DOCUMENT RESUME

ED 229 567 CE 035 819

TITLE Heating and Ventilating III, 11-4. Military Curriculum Materials for Vocational and Technical Education.

INSTITUTION Army Engineer School, Fort Belvoir, Va.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.

SPONS AGENCY Office of Education (DHEW), Washington, D.C.

PUB DATE [78]

NOTE 65p.; For related documents, see CE 035 817-820.

PUB TYPE Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01/PC03 Plus Postage.

DESCRIPTORS Autoinstructional Aids; Behavioral Objectives; Building Trades; Electrical Occupations; *Heating; Individualized Instruction; Learning Activities; Pacing; Postsecondary Education; Secondary Education; Textbooks; *Trade and Industrial Education; *Ventilation; Workbooks

IDENTIFIERS *Heaters; Military Curriculum Project

ABSTRACT

This third 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 three lessons in the course cover these topics: (1) Warm-Air Heating, (2) Domestic Hot-Water Heating, and (3) High-Temperature Hot Water Heating. 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)

DOCUMENT RESUME

ED 229 567 CE 035 819

TITLE Heating and Ventilating III, 11-4. Military Curriculum Materials for Vocational and Technical Education.
INSTITUTION Army Engineer School, Fort Belvoir, Va.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY Office of Education (DHEW), Washington, D.C.
PUB DATE [78]
NOTE 65p.; For related documents, see CE 035 817-820.
PUB TYPE Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS Autoinstructional Aids; Behavioral Objectives; Building Trades; Electrical Occupations; *Heating; Individualized Instruction; Learning Activities; Pacing; Postsecondary Education; Secondary Education; Textbooks; *Trade and Industrial Education; *Ventilation; Workbooks
IDENTIFIERS *Heaters; Military Curriculum Project

ABSTRACT

This third 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 three lessons in the course cover these topics: (1) Warm-Air Heating, (2) Domestic Hot-Water Heating, and (3) High-Temperature Hot Water Heating. 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

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

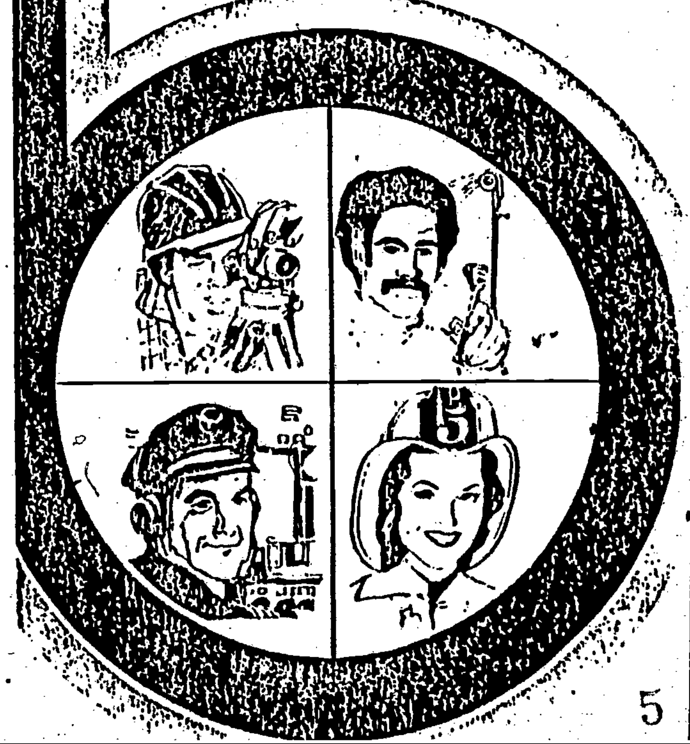
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
The Ohio State University · 1960 Kenny Road · Columbus, Ohio 43210
Tel: (614) 486-3655 Cable: CTVOCEDOSU/Columbus, Ohio

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	Food Service
Aviation	Health
Building & Construction Trades	Heating & Air Conditioning
Clerical Occupations	Machine Shop
Communications	Management & Supervision
Drafting	Meteorology & Navigation
Electronics	Photography
Engine Mechanics	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
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

HEATING AND VENTILATING III

Table of Contents

Course Description — Page 1

Warm-Air and Hot-Water Heating

Lesson 1 - Warm Air Heating — Page 5

Lesson 2 - Domestic Hot-Water Heating — Page 8

Lesson 3 - High-Temperature Hot-Water Heating — Page 11

Workbook — Page 26

Developed by:

United States Army

Development and Review Dates

Unknown

Occupational Area:

Heating and Air Conditioning

Cost:

Print Pages:

57

Availability:

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

Suggested Background:

