You will notice that the boiler shown in figure 31 has handholes for accessibility in cleaning the

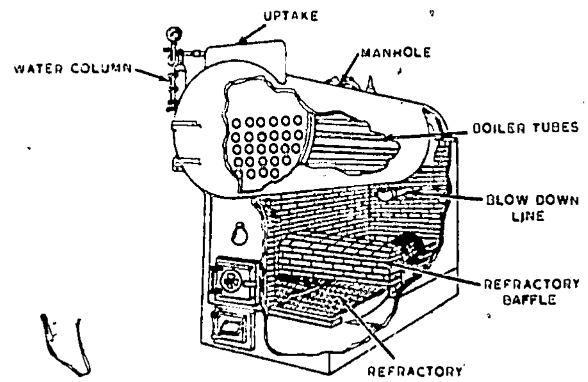

Figure 32. A typical horizontal return tubular boiler.

water legs. There is also a manhole in the top of the shell for access to the watersides.

19. The horizontal-return tubular boiler, often called the HRT boiler, is used for industrial heating (see fig. 32). This boiler is round and has one or two sets of tubes extending throughout its length. The firebox must be constructed separately of firebrick. Approximately one-half of the boiler extends beyond the firebox. Large boilers are supported from the floor by four columns, with the firebrick forming four sides of the firebox. The initial cost of the HRT boiler is relatively low, and it is not difficult to install. The boiler setting can be readily changed to meet different fuel requirements—coal, oil, wood, or gas. Tube replacement is also a comparatively easy task since all tubes in the HRT boiler are the same in size, length, and diameter.

20. The gas flow in the HRT boiler is from the firebox toward the rear of the boiler, where the gases are directed upward to the tubes by means of a refractory baffle, then it returns through the tubes to the front of the boiler where it is discharged to the breeching, as shown in figure 32. The HRT boiler has a pitch of 1 to 2 inches to the rear. This allows sediment to settle toward the rear. The fusible plug of the boiler is located 2 inches above the top row of tubes. Boilers over 40 inches in diameter require a manhole in the upper part of the shell. Those over 48 inches in diameter must have a manhole in the lower as well as the upper part of the shell. Don't fail to familiarize yourself with the location of these and other essential parts of the HRT boiler.

21. The Scotch marine boiler, shown in figure 33, is popular because of its compactness. It is tubular in shape and has a built-in-firebox that extends lengthwise through its center. The Scotch marine boiler is a portable or package unit and can be moved with ease and with a minimum of foundation work. It is a complete self-contained unit which includes automatic controls, steel boiler, and burner equipment. These features are advantageous because no disassembly is required when you have to take the boiler to the field for emergency work or move it to a more suitable location in the area.

22. The Scotch marine boiler has a two-pass arrangement of the tubes, which run horizontally. This allows the heat inside the tubes to travel back and forth. It also has an internally fired furnace with a cylindrical combustion chamber. Its corrugated, sheet-metal firebox makes suitable provision for expansion. There is also a flue gas outlet, or smoke breeching, located on the front end of the boiler. Oil is the fuel commonly used to fire the Scotch boiler. When desirable, though, it can be fired by gas or coal.

23. Another major advantage that the Scotch boiler has over the water-tube boiler is that it requires less space, and can be set up in a room with a low ceiling. The fact that its tubes are all the same size saves time and trouble in making tube replacements.

24. The Scotch boiler has a few disadvantages. Its shell is from 6 to 8 feet in diameter and makes a large amount of reinforcing necessary. The fixed dimensions of its internal furnace create come difficulty in cleaning the surface of the section located below the combustion chamber. Another drawback is the limited capacity and pressure of the Scotch boiler.

25. The setting of the Scotch marine boiler is self-supporting. The shell rests in two or more cast-iron cradles, and the boiler pitches 1 to 2 inches toward the rear. The setting includes a blowdown pipe that is connected to the bottom of the shell, which, in turn, is screwed into a pad riveted to the shell. The flow of gases in the Scotch marine boiler is toward the rear of the combustion chamber; then they return by way of the tubes to the front and go out into the smokebox and stack breeching. The fusible plug of the Scotch boiler is usually located in the crown sheet. However, it is sometimes found in the upper back of the combustion chamber. The

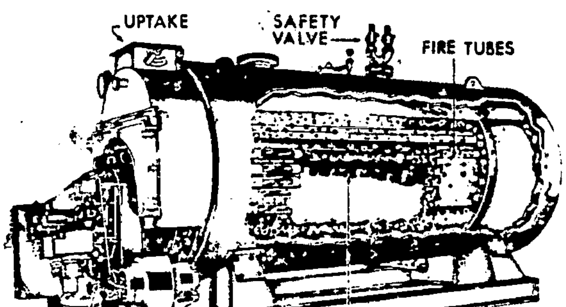

Figure 33. A Scotch marine boiler.

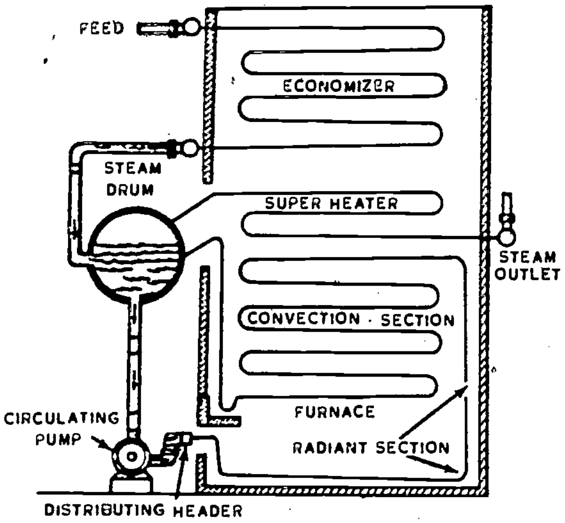

Figure 34. Schematic of a forced-circulation steam boiler.

fusible plug will be discussed in more detail later in this chapter.

26. Aids to cleaning and repairing the boiler are provided through a manhole in the top of the boiler shell and a handhole in the water legs. The manhole is an opening large enough for a man to enter the boiler shell for inspection and cleaning purposes. For the safety of the man inside, always make sure that all valves are secured, locked, and tagged, and that the man in charge knows someone is in there. A man must also be stationed at the outside entrance to aid and assist. The handhole is an opening large enough to permit hand entry for cleaning, inspecting, and repairing the headers and tubes.

27. *Water-tube boilers*. Steel boilers in which the water circulates inside of boiler tubes located in the path of the flue gases are water-tube boilers. These boilers avoid the use of large, flat, steam-containing surfaces; they can be designed for use at high pressures with safety. The boiler has the further advantage of being easier to clean than fire-tube boilers. Because they require much masonry construction at the time of installation, they are more expensive than the fire-tube boilers and are seldom used, except the large sizes. Water-tube boilers can be classified according to the details of construction, size, arrangement of tubes, method of circulation, and other special design features.

28. All boilers having tubes 2 inches or more in diameter are classified as large tube boilers. Boilers having tubes less than 2 inches in diameter are small tube boilers, and are commonly called the *express* type. Practically all of the modern steam boilers are the express type. Water-tube boilers are end-fired, side-fired, single- or double-uptake, air-encased, and are divided heating units. The modern boilers, of the express type, employ either natural or forced circulation to move the boiler water. Natural circulation depends upon the differences in density of the water caused by the heat absorbed by the boiler tubes. The water in a steam boiler depends upon external pumps to provide forced circulation. These pumps provide a mechanical head which maintains continuous flow of water through the boiler circuits. A schematic of a steam boiler of the forced-circulation type is shown in figure 34.

29. The types of tube arrangements used in water-tube boilers are straight, bent, and coiled. Modern boilers are usually of the bent-tube type. In this course, however, we will discuss only the straight-tube and bent-tube arrangements. These arrangements will be discussed separately in the paragraphs that follow. To avoid confusion, you should study carefully each illustration referred to throughout the discussion.

30. The straight-tube arrangement of water-tube boilers includes three types: sectional-header cross-drum, box-header cross-drum, and box-header longitudinal-drum.

31. The first type, shown in figure 35, is a sectional-header cross-drum boiler that has vertical headers. The headers are steel boxes into which the tubes are connected. Feed water enters the drum and passes down through the pipes (downcomers) into the rear sectional-headers from which the water tubes are supplied. As the water is heated, some of it changes into steam and flows through the tubes to the front headers. The steam-water mixture then returns to the steam drum through the circulating tubes and is discharged in front of the steam-drum baffle. This baffle helps to separate the water from the steam. The steam is released from the top of the drum through the dry pipe. This pipe extends along the length of the drum, and has holes or slots in the top half through which the steam enters. This helps to prevent water from being carried into the steam lines.

32. Headers are distinguishing features of the sectional-header cross-drum boiler. They are usually made of forged steel and are connected to the drums by the tubes. The headers are connected at right angles to the tubes, as shown in figure 35. The tubes are rolled and flared into each header. A handhole is located opposite both ends of each tube to facilitate inspecting and cleaning. A mud drum is connected, by short nipples, to the bottom of each rear header. Its purpose is to collect sediment, which is removed by blowing down the boiler. Baffles are usually arranged so that the gases are directed across the tubes at least three times before they are discharged from the boiler below the drum.

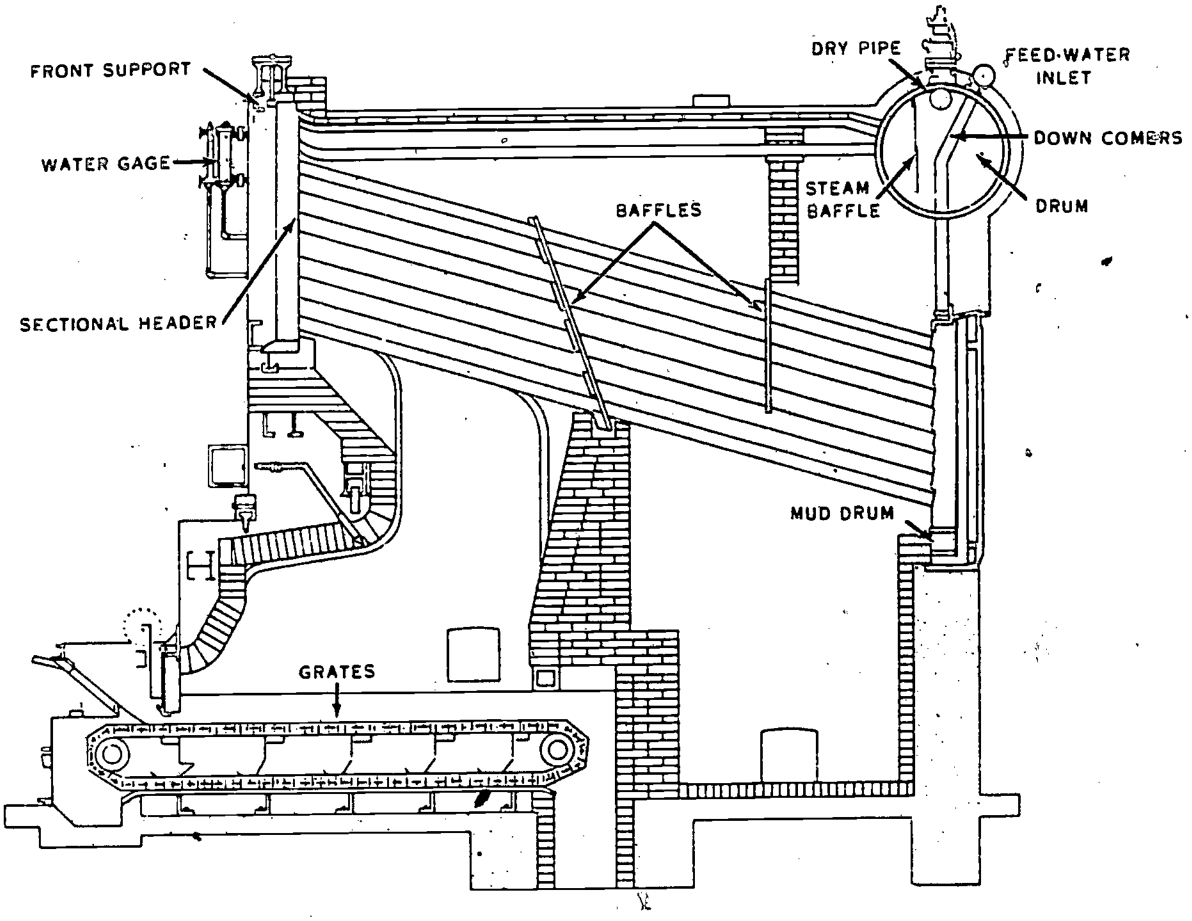

Figure 35. A typical sectional cross-header boiler.