Heating and Ventilating I & II (Courses II-2 and II-3 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 III (Warm Air and Hot Air Heating)		
Lesson 1 — Warm-Air Heating	11	Flexible
Lesson 2 — Domestic Hot-Water Heating	12	Flexible
Lesson 3 — High-Temperature Hot-Water Heating	8	Flexible
Workbook	11	

Supplementary Materials Required:

None

Expires July 1, 1978

Course Description

This is the third of four courses on heating and ventilating. The previous courses discussed blueprints, tools and piping; electricity, insulation, principles of heating, and heating units. This course offers instruction on gravity and forced warm-air heating equipment, including its installation, operation, and maintenance. In addition there is a lesson on the characteristics, effectiveness, and advantages of several types of high-temperature hot-water (HTHW) heating systems. This course consists of the following three lessons:

Lesson 1 — *Warm-Air Heating* contains information on gravity warm-air heating systems and forced warm-air heating systems including an explanation of the furnaces and ducts used in each system.

Lesson 2 — *Domestic Hot-Water Heating* discusses the types, accessories, installation, operation, and maintenance of hot-water boilers; gravity and forced-circulation hot-water distribution systems; and hot-water heaters.

Lesson 3 — *High-Temperature Hot-Water Heating* covers the characteristics, types, pressurization, operation, and safety characteristics of high-temperature hot-water heating systems. The safety characteristics of steam and hot water, and installing the piping system are also explained.

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 course 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 566-2

HEATING AND VENTILATING III

(WARM-AIR AND HOT-WATER HEATING)

11-4

CORRESPONDENCE COURSE PROGRAM

U. S. ARMY ENGINEER SCHOOL

FORT BELVOIR, VIRGINIA

MOS: 51J20

EDITION 2 (NRI 201)

INTRODUCTION

This is the third of four subcourses on the subject of Heating and Ventilating. The preceding subcourse discussed heat transfer, fuels, and the operation of furnaces and boilers. The present subcourse gives instruction on gravity and forced warm-air heating equipment, including its installation, operation, and maintenance. In addition, there is a lesson on the characteristics, effectiveness, and advantages of several types of high-temperature hot-water (HTHW) heating systems.

The subcourse consists of three lessons and an examination as follows:

Lesson 1. Warm-air Heating.

2. Domestic Hot-water Heating.

3. High-Temperature Hot-water Heating.

Examination.

Eight credit hours are allowed for this subcourse. You will not be limited as to the number of hours that you may spend on the subcourse, any lesson, or the examination.

Text furnished: Memorandum 566, Heating and Ventilating III (Warm-air and Hot-water Heating).

Each exercise has four choices with only ONE best answer. Select the choice that you beleive is best. Check your answers with the solutions found in this subcourse packet.

When you have completed all lessons to your satisfaction, complete the examination and forward the examination answer card to the USAES for grading. The grade you receive on the examination is your grade for the subcourse.

12

5

LESSON 1

WARM-AIR HEATING

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

TEXT ASSIGNMENT ----------------------------Memorandum 566, Chapter 1.

LESSON OBJECTIVE ---------------------------To teach you the principles of warm-air heating systems and the use and maintenance of the equipment used in this heating process.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. Warm air is circulated in the gravity warm-air system by

a. direct conduction

b. indirect radiation

c. natural convection

d. indirect gravitation

2. The total cross-sectional area of all the warm-air ducts in a gravity warm-air heating system is 50 square inches; therefore, the total cross-sectional area of all the cold-air ducts must be at least how many square inches?

a. 25 c. 70

b. 50 d. 80

3. You are installing a gravity warm-air duct 20 feet long. How many inches of upward pitch would you give to this duct?

a. 5 c. 20

b. 10 d. 25

4. Which of the following would you use to seal gastight the sections of a cast iron furnace?

a. graphite rope

b. tar paper

c. manila fiber tape

d. furnace cement

5. If a bottom floor panel is not furnished with a gas furnace, you would make the casing airtight with

a. cement c. asbestos paper

b. tar d. baffles

6. You must use a locally manufactured downdraft diverter in a gas-fired furnace. Before installing it, you make sure that it

a. has been calibrated for this unit

b. is the adjustable type

c. has large vent-pipe sheet

d. is the correct size

7. A horizontal smokepipe 6 feet long would require a pitch of at least

a. 1 inch
b. 3 inches
c. 6 inches
d. 8 inches

8. A chimney having a cross-sectional area of 3 square feet was erected at an Army post situated at sea level. If you had to construct such a chimney at a post located 5000 feet above sea level, what would be its minimum cross-sectional area in square feet?

a. 3
b. 3.6
c. 4
d. 4.2

9. The peak of the roof of a building is 25 feet high. What should be the minimum height of its chimney in feet?

a. 25
b. 28
c. 31
d. 34

10. A furnace has an input rating of one million Btu per hour. How many square inches of area in the free air opening must be provided to supply combustion air to the furnace?

a. 1,000
b. 10,000
c. 100,000
d. 1,000,000

11. A newly assembled cast iron furnace has a casing with a crack in it. What is the probable cause?

a. short push nipple
b. bolts too loose
c. missing bolt
d. bolts too tight

12. Why are metal pipes covered with asbestos paper?

a. lower furnace temperature
b. prevent leaks
c. increase radiation
d. reduce heat loss

13. What action would you take if your warm-air heating system kept some rooms at 65° F and other rooms at 79° F?

a. remake furnace fire
b. decrease furnace fire
c. adjust the dampers
d. balance the butterfly valves

14. In maintaining the air ducts for gravity heating, you should clean them with a vacuum cleaner once each

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

15. The primary difference between the forced warm-air heating system and the gravity heating system is in the

a. placement of the cold-air returns
b. method of circulating the air
c. number of registers
d. number of warm-air pipes

16. Which of the following allows the forced warm-air system furnace to be placed on the same floor as the rooms to be heated?

a. fan or blower
b. cold-air returns attached to ceiling
c. the number of registers
d. the use of small ducts

17. In maintaining a forced warm-air furnace, how often would you inspect the air filters?

a. once each week
b. twice each week
c. once a month
d. twice a month

18. How much play would you allow in the blower belt of a forced warm-air furnace?

a. ¼ to ½ inch
b. ½ to ¾ inch

c. 1½ to 2½ inches

d. 1 to 1½ inches

19. In the forced warm-air heating system, the air ducts are usually

a. larger than gravity air ducts

b. attached to the walls of the heated rooms

c. sloped up 0.50 inch per 6 feet

d. hung from the ceiling

20. At how many feet per minute should the air issue from the register of a forced warm-air heating system?

a. 35

b. 40

c. 45

d. 50

LESSON 2

DOMESTIC HOT-WATER HEATING

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

TEXT ASSIGNMENT ------------------ Memorandum 566, Chapter 2.

LESSON OBJECTIVE ---------------- To teach you the installation, operation, and maintenance of hot-water boilers, heaters, and their distribution systems.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. The hot-water boiler that has a self-contained firebox and is somewhat portable is called

a. self-contained c. circulating
b. skid-mounted d. package

2. What type of boiler is constructed in several sections?

a. cast iron c. wrought iron
b. steel d. brick

3. The number of intermediate sections in a square cast iron boiler is determined by the size of the

a. push nipples c. boiler
b. header d. firebox

4. One of the two sections of a steel hot-water boiler consists of the base and either the grates or burner. It is constructed accordng to the

a. number of water jackets
b. type of fuel used
c. size of smoke passages
d. location of combustion chamber

5. The pressure relief valve on a hot-water boiler may corrode or stick, and therefore should be forced to operate once each

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

6. In the event of an induced or a forced draft failure in a boiler, which of the following would shut down the firing equipment?

a. airflow switch
b. pressure relief valve
c. pressure gage
d. water level valve

7. The baffles in a hot-water boiler

a. reduce water evaporation
b. hold the hot gases
c. mix air and fuel
d. clean boiler tubes

8. A steel boiler has developed a very large hole in the boiler flue. What should you do?

a. weld the hole

b. cover hole with asbestos paper

c. replace the flue

d. replace a boiler section

9. In the two-pipe open-type gravity system, the amount of temperature drop between the beginning and the end of the line depends upon

a. radiator size and atmosphere vent

b. location of expansion tank

c. size of pneumatic compression tank

d. length of main and the heating load

10. In a gravity open-tank system, with an average boiler temperature of 170° F, the radiator emission rate of Btu psf is

a. 100 c. 135

b. 125 d. 150

11. The expansion tanks in the gravity and forced circulation systems

a. allow water in distribution system to expand

b. hold the water extracted from the steam lines

c. hold the steam extracted from the water lines

d. force water in distribution system to condense

12. When a hot-water system is first filled with water, it is normally necessary to

a. close air vents on the radiators

b. keep water temperature below 150°

c. increase intake of air

d. bleed air out of system

13. In the one-pipe, closed-tank, forced circulating system, which of the following would you install to improve the circulation through individual radiators?

a. pressure valves c. elbows

b. connecting tees d. branches

14. You are installing a 100-foot branch line in a hot-water system. How many inches of pitch, as a minimum, do you give to this line?