33. The box-header cross-drum boiler is the second type, and it is illustrated in figure 36. The box-headers are shallow boxes made of two metal plates: (1) a tube-sheet plate, which is bent to form the sides of the box, and (2) a plate containing the handholes, which is riveted to the tube-sheet plate. The tubes enter at right angles to the box-header and are expanded and flared in the same manner as in the sectional-header boiler. The boiler is usually built with the drum located in front. This boiler has either cross or longitudinal baffling that is arranged to divide the boiler into three passes. Water enters the bottom of the drum, flows through connecting tubes to the box-header, moves through the tubes to the rear box-header, and goes back to the drum.

34. The third type is the box-header longitudinal-drum boiler, which has either a horizontal or an inclined drum. Box-headers are fastened directly to the drum when the drum is inclined. If the drum is horizontal, the front box-header is connected to it at an angle greater than 90°. The rear box-header is connected to the drum by tubes. Longitudinal or cross baffles can be used with either type.

35. Boilers of the bent-tube type usually have three drums, each the same in diameter but not all set on the same level. The tubes are bent at the ends to enter the drums radially. A typical bent-tube boiler is shown in figure 37. Water enters the top rear drums, passes through the tubes to the bottom drum, and then moves up through the tubes to the top front drum. A mixture of steam and water is discharged into this drum;

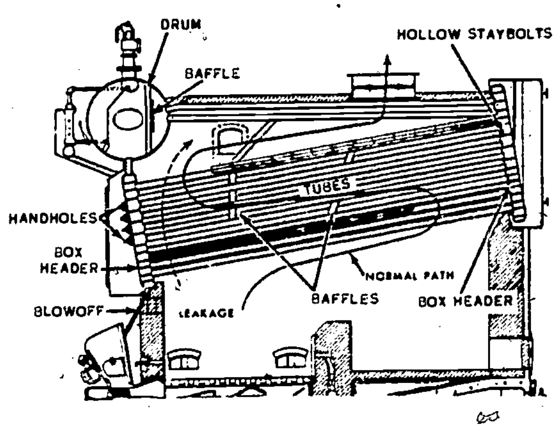

Figure 36. A cross-drum box-header boiler.

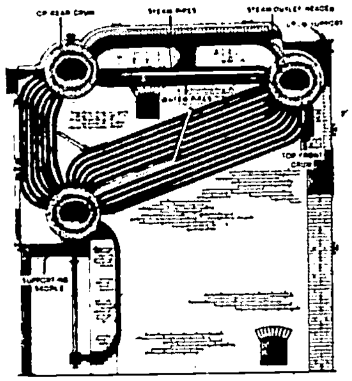

Figure 37. A typical bent-tube boiler.

the steam returns to the top rear drum through the upper row of tubes while the water travels through the tubes in the lower rows. The steam is removed near the top of the rear drum by tubes extending across the drum, and it enters a small collecting header above the front drum.

36. Many baffle arrangements are used with bent-tube boilers. Usually, the baffles are installed so that 70 to 80 percent of the heat will be absorbed by the inclined tubes between the lower and upper front drums.

37. Water-tube boilers offer a number of worthwhile advantages. For one thing, they afford flexibility in starting up. They also have a high productive capacity, which ranges from 100,000 to 1,000,000 pounds of steam per hour. In case of tube failure there is little danger of a disastrous explosion of the water-tube boiler. The furnace not only can carry a high overload, but it can also be modified easily for firing by oil or coal. Still another advantage is afforded by the minimum of difficulty encountered in getting to the sections inside the furnace for cleaning and repairing.

38. There are several disadvantages that are common to water-tube boilers. It should be pointed out here that high construction costs are involved, which is one of the major drawbacks to using water-tube boilers. The large assortment of tubes required by this boiler and the excessive weight per unit weight of steam generated are also other unfavorable factors.

39. **Boiler Fittings and Accessories.** Now that you have a general idea of the overall basic structure of a boiler, several questions no doubt have come to your mind. You are probably wondering about the importance of certain boiler parts and the operation or function of various devices, such as controls, valves, tricocks, and the like. Your interest, consequently, brings us to the topic of fittings and accessories. A sufficient number of essential accessories and fittings will be discussed to provide you with a background for further study. As a reminder, and in case you should run across some unit or device not covered in this chapter, check the manufacturer's manual for information on the details of its construction and its method of operation.

40. The term "fittings" pertains to the various controlling devices installed on the boiler. Bear in mind that the fittings are vitally important to the economy of operation and safety of personnel and equipment. A thorough knowledge of fittings is necessary if you are to acquire skill in the installation, operation, and servicing of steam boilers.

41. *Steam gage.* The steam gage is located on top of the boiler, as illustrated in figure 38, and is used to indicate the pressure of steam in the boiler. It must be accurately calibrated and have a loop of tubing called a siphon loop between the boiler and gage. This prevents live steam from coming in direct contact with the gage mechanism and prevents damage to the gage. The steam gage is installed so that it cannot be shut off from the boiler except by a cock placed near the gage. This cock has a tee or lever handle which is parallel to the pipe in which it is located when the cock is open.

42. Provisions should be made so that a test gage can be installed to check the accuracy of the regular gage while the boiler is in service. The gage dial is usually graduated to read approximately twice the pressure at which the safety valve is set; it is never graduated to read less than 1½ times this pressure. Most of the gages used by the military on boilers are of the Bourdon type.

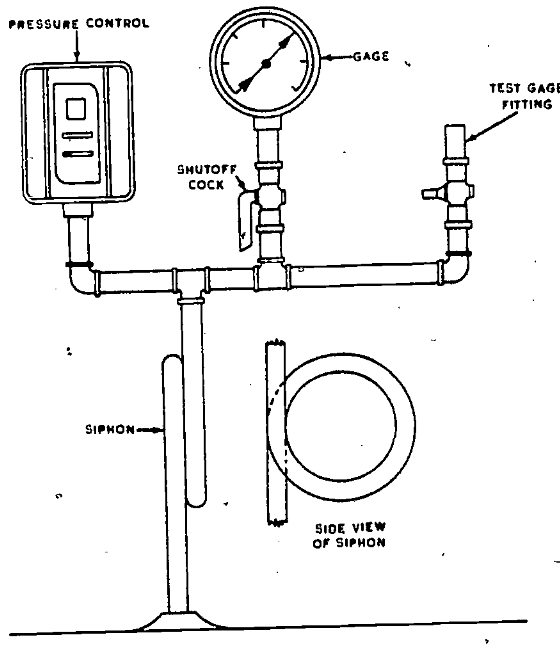

Figure 38. A typical steam gage installation.

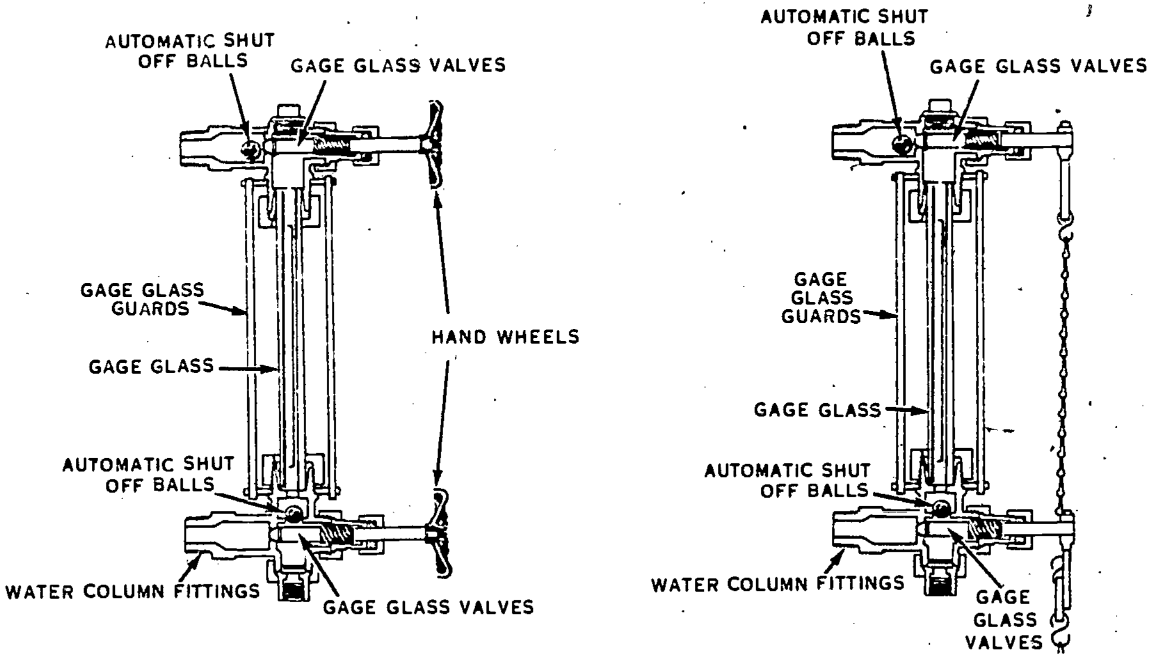

Figure 39. Gage glasses.

They contain a Bourdon tube which operates the pointer.

43. *Pressure control.* Pressure controls are designed primarily for steam-heating systems, but are also available for controlling air, liquids, or gases that are not chemically injurious to the control. The purpose of the pressure control is to control the pressure in the boiler, to secure the fuel-burning equipment when the pressure reaches a predetermined cutout, and to start the fuel-burning equipment when the pressure drops to the cut-in point. There are two settings on the pressure control: the cut-in point and the differential. To find the cutout point you add the differential to the cut-in pressure. For example, if you were operating a boiler with a cut-in pressure of 90 pounds and a differential of 13 pounds, the cutout pressure should be 103 pounds. When excessive vibrations are encountered, you should mount the pressure control remotely from the boiler on a solid mounting with a suitable piping connection between them. Pressure controls that are located remotely from the boiler must be installed at a slightly higher level than that shown in figure 39. The piping must be properly pitched to drain all condensation back into the boiler. A siphon must be connected between the pressure control and the boiler.

44. When a mercury-type switch control is used, be sure that it is mounted level and that the pigtail siphon has the loop extending in the direction of the back of the control and at a 90° angle to the front. This prevents expansion and contraction of the siphon from affecting the level and accuracy of the control.

45. The pressure control can be mounted either on a tee along with the pressure gage on the pressure-gage tapping, as shown in figure 38, or it can be mounted on the low-water cutout provided by some manufacturers. In either case, be sure that the pipe dope is not permitted to enter the control. You apply the dope to the male threads, leaving the first two threads bare.

46. *Gage glass.* Each boiler must have at least one water-gage glass. If the operating pressure is 400 psi or more, two gage glasses must be provided. This is required by the ASME code. The gage glass allows you to tell, by sight, the water level in the boiler. Each gage glass must have a valved drain, and the gage glass and pipe connections must not be less than ½-inch pipe size. The lowest visible part of the water gage must be at least 2 inches above the lowest permissible water level. This level is defined as the lowest level at which there is no danger of overheating any part of the boiler when in operation at that level. Horizontal fire-tube boilers are set to allow at least 3 inches of water over the highest point of the tubes, flues, or crown sheet at the lowest reading in the gage glass.

47. Water-gage glasses, shown in figure 39, are used with boilers operating at low and medium pressures. Each consists of a strong glass tube connected to the boiler or water column by two special fittings. These fittings sometimes have an automatic shutoff device, usually nonferrous balls,

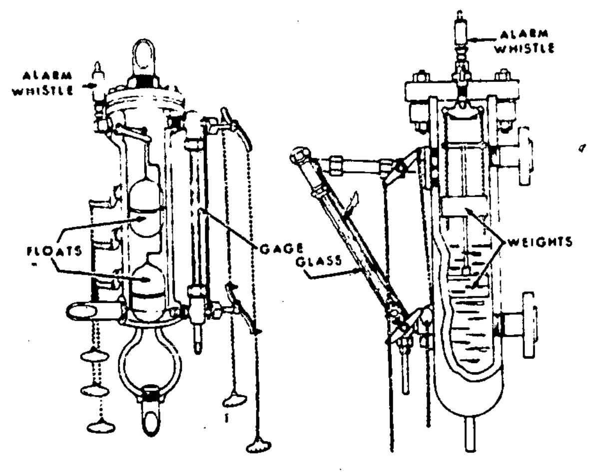

Figure 40. Water columns.

which function when the water glass fails. The top ball does not completely shut off the flow, and the bottom ball must rise vertically to the seat. Both balls must be accessible for inspection, and the removal and inspection of the bottom ball must be made while the boiler is in service.