a. 4 c. 10

b. 6 d. 12

15. You find a badly cracked section in your cast iron radiator. This section should be

a. riveted c. replaced

b. welded d. inverted

16. The boiler of your hot water system smokes through the feed doors. There are no chimney leaks. Which of the following do you do next?

a. blow down the boiler

b. increase furnace draft

c. change kind of fuel

d. clean flues and flue pipes

17. The radiators in a forced circulation hot-water heating system will not heat. There is sufficient water in the system, radiator valves are open, no corrosion is present, and you have bled the air from the system. Which of the following would you do next?

a. check circulation pump

b. clean boiler flues

c. change to larger boiler

d. increase draft

18. The distribution piping in a hot-water system fails to transfer water to the upper radiators. There is no stoppage in the lines, the circulation pump runs, and you have bled the air from the system. Which of the following could be the cause of this failure?

a. insufficient water

b. decreased furnace draft

c. wrong type of fuel

d. chimney leaks

19. Boiler water is not used for domestic purposes because

a. it is too hot

b. of chemical added

c. quantity is limited

d. it has been aerated

20. What is the gallon capacity of domestic hot-water heaters?

a. 5 to 10

b. 5 to 20

c. 10 to 25

d. 20 to 50

LESSON 3

HIGH-TEMPERATURE HOT-WATER (HTHW) HEATING

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

TEXT ASSIGNMENT ---------------------------Memorandum 566, Chapter 3.

LESSON OBJECTIVE ---------------------------To teach you the operation and maintenance of HTHW systems, the characteristics of their heat-carrying media, and the installation of piping equipment.

EXERCISES

Requirement. Solve the following mulitple-choice exercises.

1. The HTHW system uses very little make-up water because it

a. is a closed system

b. requires frequent blowdowns

c. has considerable leakage

d. operates at low thermal level

2. What is the total of Btu/cu. ft. of water under 60 psi gage pressure and at a temperature of 308° F?

a. 13,800 c. 15,000

b. 14,000 d. 15,840

3. If water and steam each were subjected to 70 psig at a temperature of 316° F, the water would contain how many times more Btu/cu. ft. than would the steam?

a. 50 c. 63

b. 58' d. 71

4. When the temperature of the water in an HTHW system is 100° F, the density is about 63 pounds per cubic foot. What will be the density of the water in pounds per cubic foot when the temperature rises to 200° F?

a. 60 c. 90

b. 70 d. 120

5. Which of the following is an important characteristic of the HTHW system?

a. constant water density

b. no pipe radiation

c. simplicity of construction

d. no pump leakage

6. A 1-inch steam line transfers 9000 Btu per hour. If this heating system is changed to HTHW, how many Btu would you expect the line to transmit?

a. 9,000 c. 270,000

b. 27,000 d. 900,000

7. For a given volume, steam contains how many times more heat than does air?

a. 38 to 65
b. 38 to 70
c. 40 to 80
d. 40 to 90

8. The high fahrenheit temperature range for most military HTHW heating plants is

a. 100° to 200°
b. 200° to 300°
c. 300° to 400°
d. 350° to 450°

9. The second pump in the two-pump HTHW system is used to

a. pump water to distribution system
b. circulate water through generator
c. circulate water throughout system
d. pump water to expansion tank

10. In the cascade heater method, the water is heated by

a. direct contact with steam
b. inert gas pressure
c. a steam boiler
d. a hot-water generator

11. In pressurizing the HTHW system, an expansion tank is required. Why?

a. water expands when heated
b. it reduces saturation temperatures
c. it prevents vaporization when temperature falls
d. it keeps water below 212° F

12. When operating with the saturated-steam cushion design in pressurizing the HTHW system, it is necessary to generate an excess amount of heat in order to

a. allow for expansion in drum
b. increase flow of hot water
c. provide saturated steam
d. offset radiant heat loss

13. Which of the following is a characteristic of the mechanical-gas cushion design for pressurizing the HTHW system?

a. extra large steam drum
b. expansion tank is part of generator
c. expansion tank is independent of generator
d. subject to frequent flashing of steam

14. What is the minimum number of gallons of sodium sulfite that you would use to treat five million gallons of water?

a. 50
b. 100
c. 130
d. 150

15. A low-pressure steam line is at 5 psi and 230° F. A break in this line would cause the discharge of this steam into the atmosphere at a velocity of how many feet per second?

a. 1000
b. 1200
c. 1500
d. 1600

16. A high-pressure steam line is at 125 psi and 300° F. A break in this line would cause the discharge of the steam at a velocity of how many feet per second?

a. 1200
b. 1400
c. 1600
d. 1800

17. A break in a low-pressure water line at 15 psi and 200° F would cause discharge of the water at a velocity of how many feet per second?

a. 175
b. 500
c. 1000
d. 1750

18. Which of the following could cause an explosion in a steam boiler?

a. steam pressure equaling atmospheric pressure

b. excessive steam pressure inside steam drum

c. sudden lowering of water level

d. collapse of generator tube

19. After the loss of water on the inside of the tubes, tube failure in a forced circulation HTHW system can take place in

a. 2 seconds

b. 30 seconds

c. 1 minute

d. 2 minutes

20. All piping in an HTHW system should be

a. riveted

b. soldered

c. cemented

d. welded

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 566-2 . . . . Heating and Ventilating III (Warm-Air and Hot-Water Heating).

LESSON 1 . . . . Warm-Air Heating.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 566-2.

1. *c* (par 1-1)
2. *b* (par 1-2)
3. *c* (par 1-3)
4. *d* (par 1-5)
5. *a* (par 1-15)
6. *a* (par 1-16)
7. *c* (par 1-17)
8. *b* (par 1-19)
9. *b* (par 1-19)
10. *a* (par 1-20)
11. *d* (par 1-13)
12. *d* (par 1-27)
13. *c* (par 1-31)
14. *d* (par 1-32)
15. *b* (par 2-1)
16. *a* (par 2-3)
17. *a* (par 2-11*b*)
18. *c* (par 2-11)
19. *d* (par 2-14)
20. *d* (par 2-18)

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. In the gravity warm-air system, **natural convection** (c) causes circulation. The circulation takes place because of the difference in weight between warm air and cold air.

2. The total cross-sectional area of all the cold-air ducts must be at least equal to the total cross-sectional area of all the warm-air ducts — 50 (b) square inches.

3. The ducts are installed with at least 1 inch of upward pitch per linear foot and leaves room for proper air circulation. 20 × 1″ = 20″ (c)

4. Cast iron furnaces are constructed in sections which are made gastight with asbestos rope packing and **furnace cement** (d).

5. If there is no bottom floor panel furnished, grout the casing to make it airtight by chipping and wetting the floor, and then using a liberal amount of cement (a) mixture.

6. Diverters are developed for individual furnaces, so you should never use a diverter of local manufacture unless it **has been calibrated for the specific heating unit** (a).

7. Install all horizontal smokepipes so that they have a pitch of not less than 1 inch per linear foot, as illustrated in figure 4. 6″ × 1″ = 6″ (c)

8. To be satisfactory above sea level, the area of the chimney must be increased 4% for each 1000 feet above sea level.

   5000 ÷ 1000 = 5 × 4% = 20% increase

   3′ × .20 = .6 square feet increase

   3′ + .6′ = 3.6 square feet (b)

9. The chimney must never be less than 15 feet high and always extend at least 3 feet above the peak of the roof.

   25′ + 3′ = 28′ (b)

10. An opening having 1 square inch of free air area must be provided for each 1000 Btu per hour of furnace input rating, with a minimum of 200 square inches.

    1,000,000 ÷ 1000 = 1000 Btu × 1 sq in = 1000 sq in (a)

11. Bolts must be tightened with care. **Drawing bolts too tight** (d) cracks or breaks a casing or buckles a steel plate.

12. The metal pipes are covered with a thin layer of asbestos paper to **reduce heat loss** (d) through radiation.

13. You can balance the heating system by **adjusting the dampers** (c) in the duct branches while the furnace is in full operation.

14. Gravity cold-air and warm-air ducts require very little maintenance. So that the warm air flows properly, clean the ducts with a vacuum cleaner once each **season (d).**

15. The difference between the two heating systems is in the **method of circulating the air (b).** Gravity causes the air to circulate in the gravity system, and an electric blower or fan causes the air to circulate in a forced warm-air heating system.

16. The furnace can be located on the same floor as the rooms to be heated because the **fan or blower (a)** insures that warm air reaches all the rooms.

17. Inspect air filters at least **once each week (a).** You should clean or replace them whenever they need cleaning or replacing.

18. Unless the manufacturer recommends tighter adjustment, adjust the base of the motor so that there is **1½ inches to 2½ inches (c)** of play in the belt, as illustrated in figure 11.

19. Both the warm-air and cold-air ducts are usually **hung from the ceiling (d)** with metal strapping.

20. You should regulate the dampers until the air from the register is about **50 (d)** feet per minute. Take this measurement about three-fourths of the distance away from the register to the opposite wall.

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 566-2 . . . . Heating and Ventilating III (Warm-Air and Hot-Water Heating).

LESSON 2 . . . . Domestic Hot-Water Heating.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 566-2.