48. Unless two gage glasses are installed on the same horizontal line, each boiler must have three or more gages or tricocks located within the visible length of the gage glass to prove the boiler water level. The middle tricock is usually at the mean water level of the boiler. The other two are spaced equally above and below it; the actual distance depends upon the size of the boiler.

49. Only two tricocks are required if the boiler is not over 36 inches in diameter and the total of the heating surfaces does not exceed 100 square feet. Gage cocks are used to check the accuracy of the gage glass, and as shutoffs when the gage glass is broken. They are opened by means of a handwheel, chainwheel, or lever, and are closed by hand, by a weight, or by a spring.

50. *Water column.* A water column is a hollow cast-iron, malleable-iron, or steel vessel that has two connections to the boiler, as illustrated in figure 40. The main purpose of the water column is to help prevent fluctuation of the water level in the gage glass. The top connection enters the steam space of the boiler through the top of the shell, or head, and the water connection enters the shell, or head, at least 6 inches below the lowest permissible water level. The pipe used to connect the water column to the boiler may be brass, iron, or steel, depending on the pressure requirement; it must be at least 1 inch in diameter.

51. Valves or cocks are used in these connecting lines if their through-blow construction prevents stoppage by deposits of sediment and if the position of the operating mechanism indicates whether they are open or closed. A valved drain or blowdown line (¾-inch pipe size or larger) is connected to the water column for the removal of mud and sediment from the lines and the column.

52. The water columns illustrated in figure 40 are equipped with high-water and low-water alarms, which sound a whistle to warn the operator. The whistle is operated by either of the two floats or solid weights.

53. *Safety valve.* Safety valves are installed to relieve excessive pressures in the boiler. Their construction, installation, and performance are rigidly prescribed in the boiler ASME code. Each boiler must have at least one safety valve. If the boiler has more than 500 square feet of heating surface, there must be two or more safety valves installed. No valve or stopcock will be installed between the boiler and the safety valve. The discharge line is supported separately to prevent any undue stress on the valve. The capacity of the safety valve must be sufficient to discharge all of the steam generated by the boiler without allowing the pressure to rise more than 6 percent above the maximum working pressure. Safety valves should be popped daily by hand to insure that they are not sticking and that they operate freely. They should also be opened periodically by building up the steam pressure to the relieving

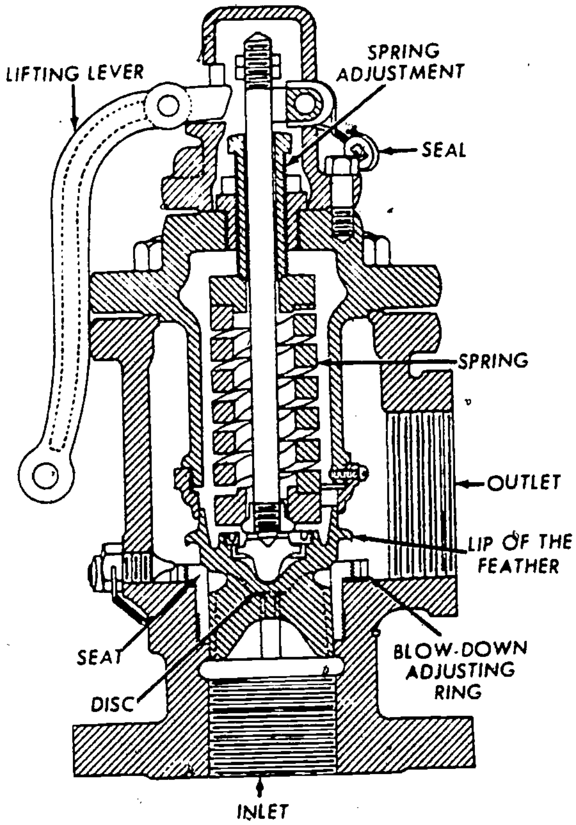

Figure 41. A typical spring-loaded safety valve.

point and causing them to open by steam pressure to insure that they are opening at the correct pressure.

54. The spring-loaded safety valve is often called a pop-off valve because of the characteristic sound it makes when it opens. The safety valve is equipped with a lever for manual operation. A typical spring-loaded safety valve is illustrated in figure 41. The setting and adjustment of safety valves is done only by authorized personnel. All safety valves should be properly sealed to prevent tampering with the adjustment.

55. *Fusible plug.* The fusible plug is designed to give additional protection to the boiler against low water. The plug is installed so that the largest area of the core is exposed to the water for cooling. The core of a fusible plug is made of tin, copper, and lead. Fusible plugs are of two types: fire-actuated and steam-actuated. A fusible plug should be replaced every 12 months. If the core of the plug is exposed to heat for longer periods of time than this, it has a tendency to harden and lessen or remove its value as a safety device. Too high a temperature would then be required to melt the core in event of loss of water in the boiler. When the core melts, steam escapes and warns the operator.

56. The fire-actuated fusible plug is generally screwed into the boiler shell about 2 inches above the top row of tubes or at the lowest permissible safe water level. The boiler must be shut down to replace the fusible plug.

57. The steam-actuated type of fusible plug is screwed into the end of a special tube that extends down into the water to the lowest permissible safe water level. When the water level drops below the end of this tube, steam enters the tube and melts the core. When the core melts,

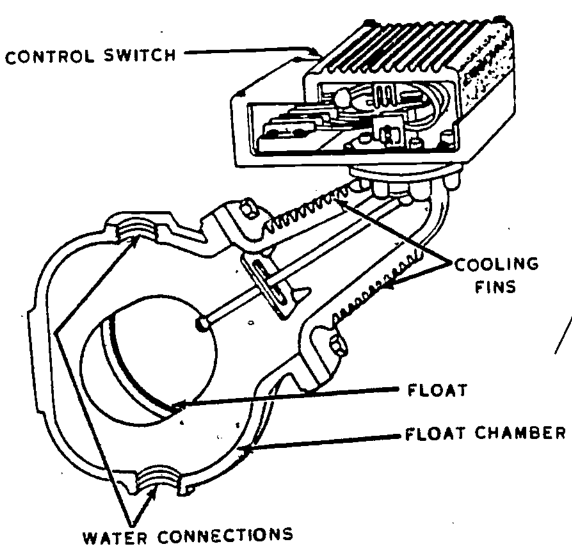

Figure 42. A typical boiler feed-water control.

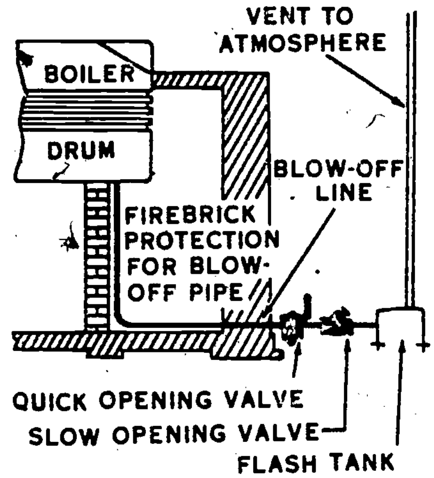

Figure 43. A typical blowdown system.

the steam rushes out of the tube and warns the boiler operator. A stop valve is usually installed in the tube between the plug and the boiler. This is done so that the plug can be replaced without taking the boiler out of service.

58. *Feed-water control.* The boiler feed-water control unit, shown in figure 42, is provided to maintain a fixed water level and thereby protect the boiler from feed-water failure. This unit consists basically of an inclosed float-actuated valve, an electrical switch, or a combination of both, mounted on the outside of the boiler near the water-sight gage. The feed-water control unit adds water to a boiler by opening a water valve or operating a water pump. It eliminates a high-water line by actuating an overflow valve. The control provides for ringing a bell when the water in the boiler becomes dangerously high or low. The unit also stops the operation of a stoker, oil, or gas burner when the water line is low. You will recall that we discussed the operation of the feed-water control in chapter 2 of this memorandum

59. *Blowdown system.* All steam heating systems must have the provision to blow down the boiler. The amount of blowdown is indicated by the results of the total dissolved test. The object of blowing down the boiler is to remove sediment such as mud, scale, and other impurities that are harmful to the boiler. Blowdown is also used to remove excess water from the boiler. The blowdown system is usually connected to the lower tapping on the boiler and consists of a slow-opening valve, a quick-opening valve, a flash tank, and the necessary piping, as illustrated in figure 43.

60. When a boiler is blown down, the quick-opening valve is opened first and the slow-opening valve is opened second. The reason for doing this is to avoid undue stress on the boiler and the blowdown piping. When sufficient blowdown time

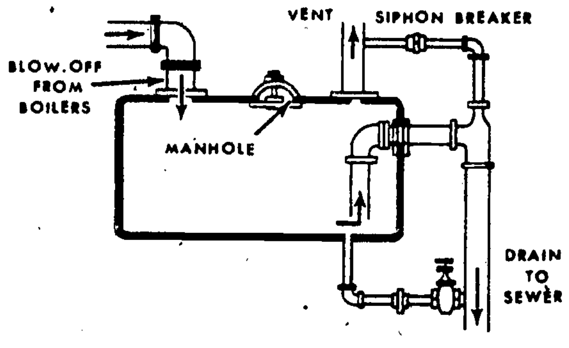

Figure 44. A typical flash tank.

has elapsed, the slow-opening valve is closed first and the quick-opening valve is closed last.

61. The blowdown water or steam should never be piped directly into the atmosphere or sewer because of the possibility of injuring people and damaging the sewer connections. The correct method of disposing of this hot water and steam is by the use of a flash tank, sometimes called a *blowdown basin.* (See fig. 44.) This tank is usually buried underground to prevent freezing. It is equipped with a bottom drain for emptying the tank when cleaning is necessary. A manhole is also provided for cleaning and inspecting purposes.

62. When the hot water from the boiler enters the flash tank, part of the water flashes into steam and is vented into the atmosphere. The water that does not flash into steam, however, will raise the water level in the tank and cause cold water in the tank to overflow into the sewer.

63. **Boiler Code Requirements.** The ASME Boiler and Pressure Vessel Code, sponsored by the American Society of Mechanical Engineers, requires that all boilers carrying over 100-psi working pressure (except traction or portable boilers) have two blowdown valves on each blowdown pipe. The arrangement may include two slow-opening valves or one slow-opening valve and a plugcock. Traction and portable boilers must have one slow- or one quick-opening blowdown valve. All types of boilers must have the blowdown valves installed with extra-heavy steel or malleable iron piping.

64. **Boiler Identification Markings.** Each boiler is stamped with a National Board number, manufacturer's name, steam working pressure, amount of square feet of heating surface, and the year it was built. For example,

NATIONAL BOARD
35678
KEWANEE
125 lbs
715 HS
1947

65. Boilers are also stamped with the manufacturer's stock number, boiler size, and the dry weight of the boiler. For example,

08360
583
13770 lbs

66. **Pipe Identification Markings.** Boilerroom piping is usually painted different colors to identify the contents that flow through them. It is recommended that the heating operator acquaint himself with the color code used in his particular installation.

67. **Installing Steam Boilers.** The installation of steam boilers is similar to the installation of hot-water boilers. General information for installing hot-water boilers is included in the chapter covering hot-water heating. Specific instructions for installing steam boilers are furnished by the manufacturer and the building plans are furnished by the Facilities Engineer.

68. **Operating Steam Boilers.** The specific instructions for operating a particular steam boiler are usually furnished by the manufacturer. There are some specific things, however, that a prospective operator should do when first taking over the operation of a boilerplant. When you become a new operator you should make a preoperation inspection of the boilerplant to satisfy yourself that the plant is in good operating order before the other operator is relieved.