1. *d* (par 3-2)
2. *a* (par 3-3)
3. *c* (par 3-6)
4. *b* (par 3-10)
5. *d* (par 3-14)
6. *a* (par 3-18)
7. *b* (ar 3-21)
8. *c* (par 3-25)
9. *d* (par 4-6)
10. *d* (par 4-9)
11. *a* (par 4-11)
12. *d* (par 4-13)
13. *b* (par 4-17)
14. *c* (par 4-21)
15. *c* (par 4-22)
16. *d* (par 4-37)
17. *a* (par 4-37)
18. *a* (par 4-37)
19. *b* (par 5-1)
20. *d* (par 5-2)

For further explanation, see Discussion.

DISCUSSION

Exercise:

1. The **package** (d) boiler is generally one with a self-contained firebox and is somewhat portable. This accounts for the term "package boiler."

2. **Cast iron** (a) boilers are usually constructed of several sections joined by some form of connection, such as push nipples.

3. Square sectional cast-iron type boilers consist of a front and rear section and a number of intermediate sections depending on the size of the **boiler** (c).

4. Most hot-water boilers are constructed in two sections. The section consisting of the base and either the grates or burner is constructed according to the **type of fuel used** (b).

5. Pressure relief valves may corrode or stick if they are not forced to operate occasionally. It is good practice once each **month** (d) to increase the pressure to a point that operates the valves.

6. The **airflow switch** (a) shuts down the firing equipment in event of an induced or forced draft failure.

7. Boilers are designed with baffles in order **to hold the hot gases** (b) as long as possible. In this way, the gases give up maximum heat before passing into the chimney.

8. When steel boilers develop a leak, weld or rivet them; but when a boiler flue is unserviceable, **replace** (c) it.

9. The amount of temperature drop between the beginning and the end of the line depends upon **the length of the main and upon the heating load** (d).

10. A gravity-open-tank system with an average boiler water temperature of 170° F **has** a radiator emission rate of 150 (d) Btu, psf.

11. In the gravity and forced circulation systems, open and closed **expansion tanks allow the water in the distribution system to expand** (a) as the temperature rises.

12. When a hot-water system is first filled with water, it is normally necessary to **bleed the air out of the system** (d) at the same time. You can remove the air by opening an air vent on a radiator or by breaking a union near the end of the line.

13. The circulation to individual radiators is improved by special supply and return **connecting tees** (b). These tees combine to use a portion of the velocity head in the main in order to increase circulation through the radiators.

14. The pitch is generally not less than 1 inch for every 10 feet of branch line. $100' \div 10' = 10 \times 1'' = 10''$ (c)

15. A radiator is usually constructed of cast iron and assembled in sections as shown in figure 24. Damaged radiator sections can be **replaced** (c) without replacing the entire radiator **assembly**.

16. In the list of discrepancies in par 4-37, the remedy indicated is to **clean the boiler flues and flue pipes (d)** as there are no chimney leaks in this instance.

17. To get circulation of the hot water through the radiators under the conditions described, you should check the operation of the **circulation pump (a)**, as suggested in par 4-37.

18. In the situation described, the most likely cause is **insufficient water (a)**, as indicated in the discrepancy list in par 4-37.

19. Clean water is required in many installations for domestic and industrial use. Since boiler water cannot be used for this purpose because of the **chemical added (b)**, it is necessary to heat other water.

20. Domestic hot-water heaters are built in various sizes from **20- to 50- (d)** gallon capacities. Industrial type hot-water heaters are designed to heat thousands of gallons of water, depending on the amount an installation uses.

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 566-2 . . . . Heating and Ventilating III (Warm-Air and Hot-Water Heating).

LESSON 3 . . . . High-Temperature Hot-Water Heating.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 566-2.

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

For further explanation, see Discussion.

DISCUSSION

Exercise:

1. The HTHW system is a closed system (a). Very little water is consumed during operation, which means that only a small amount of make-up water is used, practically eliminating boiler blowdown.

2. The water has 15,840 (d) Btu/cu. ft., as shown in Table I.

3. The water would store 71 (d) times more heat than the steam would, as shown in Table I.

4. When the temperature rises to 200° F, the density drops to 60 (a) pounds per cu. ft., and the percent of increase in volume rises from almost zero to 2.50 percent.

5. An important characteristic of the HTHW system is its simplicity of construction (c) with the absence of complicated traps and valves.

6. For a given size of line, about 30 times as much heat can be transmitted by water than can by steam. For the exercise, $9000 \times 30 = 270{,}000$ (c) Btu.

7. A given volume of steam is capable of containing a great amount of heat (38 to 70 (b) times that of air) and, like HTHW, is a good means of transferring heat for long distances.

8. The high-temperature range for most military and federal heating plants is 350° F to 450° F (d), which corresponds to saturated pressures of 135 to 425 psi.

9. The two-pump system uses one pump to circulate the water through the distribution system, and a second pump to circulate the water through the generator (b) for positive circulation.

10. In the cascade heater, the water is forced through spray nozzles, and comes into direct contact with the steam (a). The steam condenses into the circulating water.

11. An expansion tank is required because the water is not compressible to a smaller volume, and the water expands when heated (a).

12. Excess heat is generated to offset radiant heat loss (d) from the expansion tank.

13. The expansion tank is independent of the generator (c) and remains cool.

14. To prevent oxygen corrosion, add the chemical to furnish 20 to 40 parts of sodium sulfite per million parts (ppm) of water.

$$\frac{5{,}000{,}000}{1{,}000{,}000} = 5 \qquad 20\ (\text{min.}) \times 5 = 100\ \text{(b) gallons}$$

15. Steam at 5 psi and 230° F discharges to the atmosphere at a temperature of approximately 229° F and at a velocity of about 1500 (c) feet per second.

16. Steam at 125 psi and 300° F is discharged into the atmosphere at 290° F and a velocity of about 1600 (c) feet per second. Because of the greater expansion that takes place, there is a slightly greater drop in temperature with high-pressure steam.

17. Water at 15 psi and 200° F discharges through a break into the atmosphere at about the same temperature and at a velocity of about 175 (a) feet per second. Less hazard is present in this case than with steam, because the lower water-ejection velocity does not tend to fill the inclosure.

18. Explosion of a steam boiler can be the result of excessive steam pressure created inside the steam drum (b). When this happens, considerable damage is sustained by the heating plant.

19. The tube collapses from overheating when liquid contact is lost on the interior of the tubes for as short a time as 2 minutes (d).

20. All piping in an HTHW system should be welded (d). No screwed joints should be permitted, and flanges allowed only where necessary.

23

EXAMINATION

ARMY CORRESPONDENCE COURSE • ENGINEER SUBCOURSE 566-2

HEATING AND VENTILATING III

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

TEXT ASSIGNMENT ------------------------ Review previous assignments.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. A firebrick lining is installed in the combustion chamber of a steel furnace in order to

a. increase flame

b. reduce fuel consumption

c. act as heat exchanger

d. protect its wall

2. Which of the following accounts for the circulation of warm air in a gravity warm-air furnace?

a. the blower fan

b. back pressure

c. warm air is lighter than cool air

d. setting

3. Humidifiers in furnaces usually consist of a pan and a float-operated needle control valve. This valve controls the

a. temperature of room

b. air flow

c. water level in the pan

d. back pressure of warm air

4. Which of the following would you use for a base on which to install a furnace?

a. sand

b. masonry

c. asbestos

d. rubber

5. In installing a furnace, which of the following would you use to make sure that the unit is level?

a. spirit level

b. steel tape

c. T-square

d. mason's square

6. Which of the following would you use to seal the joints of furnace sections gastight?

a. furnace cement

b. asbestos paper

c. liquid wood

d. furnace shims

7. The cross-sectional flue area of a chimney is 8" x 16". What is the maximum diameter, in inches, of furnace flue pipe that may be correctly used?

a. 10
c. 14
b. 12
d. 16

8. In maintaining gravity warm-air furnaces, you would bear in mind that deposits on the heat exchanger will

a. increase heat transmission
b. reduce furnace draft
c. insulate it
d. create air leaks

9. You are installing a warm-air conditioning blower unit on a masonry base. What is the minimum thickness, in inches, that you would make this base?

a. 2
c. 4
b. 3
d. 5

10. In maintaining a forced warm-air furnace, what is the minimum number of times that you would oil the blower and the electric motor bearings?

a. monthly during heating season
b. once each quarter
c. once each heating season
d. twice each heating season

11. The sections of a cast iron hot-water boiler are joined by

a. header connections
b. baffle joints
c. capscrew plates
d. adjusting rings

12. Round cast iron boilers are built in sizes that can supply a maximum of how many square feet of radiation?

a. 1200
c. 1700
b. 1500
d. 1850

13. Which of the following would you use to calibrate a pressure gage?

a. airflow switch
b. deadweight tester
c. water level control valve
d. circulation pump pressure

14. You have cleaned the inside of a boiler with a stream of hot water from a hose. You dry the inside of the boiler with

a. boiler's burner
b. large fan
c. compressed air
d. kerosene stove

15. In installing a one-pipe open-tank gravity system, you located the larger radiators at the end of the system in order to

a. equalize heat radiation
b. raise water temperature
c. lower water temperature
d. decrease rate of water circulation