69. During the preoperation inspection, you should check the pertinent details of every unit. You should be satisfied that they are in satisfactory operating condition and that the operation of the units is clear to you. Upon arriving at a boilerplant, the first thing you should check is the water level in the boiler. If you find that the water is excessively low, you will have to quickly secure the firing equipment. You will have to allow the boiler to cool before you add water to the boiler. To add the water before the boiler has cooled creates the possibility of a serious explosion. The step-by-step procedure for making a preoperational inspection will, no doubt, be given to you by your supervisor.

70. **Maintaining Steam Boilers.** The knowledge requirements for maintaining steam boilers are similar to those for maintaining hot-water boilers. General information for maintaining hot-water boilers is included in the chapter pertaining to hot-water heating. Specific information regarding the maintenance of boilers will usually be furnished by the manufacturer of the boiler. You will also find the information and requirements set forth in post regulations and standing operating procedures.

Steam Distribution

IN THE PREVIOUS chapters of this memorandum you studied about types of steam boilers, their construction, how they operate, and how to maintain them. You were told about the water used in boilers, how it is fed into a boiler, and how the water is treated to minimize damage to a boiler. Finally, you studied about how steam is generated.

2. At this point, however, you ask yourself, "What good is the steam without some means of transporting it from the steamplant to the user?" In answer to this question, you will find some information in this chapter about steam distribution systems. A steam boiler is virtually useless for heating without a good distribution system for taking the steam to the areas to be heated. Let us say that the term "distribution system," as used in this chapter, refers to the network of piping required to distribute steam from a boilerroom or a boilerplant through the steam pipes to the equipment using it.

3. Steam distribution systems are grouped under two classifications: exterior and interior. The first discussions will pertain to types of exterior distribution systems.

21. Exterior Steam Distribution Systems

1. The exterior distribution system is further divided into underground and aboveground systems.

2. **Underground Systems.** The major underground systems are the conduit and the utilidor types of systems. These systems are normally installed only in permanent heating installations because of their high cost of installation.

3. *Conduit type.* In the conduit type of steam distribution system, the pipe is installed inside a conduit that is usually buried in the ground below the frostline. The frostline is the lowest depth that the ground freezes during the coldest part of the winter. The pipe used for steam is black steel pipe, which is not as strong as that required for condensate return lines. The conduit and insulation serve to protect and insulate the steam pipe. One type of conduit is illustrated in figure 45. The conduit must be strong enough to withstand the pressure of the earth and the usual additional loads that are imposed upon it.

4. Several types of materials and various designs are used in the manufacture of conduit. Common types of conduit are constructed of masonry cement, galvanized iron, and steel. The conduit is usually sealed with asphaltic tar or some other type of sealer to prevent water from getting into the insulation and deteriorating it. Insulation may be attached directly to the pipe, attached to the inner surface of the conduit, or in loose form and packed between the pipe and the conduit.

5. The bottom of the trench for the conduit should be filled with coarse gravel or broken rock to provide support and adequate water drainage. When allowed to collect, the water seeps into the conduit through porous openings in the sealer. This wets the insulation and causes it to lose much of its insulating value. Manholes are required at intervals along the line to house the necessary valves, traps, and expansion joints. A typical manhole is illustrated in figure 46.

6. *Utilidor type.* The utilidors or tunnels of the utilidor type of system are constructed of brick or concrete. The size and shape of the utilidor usually depends upon the number of distribution pipes to be accommodated and the depth the utilidor must go into the ground. Manholes, sometimes doors, are installed to provide access to the utilidor (tunnel). A typical utilidor is shown in figure 47. The utilidor is usually constructed so that the steam and condensate return lines can be laid along one side of the tunnel on pipe hangers or anchors. This is usually done with the type of pipe hanger with rollers that provides for the free movement required by the expansion of the pipe that occurs. The other side of the utilidor should be a walkway that provides easy access to lines when you are inspecting and doing maintenance.

7. **Aboveground Systems.** Aboveground steam distribution systems are further divided into overhead and surface systems.

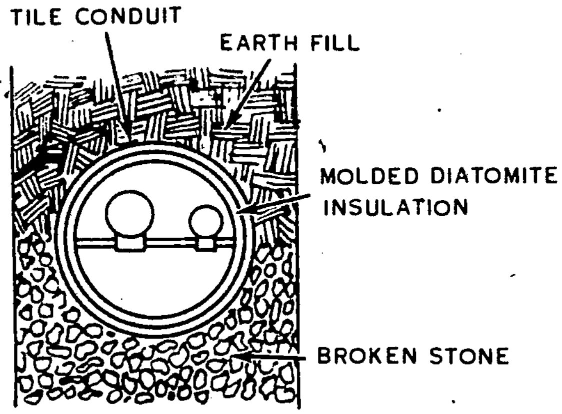

Figure 45. One type of steam distribution conduit.

8. *Overhead distribution systems.* Overhead distribution systems are often used in temporary installations; however, they are sometimes used in permanent installations. The main drawback to this type of distribution system is the high cost of maintaining it. These overhead systems are similar in many respects to underground distribution systems. They require valves, traps, provision for pipe expansion, and insulated pipes. The main difference is that the steam distribution and condensate return piping are supported on pipe hangers from poles, as illustrated in figure 48, instead of being buried underground.

9. *Surface.* In some cases you will find that steam and condensate lines are laid in a conduit along the surface of the ground. These systems, however, are not as common as overhead and underground systems. Surface systems require about the same components as the overhead and the underground systems—traps, valves, pipe hangers to hold the pipes in place, and provision for pipe expansion. Sometimes an expansion loop, formed by a loop of pipe, is used instead of an expansion joint to provide for pipe expansion.

10. **Maintenance.** The maintenance required for exterior distribution systems normally consists of inspecting, repairing, and replacing insulation, traps, valves, pipe hangers, expansion joints, conduit, utilidors, and aluminum or galvanized metal coverings used on aboveground distribution systems. The maintenance required on conduit and utilidors consists of keeping the materials of which they are constructed from being damaged and of insuring that water is kept out of the tunnels and pipes. The maintenance required on outside metal coverings is about the same as that for the conduit and utilidors. Information about the maintenance of traps, expansion joints, and pipe hangers will be given later in this chapter in discussions of system components. The use of valves has already been covered in Chapter 3 of Memorandum 564.

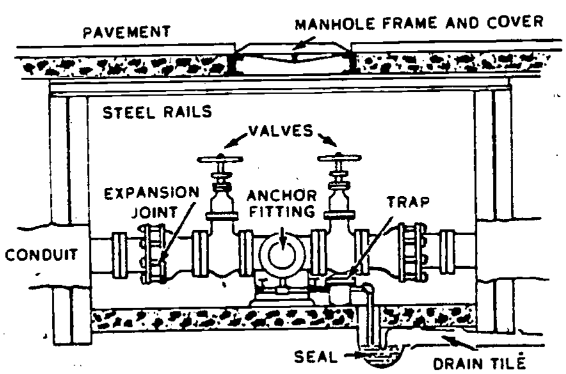

Figure 46. A typical manhole.

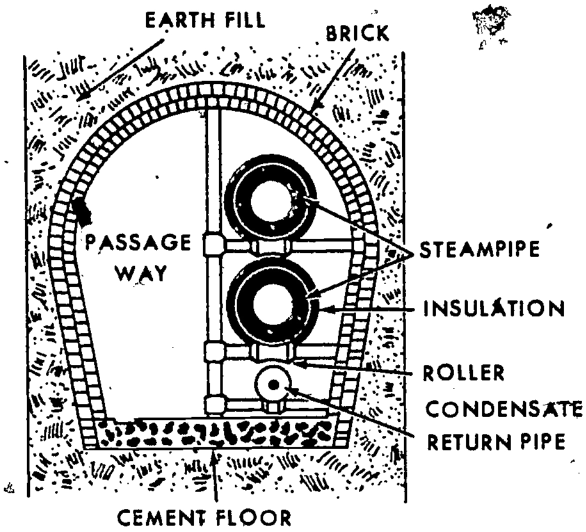

Figure 47. A typical utilidor.

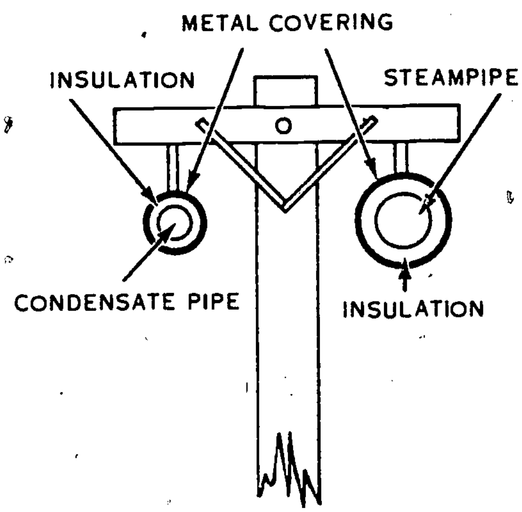

Figure 48. Steam and condensate lines supported by poles.

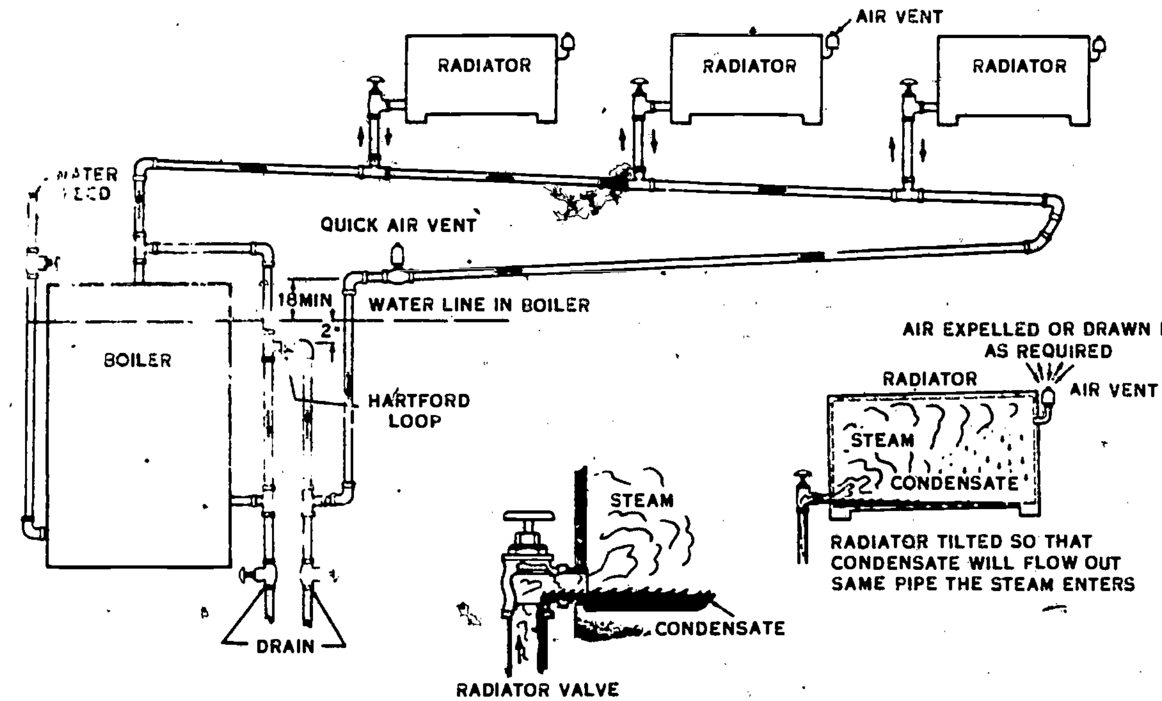

Figure 49. A gravity one-pipe air-vent system.

22. Internal Steam Distribution Systems

1. Internal steam distribution systems may be classified according to pipe arrangement, accessories used, method of returning condensate to the boiler, method of expelling air from the system, or the type of control employed. The interior steam systems that are discussed in this chapter are classified according to pipe arrangement.

2. Steam may be fed to interior steam distribution systems from a boiler in the same building or from the exterior distribution system of a central plant.

3. **Gravity, One-Pipe, Air-Vent System.** The gravity, one-pipe, air-vent system, shown in figure 49, is one of the oldest types of internal distribution systems. Its capacity is usually ample, and its installation cost is low. Because the condensate is returned to the boiler by gravity, this system is usually confined to one building and is seldom used as a central plant distribution system. The steam is supplied by the boiler and is carried by a single system of piping to the radiators. The return of condensate depends upon the hydrostatic head. Therefore, the end of the steam main, where the main is drained to the wet return, should be high enough above the waterline to provide the required hydrostatic head above the entrance to the boiler. The radiators in the system are equipped with an inlet valve and an air valve. The inlet valve is the radiator shutoff valve, while the air valve permits the venting of air from the radiators. Condensate is drained from the radiators through the same pipe that supplies the steam; they flow in the opposite directions, however, which is a disadvantage. Under certain conditions, the condensate is held in the radiators, and causes noisy operation and a fluctuating water level in the boiler. Water hammer and slow heating are characteristic of this system when the pipe sizing, pitch, and general design are inadequate.

4. *Installing.* Although all gravity, one-pipe, air-vent systems are alike in design, it is seldom that two installations are alike in installation details. Since the details differ with the make and model of equipment, it is recommended that the manufacturer's installation procedures be followed. Also, you should follow the mechanical blueprints for the particular installation. There is some general information, however, that we are going to give you, which applies to most heating systems of this type.

5. To prevent water hammer and re-evaporation of the water, all condensate should be properly drained from the lines. The necessary internal drainage can be obtained by sloping the lines down, in the direction of condensate flow, at least ¼-inch for every 10 feet of pipe. The radiators must also be tilted so that the condensate will flow out of them into the same pipe through which the steam is entering.

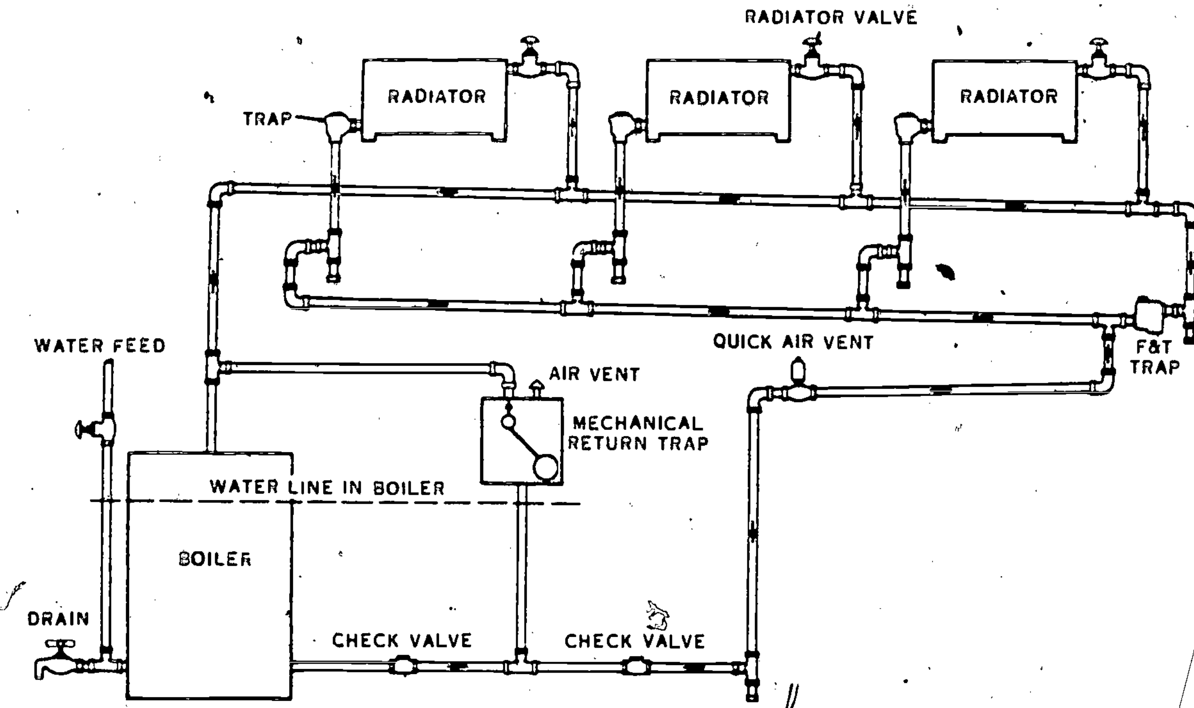

Figure 50. A two-pipe vapor system with a return trap.

6. Air vents are installed in the steam lines and radiators to eliminate any air in the system. Air in the system tends to block the flow of steam, and it consequently acts as an insulator and prevents the emission of heat from the heating surface. Therefore, the air must be quickly and effectively vented from the heating equipment and steam lines to get quick and even heating from the steam-heating system. Most steam distribution systems are now fitted with automatic vents which will permit the air to pass but which block the passage of steam. Figure 49 shows air vents in the radiator and the distribution system.

7. *Operation.* The operating instructions for gravity, one-pipe, air-vent systems will vary from one installation to another. The manufacturer of the equipment usually furnishes the specific operating instructions for his equipment.

8. Generally speaking, you will find that most steam systems have a main steam stop valve located on the top of the boiler. The purpose of this valve is to hold the steam in the boiler until you are ready to let it out. When you are ready to turn the steam into the distribution system, you should only crack (open it very little) the valve. The reason for doing this is to allow the system to warm up slowly and avoid any thermal shock to the lines and fittings. After the system has warmed up, the main steam stop valve should be opened slowly. While opening the valve, you should check often to insure that the proper water level is maintained in the boiler.

9. You will also note that the radiator valves in one-pipe steam distribution systems should be either completely open or completely closed. Partial opening of the valve will interfere with the proper drainage of water from the radiator.

10. **Maintaining.** In this portion of the text we are discussing some of the common problems you are most likely to encounter in the field when maintaining a gravity one-pipe distribution system. The most probable causes of these problems and the remedies for them are considered.

11. When a radiator fails to heat or water hammer occurs, there are several probable causes. One is the failure of the air vents to function, thereby causing the radiator to become airbound. A second cause is that the radiator valves are not completely open. Another cause is that the radiators and lines are not correctly pitched. To remedy these causes of heat failure, you should inspect the operation of the air vents and the positions of the radiator valves to make sure they are open. You should then check and correct, if necessary, the pitch of the radiators and lines when the other checks do not correct the trouble.

12. A fluctuating water line in the boiler can be caused by an excessive pressure drop in the supply lines, which, in turn, is usually caused by partial stoppage in the pipes. This, of course, can only be remedied by removing the cause of the stoppage. Uneven heat distribution is another trouble that you may encounter. This can be caused either by inoperative radiator vents,

improperly vented steam mains, or incorrectly pitched mains. To eliminate this uneven heat distribution, you should check and clean the air vents at the radiator and those in the steam mains. Then, you should check and correct, as required, the pitch of the steam lines, if the other remedies have not corrected the trouble.

13. **Two-Pipe Vapor System with a Return Trap.** The two-pipe vapor system with an alternating return trap, illustrated in figure 50, is an improvement over the one-pipe system. The return from the radiator has a thermostatic trap which permits the flow of condensate and air from the radiator. It also prevents steam from leaving the radiator. Because the return mains are at atmospheric pressure, or less, a mechanical return trap is installed in the system to equalize the condensate return pressure with the boiler pressure. The mechanical return trap is primarily a double-valve float mechanism, which permits equalization of the boiler pressure and the pressure within the return trap.

14. *Installing.* Vapor-steam systems with return traps are similar in design. However, it is seldom that two installations are alike in installation details. Since the details differ with the type of heating equipment, it is recommended that the manufacturer's installation instructions be followed.

15. However, the mechanical return trap should be installed on a vertical pipe in the return system that is adjacent to the boiler. The top of the trap should be level with, or below, the bottom of the dry return main. The bottom of the trap should be approximately 18 inches above the boiler water line to provide a sufficient hydrostatic head to overcome friction in the return piping to the boiler.

16. *Operating.* The two-pipe vapor system with a return trap alternately fills and dumps. It returns condensate to the boiler by a mechanical alternating-return trap instead of by gravity. The alternating-return trap consists of a vessel with a float which, by linkage, controls two valves simultaneously so that one is closed when the other is open. One valve opens to the atmosphere; the other is connected to the steam header. The bottom of the vessel is connected to the wet return.

17. In operation, when the float is down, the valve connected to the steam header is closed and the other is open. As the condensate returns, it goes through the first check valve and rises into the return trap, which is normally located 18 inches above the boiler water line. The float starts to rise, when the water reaches a certain level in the trap, the air vent closes, and the steam valve opens. This action equalizes the trap and boiler pressures and permits the water to flow by gravity from the trap, move through the boiler check valve, and go into the boiler. The float then returns the trap to its normal vented condition, ready for the next flow of returning water.

18. *Maintaining.* The problems you will encounter in maintaining the two-pipe vapor system with a return trap will differ with each system. Although we do not discuss all of the problems you will encounter in the field, we will discuss some of the common troubles. For specific instructions you should refer to the manufacturer's manual or pamphlet pertinent to each piece of equipment.

19. When a radiator fails to heat, the condition can be caused by the air vent being plugged, or the radiator being waterlogged because of a plugged or defective trap. In case there is a plugged air vent, all you need to do is clean it. When there is a waterlogged radiator, the trap should be checked to determine if it is plugged; also you should check to see if the bellows is serviceable. If the trap is plugged, then cleaning it should solve your problem. However, if the trap is damaged, the damaged part, or the whole trap, will have to be replaced.

20. When the entire steam distribution system fails, the trouble can be caused by inoperative return traps or inoperative check valves. The return traps and the check valves should be cleaned and inspected; and, if necessary, the defective parts or the whole unit should be replaced.

21. **Two-Pipe Vapor System with a Condensate Pump.** The two-pipe vapor system with a condensate pump, such as that shown in figure 51, is similar to the two-pipe vapor system with the return trap, except that the condensate is returned to the boiler by a power-driven centrifugal pump, instead of by a return trap. This system includes a separate main, a radiator feed at the top, and a return system with themostatically trapped outlets located at the bottom of the radiators opposite to the feed end. The return main terminates at the receiver of the condensate pump, where all of the air in the system is discharged to a vent on the receiver. With the use of a condensate pump, all of the returns to the pump are kept dry, and the radiators can be located below the boiler water line. This is not possible with the steam distribution systems previously described. The radiators should, however, be installed above the return main to permit gravity flow of the condensate from the radiator, and the return main should pitch downward to the pump receiver.

22. *Installing.* Two-pipe vapor systems with condensate pumps are basically alike in design. However, it is very seldom that two installations are alike in their installation details. It is neces-

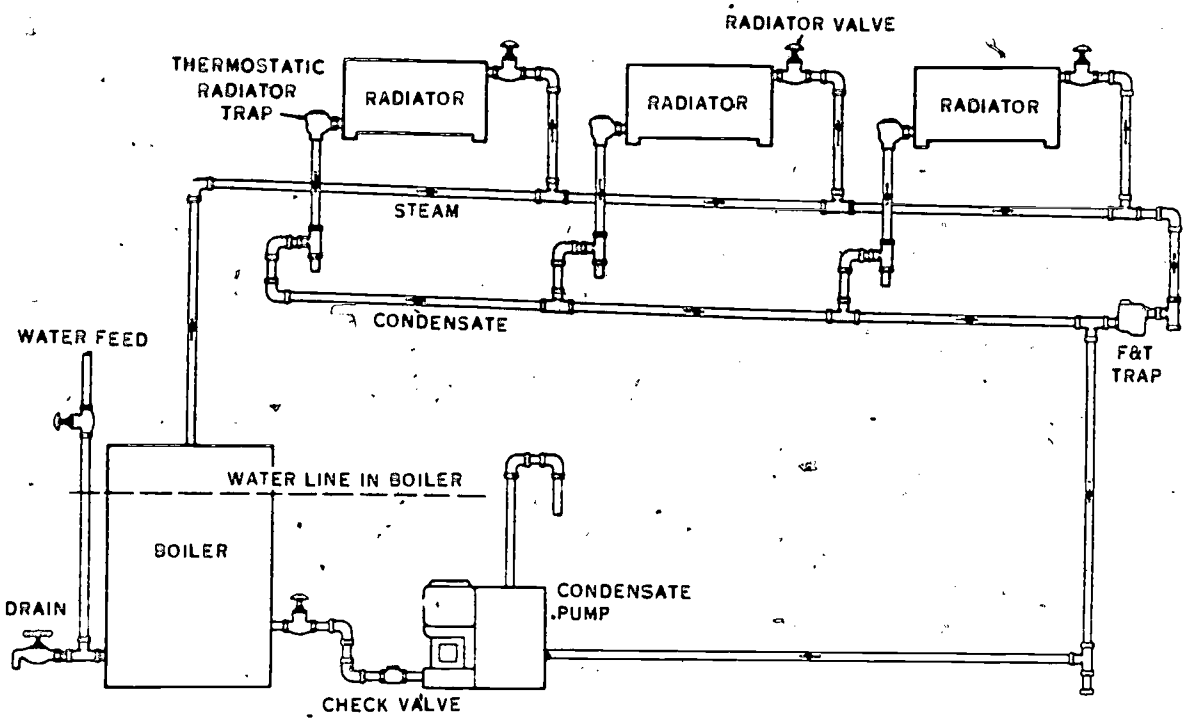

Figure 51. A two-pipe vapor system with a condensate pump.

sary, therefore, to install each system in accordance with the mechanical blueprints furnished by the civil engineer and the instructions of the manufacturer of the equipment.

23. *Operating.* The two-pipe vapor steam distribution system can be operated at the pressure limit of the steamplant boiler, provided the condensate pump is designed for sufficient discharge head necessary to overcome discharge pipe friction loss, boiler pressure, and the hydrostatic head between the pump outlet and the waterline of the boiler. The ends of the steam mains are drained and vented into the dry return main through a combination float and thermostatic trap.

24. The two-pipe system with a condensate pump is adapted to relatively large installations and is probably the most practical and trouble-free system. Most vapor systems differ somewhat with each installation. For specific instructions as to the correct operating procedures, you should refer to the job proficiency guide for your base and to the manufacturer's instructions for the specific type of equipment installed.

25. *Maintaining.* Most of the two-pipe vapor steam distribution systems will differ from one system installation to another. Therefore, you will encounter different maintenance problems with each system. In this chapter we will mention some of the common troubles. It is not feasible to try to cover all of the problems you might have with different systems of this type.

26. When you find that the individual radiator fails to heat, the trouble can be caused either by an inoperative steam trap or the radiator is not installed correctly. These troubles are eliminated by repairing or replacing the steam trap or correcting the improper installation of the radiator.

27. When it is the whole distribution system that fails to heat, the trouble can be caused by clogged or closed receiver vents, a flooded return line, the lack of pump capacity, or air binding the system. These troubles can be remedied by opening the vents, checking and adjusting the pump cut-in, replacing the pump, or repairing inoperative return traps.

28. One common trouble which occurs in this type of distribution system is the overflow of water from the receiver vent. This condition is usually caused by an inoperative pump. The pump may be causing the flooding because of its inadequate capacity or because it is unable to handle the volume of condensate required. This condition can be corrected by either repairing or replacing the pump.

29. Another cause of overflow of water from the receiver vents is an obstruction in the line between the condensate receiver and the boiler. This trouble can be remedied by eliminating the obstruction, regardless of whether it is a closed valve or a clogged line.

30. **Two-Pipe Vapor System with a Vacuum Pump and a Condensate Return.** The two-pipe vapor distribution system with a vacuum pump

and a condensate return, shown in figure 52, is similar to the two-pipe vapor system with a condensate pump. The piping in this system includes separate steam and return mains.

31. *Installing*. Most vapor distribution systems with vacuum pumps and condensate returns are similar. However, it is seldom that two steam distribution installations are alike in installation details. When installing vapor-heating distribution systems, it is advisable to refer to the manufacturer's recommendations, post engineer mechanical drawings, and specifications for the proper installation procedures.

32. *Operating*. When operating this type of distribution system, the steam is supplied at the top of the radiator, and the air and condensate discharged through a thermostatic trap from the bottom of the opposite end of the radiator. All returns are dry and terminate at the vacuum pump. The vacuum pump is usually a motor-driven unit, although low-pressure steam turbines have been successfully used to a limited extent. The vacuum pump returns the condensate to the boiler and maintains the vacuum or subatmospheric pressure in the return system. The maintenance of a vacuum in the return system (3 to 10 inches of water) enables almost instantaneous filling of the heating units at low steam pressure (0 to 2 psi), since air removal is not dependent upon steam pressure.

33. The vacuum pump withdraws the air and water from the system, separates the air from the water, expels the air to the atmosphere, and pumps the water to the boiler, feed-water heater, or surge tank. Usually, the vacuum pump is supplied with a float switch as well as a vacuum switch, and it can be operated as a condensate pump unit. The float switch should be used only when the vacuum switch is defective, and then only until the defects can be repaired or corrected.

34. This system can be used in all types of buildings, and it is of particular advantage for the satisfactory operation of indirect radiation units, heating coils, and ventilating units, and for other units which require close automatic control. Indirect radiation is a term applied to warm-air heating systems that receive their heat from steam supplied to their heat exchanger coils.

35. *Maintaining*. When considering the subject of maintenance on a two-pipe vapor distribution system having a vacuum pump, you will find that most of the troubles which have previously been discussed also apply to this system. In this distribution system, however, keeping air from leaking into the system is more of a problem than in the other distribution systems. Excessive air leakage often causes the pump to run all the time, or the leakage can cause the system to fail to heat altogether. To eliminate air leakage, you must find the point where the air is leaking in and repair it so that no air can get into the system. Rusty spots and water seepage usually indicate the points at which air is leaking into the system.

23. Steam Distribution System Components

1. In previous sections of this chapter you read about various components as you studied the various distribution systems. The components were only mentioned, however, and not explained in detail. Therefore, in this section we are going to discuss these several components from

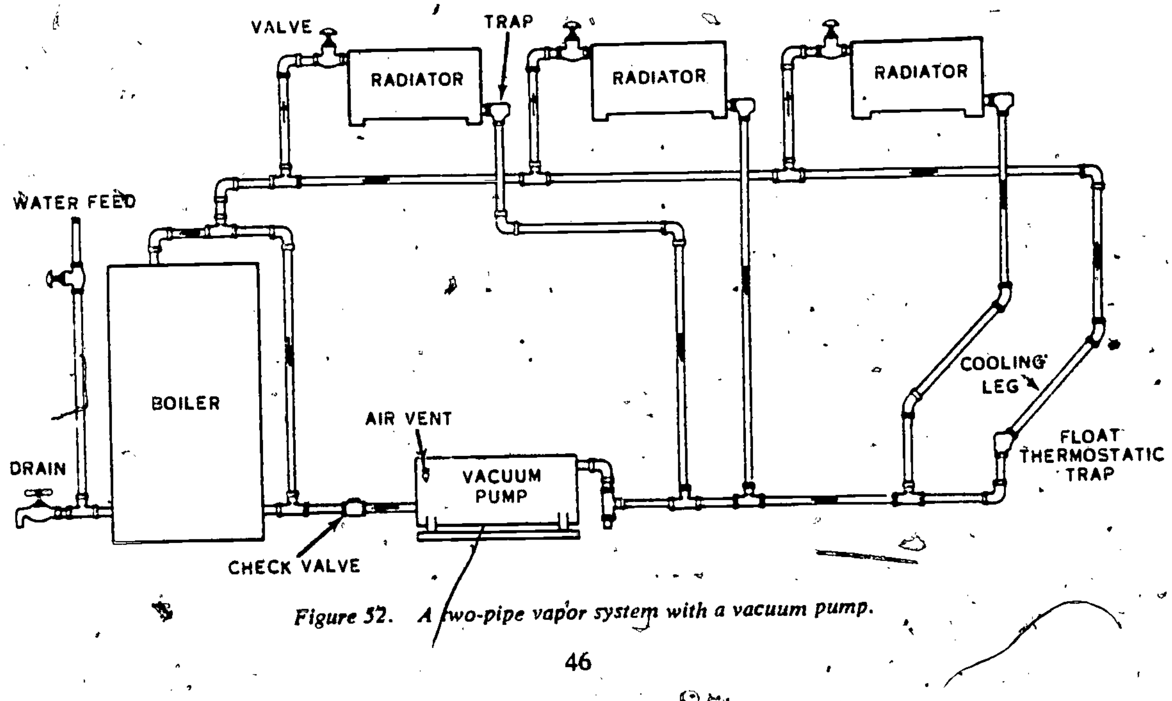

Figure 52. A two-pipe vapor system with a vacuum pump.

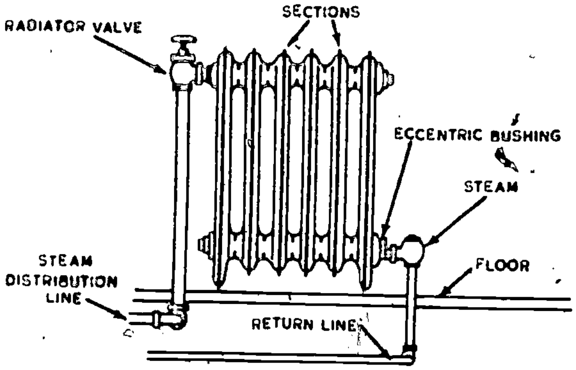

Figure 53. A typical cast-iron radiator.

the standpoints of purpose, operation, and maintenance.

2. **Radiators.** Steam radiators are normally classified into two categories. One is the fin-tube radiator which consists of a metal tube that has metal fins attached on the outside to increase its total heating surface. The fin-tube radiator generally has a valve at one end and a trap at the other end. This radiator has been used more extensively in the past 15 years. It is readily adaptable to areas where floor space is limited, since the radiator is normally mounted on the walls. The second category is the cast-iron radiator which is made in sections. A typical cast-iron radiator is illustrated in figure 53. These cast-iron radiators are similar to those used in hot-water heating systems.

3. The cast-iron radiator is generally used in the one-pipe distribution system. In this system, there is only one distribution pipe connected to the radiator. This pipe delivers steam to the radiators, and it also returns water from the condensed steam to the boiler. For this reason, the radiators must be tilted slightly toward the distribution pipe.

4. The radiators in a two-pipe steam distribution system are connected to the boiler by means of a distribution pipe as well as by a condensate return pipe. Since the steam and condensate in this system flow in separate pipes, the pipes are smaller than those required for the same size radiator in a one-pipe system. The radiator outlet is usually equipped with a steam trap, as shown in figure 53, which prevents steam from leaving the radiator until it condenses into water.

5. **Radiator Air Vents.** There are two types of radiator air vents: automatic and manually operated. A typical automatic air vent is shown in figure 54. Air vents are installed to remove air from the radiators. This must be done because air will keep the radiator from heating properly.

6. The type of air vent shown in figure 54 consists of a hermetically sealed bellows, a valve disc and seal, and a vent body. The bellows contains a volatile liquid which has a boiling point that is 10 degrees lower than that of water. So, when this liquid is heated to a temperature that is 10° below the steam and water temperature, the liquid volatilizes, expands, and closes the valve. When air surrounds the bellows, the air is cooler than the steam. This causes the bellows to contract, open the valve, and allow the air to escape. This cycle then starts over again.

7. The type that is operated manually is usually nothing more than a small valve that has a slotted screw incorporated in the stem and a little spout on one side for the discharged air. These manual vents are normally installed in the same place in the distribution system as automatic vents.

8. **Steam Traps.** Steam traps are designed to retain the steam in a radiator, or other using device, until it changes into condensate. After the steam has turned into condensate, the trap releases the water so that it can enter the return lines. However, it keeps any of the steam coming into the radiator from escaping. The trap performs an important function, since the excessive accumulation of water will prevent the proper heating of the radiator or other steam equipment. Also, steam that is permitted to blow through a defective trap results in heat loss.

9. Traps are generally classified according to their operation. The most common types of traps are float, bucket thermostatic, float thermostatic, impulse, thermodynamic, throttling, and bimetallic-element.

10. *Float trap.* The float traps normally consist of a body, float, linkage, seat, and valve.

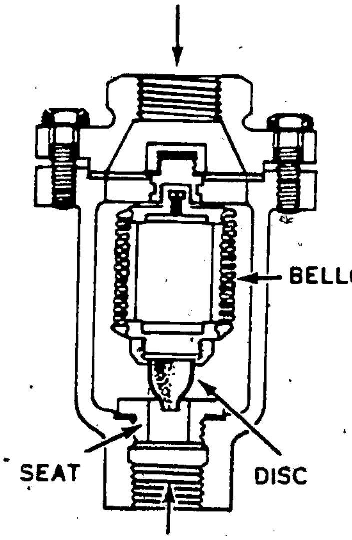

Figure 54. A typical automatic air vent,

A typical float trap is shown in figure 55. As water enters the trap, the float rises, opens the valve, and allows the accumulation of water to flow into the return lines that take it to the boiler. When the water has run out, the float falls, closes the valve, and traps the steam.

11. The maintenance to be done on a float trap is of a simple nature. One of the most common difficulties is that of the float getting water in it and not rising. In this case the float must be replaced. The valve sometimes gets plugged or worn and has to be cleaned or replaced.

12. *Bucket trap.* There are two types of bucket traps, the upright and the inverted. An example of the inverted bucket trap is illustrated in figure 56.

13. During operation of the upright bucket trap, the steam and water both enter the trap body. As the water enters, it causes the bucket to float and the valve to close. The water continues to rise; it overflows into the bucket, which sinks. When the bucket sinks, the trap valve is opened and the steam pressure forces the water out. When all of the water is expelled from the bucket, the bucket again floats, the valve closes, and the cycle has started again.

14. During the operation of the inverted bucket trap, the steam and water both enter under the bucket. The steam makes the bucket buoyant, causes it to rise, and closes the valve. When the steam condenses, the bucket drops, opens the valve, and the steam blows the water out of the trap.

15. Maintenance on bucket traps consists mainly of cleaning and inspecting them periodically. If the trap begins to leak steam, it becomes necessary to replace the valve disc and seat. However, if the bucket fails to open the valve, the trap usually becomes waterlogged. When a valve disc or seat becomes damaged, the trap will allow steam to leak through. The condensate return line will be excessively hot when the trap is leaking steam. Bucket traps contain some water at all times. Therefore, they must be drained if the system is to be off during freezing weather.

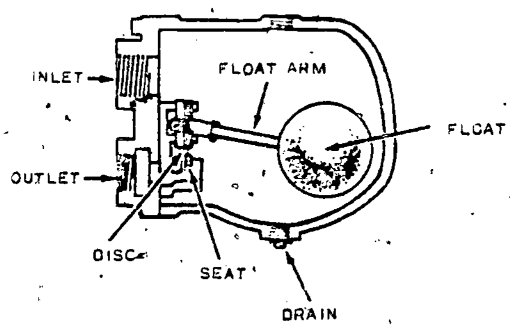

Figure 55. A typical float trap.

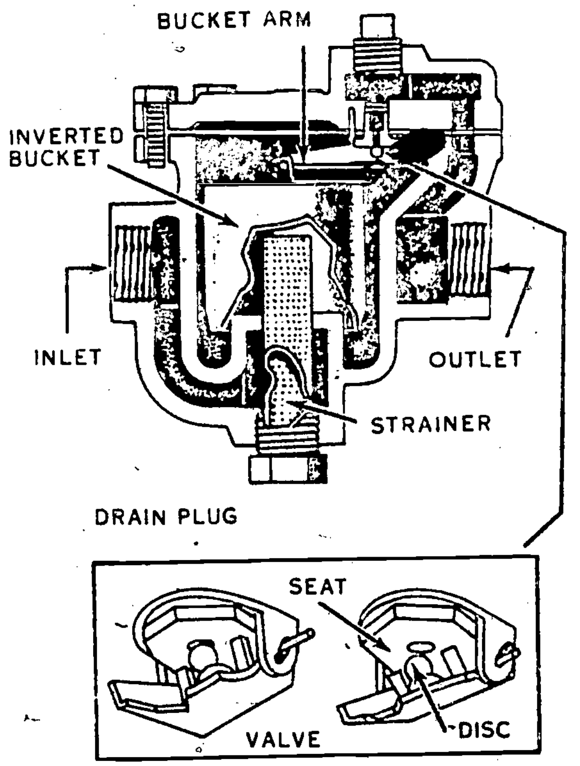

Figure 56. An inverted bucket trap.

16. *Thermostatic trap.* The thermostatic trap is often used on radiators and is commonly known as a radiator trap. It has a bellows that contains volatile fluid which expands and vaporizes when heated. Pressure builds up inside the bellows, causes it to lengthen, and thereby closes the valve. A typical thermostatic trap is shown in figure 57.

17. When water collects around and cools the bellows, the bellows contracts. This opens the valve and permits water to escape. As the water goes out, the steam that enters comes in contact with the bellows and causes it to expand, close the valve, and prevent the steam from escaping.

18. The most common trouble affecting the thermostatic trap is that of the bellows getting holes in it. This causes it to become inoperative, and consequently it must be replaced. The bellows and lower valve seat can be removed for repair without disconnecting any of the piping.

19. *Float thermostatic trap.* The float thermostatic trap operates on the principle of the float trap and the thermostatic trap. Practically the same maintenance is required. A typical example of the float thermostatic trap is shown in figure 58. The thermostatic bellows acts as an air eliminator.

20. *Impulse trap.* The operation of the impulse trap is based on the principle which holds that a portion of hot water, under pressure, will

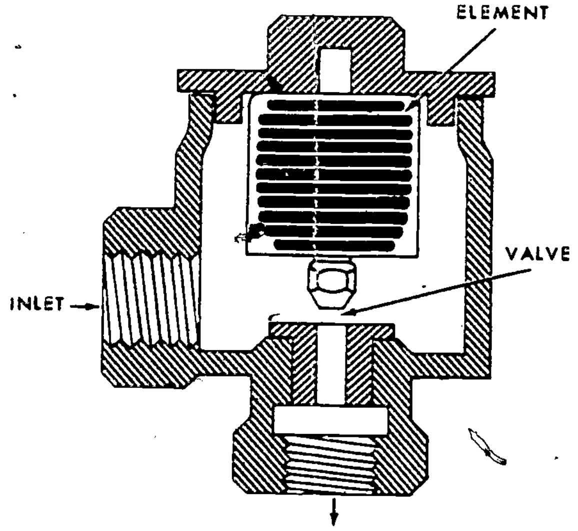

Figure 57. A typical thermostatic trap.

flash into steam when its pressure is reduced. The trap is operated by a moving valve that is impelled by changes of pressure in a control chamber. The valve has tiny orifices drilled through its center which allow the continuous bypassing of condensate from the inlet of the trap to the control chamber. This bypassing reduces the chamber pressure below the inlet pressure; so the valve opens and allows free discharge of the condensate. The temperature of the remaining condensate rises and flashes back to steam. The flow through the valve orifice is choked, and pressure builds up in the control chamber, closing the valve.

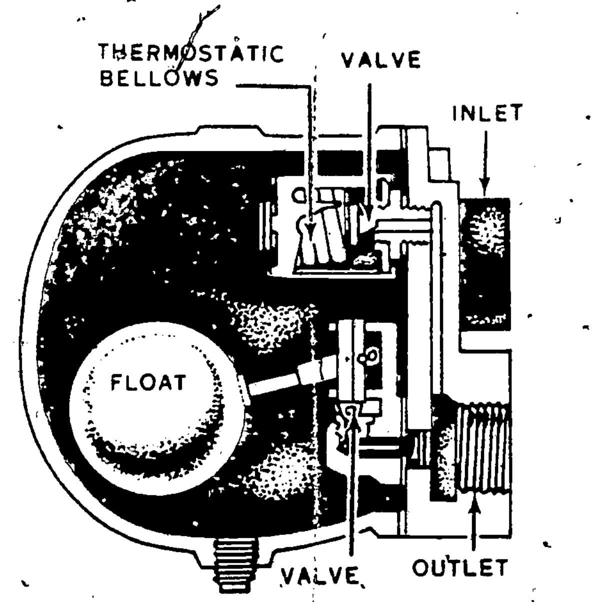

Figure 58. An example of a float thermostatic trap.

21. About 5 percent of the rated capacity of the trap flows through the valve orifice. The pressure on the discharge side of the trap should not be over 25 percent of the inlet pressure if the trap is to function properly. Very little maintenance, except some periodic cleaning, is required for the impulse trap. The trap may be disassembled for cleaning or repair without disturbing any of the piping.

22. *Thermodynamic trap.* A typical thermodynamic trap is illustrated in figure 59. The thermodynamic trap contains only one moving part—a disc. This disc is operated by changes in steam pressure. Pressure under the disc raises it to allow the condensate to be discharged. Droplets of condensate form on top of the disc. Then steam enters at high velocity and creates a low pressure under the disc; the droplets of water above the disc then flash into steam and create a high pressure above the disc. (You recall that water expands to as much as 1728 times its volume when it changes to steam.) This high pressure against the top of the disc overcomes the lower pressure of the incoming steam, so the trap closes. As more condensate collects in the trap, the steam above the disc condenses and relieves the high pressure and the cycle is repeated.

23. The most common trouble is that the trap becomes plugged and has to be disassembled and

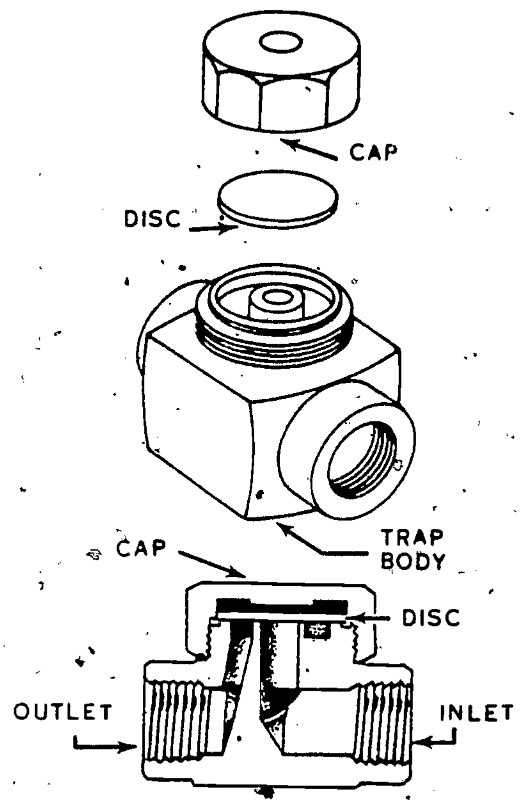

Figure 59. A typical thermodynamic trap.

cleaned. The thermodynamic trap can be cleaned or repaired without disturbing any of the piping. Very little other maintenance is required for this trap because of its simple construction. Too, the trap is usually constructed of stainless steel.

24. *Throttling trap.* The operation of the throttling trap is based on the principle that the flow of water through an orifice decreases as its temperature approaches that of the steam used. The rate of flow of the condensate may be adjusted by raising or lowering a stem (needle valve) that fits into a tapered seat. This throttling trap has no moving parts.

25. Condensate that is slightly cooler than steam enters the trap, travels up through a baffle arrangement, and is discharged through an orifice. If the condensate discharge rate is higher than the inlet rate, the water (condensate) level in the chamber drops. This allows steam to enter the baffle passage and heat the condensate. The amount of water flashing into steam increases; so the volume of steam-water mixture handled by the orifice increases and thereby reduces the capacity of the orifice. The reduced flow through the orifice permits the level of condensate in the chamber to rise until the heater water in the baffle passage has been completely discharged and replaced with water that is slightly cooler. Then the cycle is repeated. Air is vented from this trap through the same passage as the condensate.

26. The throttling trap can be replaced without disturbing any of the piping.

27. *Bimetallic-element trap.* The bimetallic-element trap contains bimetallic elements that bend when heated. The metals contained in the bimetallic strip generally are invar and copper. The copper expands very rapidly when heated, but invar expands very little. Therefore, the bimetallic strip bends when it is heated. This trap may be used for higher or lower steam pressure by increasing or decreasing the number of bimetallic leaves in the trap.

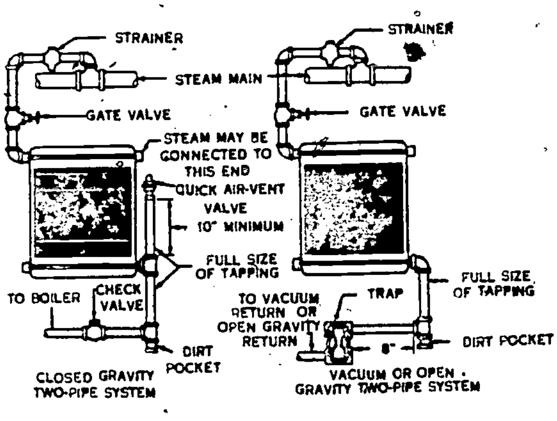

Figure 60. A typical unit heater installation.

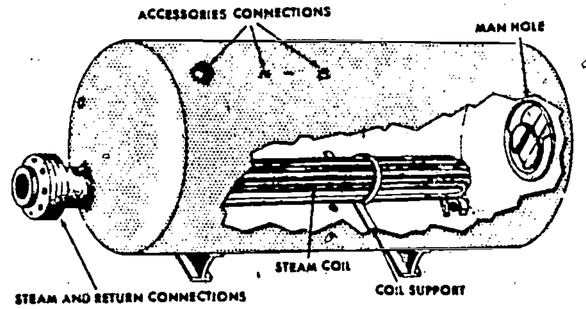

Figure 61. The storage-type hot-water heater.

28. This trap works basically the same as the thermostatic trap. When steam enters the trap, the element is heated and bends, thus closing the valve. As steam condenses, the elements cool and straighten out. This allows the valve to open and let the condensate escape. The bimetallic trap can be repaired without disturbing any of the piping.

29. **Unit Heater.** Unit steam heaters are convection heaters in which the air is circulated by means of a fan. The unit heater is similar to an automobile radiator. It is inclosed in a sheet metal case with the fan mounted at the rear. A typical unit heater is illustrated in figure 60. The steam enters the unit at the top, and the heat is transferred to the fins of the heater. The fan blows the air over the fins and out into the space to be heated. When the steam condenses, the steam trap, usually a float thermostatic type, allows the condensate to drain into the condensate return line. A strainer is installed just ahead of the trap to help keep foreign matter out of the trap.

30. Unit heaters are usually suspended from the ceilings of shops, offices, dining halls, and warehouses. This type of installation saves on floor space, provides for rapid heating, and gives wide distribution of heat.

31. Unit heaters should be taken down periodically and cleaned, because dust and lint collect between the fins and reduce the flow of air.

32. **Hot-Water Heaters.** Steam-operated hot-water heaters are used to supply hot water for laundries, dining halls, latrines, and other facilities. There are two general types of these heaters, storage and instantaneous.

33. *Storage type.* The storage-type of hot-water heater is used to provide potable (drinkable) water that can be taken internally. The steam-operated storage-type of hot-water heater consists of a steel tank that contains a steam-heating coil like that shown in figure 61. The hot-water tank is connected to the base water supply system and remains full of water at all times.

34. The steam is circulated through the heating coil or "bundle," as it is sometimes called. The

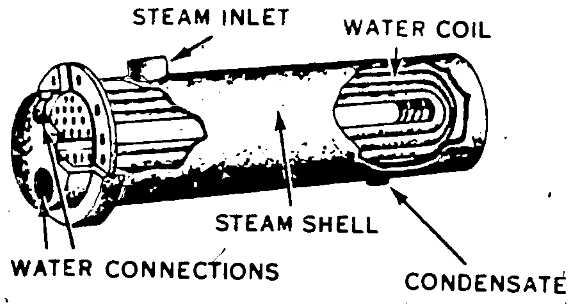

Figure 62. The instantaneous-type hot-water heater.

heat from the steam is transferred through the walls of the coil to the water in the tank. Because of the difference in weight between hot and cold water, the hot water rises and the cold water goes to the bottom of the tank where the steam heating coil is located. Here the water is heated and begins to circulate. Eventually, all of the water in the tank becomes heated. When hot water is drawn, more cold water enters the tank and this heating process repeats itself. This action maintains a full tank of hot water for use whenever hot water is needed. The hot water should not exceed 180° F. The storage type of hot-water heater may be constructed to be installed in either the horizontal or the vertical position.

35. Tappings are usually provided in the tank for a thermometer, a thermostatic element for a temperature-regulating valve (which will be discussed later in this chapter), and a safety valve. The tube coil should be inspected annually to make sure that steam is not leaking into the water. The chemicals that are sometimes used in the steam may make the people who use the water sick if they take it internally.

36. *Instantaneous type*. Instantaneous heaters are used primarily as boiler feed-water heaters; however, they are sometimes used to provide potable (drinking) water at some installations. The operation of the instantaneous-type heater is basically the same as the storage-type heater; their construction, however, is quite different. The diameter of the instantaneous heater is small in comparison to the storage-type heater. The outer shell of the instantaneous heater barely covers the tube coil, as you can see in figure 62. In some makes the water is circulated through the coil, and the steam is released in the shell and surrounds the coil. The water temperature for both types of heaters is controlled by a temperature-regulating valve.

37. **Temperature Regulator.** The temperature regulator is used to regulate the quantity of steam necessary to maintain the hot water at the desired temperature. The unit consists of a temperature bulb, copper line, diaphragm, spring and temperature adjustment, and steam valve. A typical temperature-regulating valve is shown in figure 63.

38. The bulb and copper tube are called the *capsule* and *capillary tube*. They contain a gas which expands or contracts with a change in temperature. The capillary tube is connected to the top of the temperature regulator, which contains a diaphragm (bellows). The diaphragm (bellows) is connected to the valve stem. A spring holds the valve open at low temperatures. When the temperature rises in the water tank, the gas in the temperature bulb expands and forces the diaphragm down, closing the steam valve. The water temperature can be controlled by adjusting the tension of the spring. A steam trap in the steam-heating system returns the condensed steam to the condensate tank.

39. The hot-water tank accessories consist of a temperature gage that has a range of 40° F. to 240° F. and a safety valve or pressure relief valve. The relief valve is set at a pressure that is 10 pounds higher than the operating pressure, and both the setting and the valve must comply with current ASME code specifications.

40. **Condensation Return Pumps.** Condensation return pumps cause the water which has condensed from the steam in radiators, heating coils, convectors, and unit heaters to circulate back to the boiler. One type of condensation return pump is illustrated in figure 64. Units of this type normally consist of a receiver or condensate tank and a pump independently controlled by float switches. A check valve and a vent on the

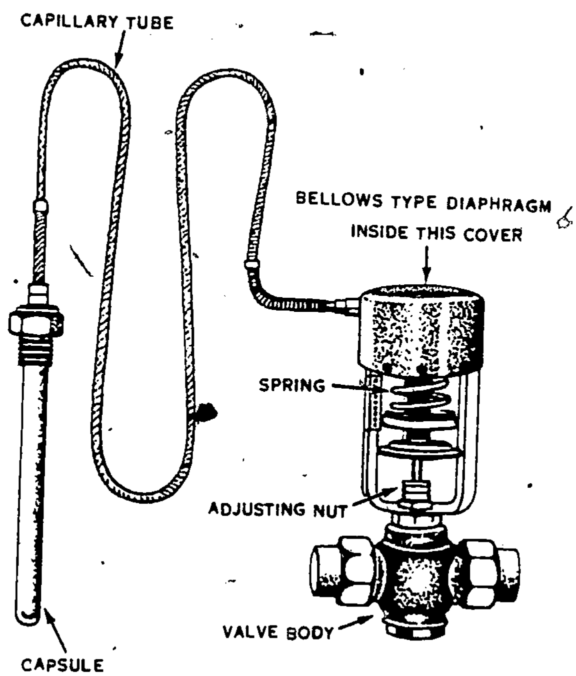

Figure 63. A typical temperature-regulating valve.

receiver allow the receiver to fill and empty as the need arises.

41. Condensate return pumps are maintained as prescribed by the manufacturer of the unit. Usually, the motor should be oiled, the check valves and vents cleaned, the float switches adjusted, the pump repacked, and the tank cleaned at least once each year.

42. **Expansion Joints.** Expansion joints and expansion loops in long heating lines are convenient devices for handling the pipe elongation caused by expansion.

43. *Types of expansion joints.* There are five major types of expansion joints which we are going to discuss at this point: slip joint, bellows joint, swing joint, expansion loop, and ball joint.

44. The slip joint is illustrated in figure 65. The female part of the joint is placed over the male part, and the joint is held tight by the packing which permits expansion. The kind of packing used determines the temperature to which the joint can be subjected.

45. The bellows joint, illustrated in figure 66, has a metal bellows which flexes as expansion occurs. The joint consists of a thin-walled, corrugated copper or stainless steel tube clamped between flanges. Rings help to keep the corrugations under relatively high pressure. The steam pipe and joint should be supported and guided to keep misalignment to a minimum.

46. The swing or swivel joint is most often used to allow expansion to occur naturally in a system that has screwed joints. When it is used with welded elbows, the swing joint introduces torsional strains in the elbows and in the swing piece.

47. The expansion loop absorbs expansion through the formation of U or Z loops in the pipeline.

48. The ball joint is often used instead of the expansion loop, because it requires less space and material. A ball joint consists of four basic parts. The joint has a casing or body to hold the gaskets and a ball. The ball is a hollow fitting that is shaped externally like a ball at one end (inside the casing) and is threaded, flanged, or adapted for welding to the pipe at the other end. There are two gaskets which hold the ball and provide the seal. There is also a retaining nut or flange that holds the ball and gaskets in the casing. The end of one of the two pipes being coupled is con-

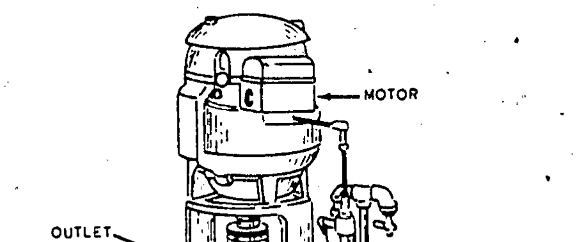

Figure 64. A typical condensate return pump.

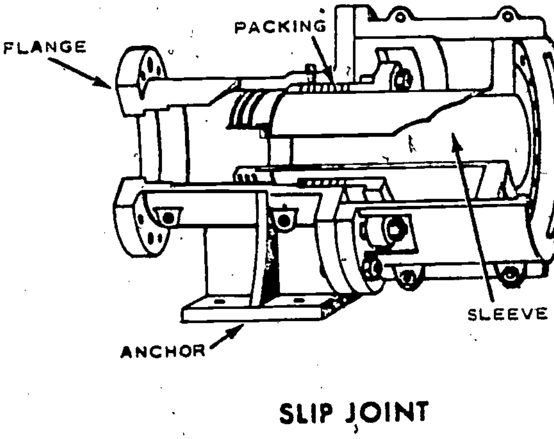

Figure 65. A typical slip-type expansion joint.

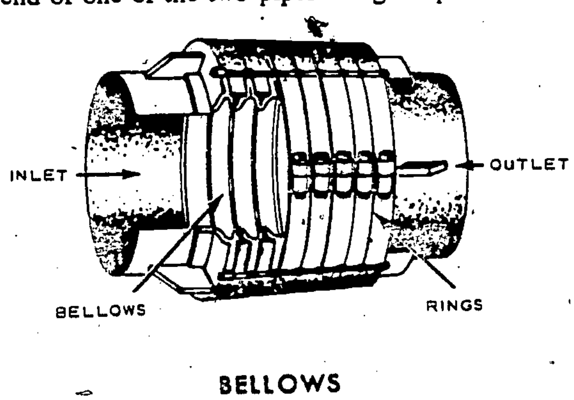

Figure 66. A typical bellows-type expansion joint.

nected to the joint casing; the end of the other pipe is connected to the ball. In operation, the ball joint accommodates the movements of the pipes by providing a flexible articulation (30° to 40° of total angular flexation plus 360° of rotation or swivel motion).

49. *Maintenance of expansion joints.* The slip-type joint must be kept properly aligned, adequately packed. within the proper limit of travel, and thoroughly cleaned and lubricated. You adjust or replace the packing, as required, to prevent leaks and assure a freeworking joint. It is necessary to lubricate every 6 months. using the proper grease for this type of joint and the service conditions. Once a year, you check the flange-to-flange distance of the slip joints. You check the flanges first when they are cold and next when they are hot. This measuring is done to make sure that the travel is within the limits shown in the manufacturer's data. A change in slip travel usually indicates a shift in anchorage of a pipe guide, so you must locate and correct the difficulty. You also inspect annually for signs of erosion, corrosion, wear, deposits, and binding. Then you repair or replace the defective parts as required.

50. The bellows-type joint is checked annually for misalignment, metal fatigue, corrosion, and erosion. You should note the amount of travel between cold and hot conditions. If the joint fails, you replace the bellows section of the joint.

51. Expansion loops require very little specific maintenance except inspection for alignment and leaks.

52. The ball joint must be kept adequately packed. You adjust or replace the gaskets, as required, to correct leaks and obtain a free-working joint. You should always refer to the manufacturer's instructions for doing maintenance work.

53. The swing joint requires only the normal maintenance required for pipe fittings.