16. The open gravity hot-water system is designed to operate at the maximum boiler temperature of 180° F. This gives an average radiator temperature Fahrenheit of

a. 150°
c. 170°
b. 160°
d. 180°

17. A unit heater is one used to heat a localized area. How often should you inspect such a heater?

a. daily
c. every 2 weeks
b. weekly
d. monthly

18. How many valves are in the water circulating pump of a forced hot-water heating system?

a. 0 c. 2

b. 1 d. 3

19. How often should you check the flow control valve in a forced hot-water circulating system?

a. daily c. monthly

b. weekly d. bi-monthly

20. Hot-water heaters are glass lined in order to

a. strengthen tank wall

b. prevent heat loss

c. resist corrosion

d. maintain water temperature

21. At what level of Fahrenheit temperature does the HTHW system maintain its water?

a. at 210° c. at 212°

b. below 210° d. above 212°

22. When water is at a temperature of 300° F, what is its approximate density in lb per cu ft?

a. 49 c. 55½

b. 52 d. 57½

23. Water at 100° F is increased in temperature to 300° F. What is the approximate percent of increase in water volume?

a. 3 c. 5

b. 4 d. 7

24. Which of the following is the factor in the HTHW system that practically eliminates internal corrosion?

a. high-pH alkaline water

b. low-pH alkaline water

c. pressure reducing valves

d. rapid absorption of additional oxygen

25. The heat in the HTHW system is about how many times greater than the heat in the steam system?

a. 20 c. 30

b. 25 d. 35

26. Water is about how many times as heavy as steam?

a. 3 c. 7

b. 5 d. 10

27. The water used in the HTHW heating system is drawn from the lower part of the expansion tank. It is mixed with the system's return water, and circulated throughout the system. This mixing is necessary in order to

a. facilitate cavitation

b. reduce gas pressure

c. prevent cavitation

d. reduce corrosion

28. In starting up the HTHW system, you would fire the boiler at what percent of its rated capacity?

a. 10 c. 20

b. 15 d. 25

29. The specific kind of fuel used in firing the boilers of HTHW systems depends upon

a. type of firing equipment

b. location of the heating plant

c. size of fuel storage area

d. amount of impurities in the water

30. A significant advantage of the HTHW system is its

a. high energy content

b. relative safety

c. generator tubes

d. slow rate of corrosion

MEMORANDUM 566-2

HEATING AND VENTILATING III

(WARM-AIR AND HOT-WATER HEATING)

U. S. ARMY ENGINEER SCHOOL

FORT BELVOIR, VIRGINIA

MOS: 51J20

EDITION 2 (NRI 201)

PREFACE

THE GOAL OF Memorandum 566 of this course is to present a description of warm-air systems, domestic hot-water heating systems, and high-temperature hot-water heating systems. To make this relevant to your Army career, we focused the discussions upon installing and maintaining warm-air and hot-water heating systems.

We have tried first to establish the principles for the heating system and then to describe the various types of furnaces for the system before we discuss installation and maintenance. We follow much the same order of presentation in our discussions of boilers, heat-carrying media, pressurizing HTHW systems, piping systems, and safety aspects of HTHW heating.

Keep this memorandum for your future use.

28

CONTENTS

		Page
	Preface	i
Chapter		
1	Warm-Air Heating	1
2	Domestic Hot-Water Heating	12
3	High-Temperature Hot-Water Heating	22

Warm-Air Heating

A HUNDRED YEARS ago, fireplaces and potbellied stoves were the most common heating systems. Now, as heating systems, they are symbols of the past. As living standards rose, heating systems improved. Today most buildings are heated by warm-air systems.

2. **The military uses both warm-air and hot-water heating systems. For the first system, the source of heat is either the gravity warm-air furnace or the forced warm-air furnace. For the second, the source is the hot-water boiler. Your job is to install and to maintain these systems. We want you to understand both systems.**

3. Warm-air heating systems are of two types —gravity warm-air and forced warm-air. Our first chapter tells you how these systems work and how to install, fire, and maintain the furnaces for these systems.

1. Gravity Warm-Air Heating System

1-1. In the gravity warm-air system, natural convection causes circulation. The circulation takes place because of the difference in weight between warm air and cold air. Warm air is lighter than cold air and rises when cold air replaces it. A typical gravity warm-air heating system is illustrated in figure 1.

1-2. Operating a gravity warm-air system depends on the size and location of the air ducts, the heat loss from the building, the heat from the furnace, and the difference in the temperatures

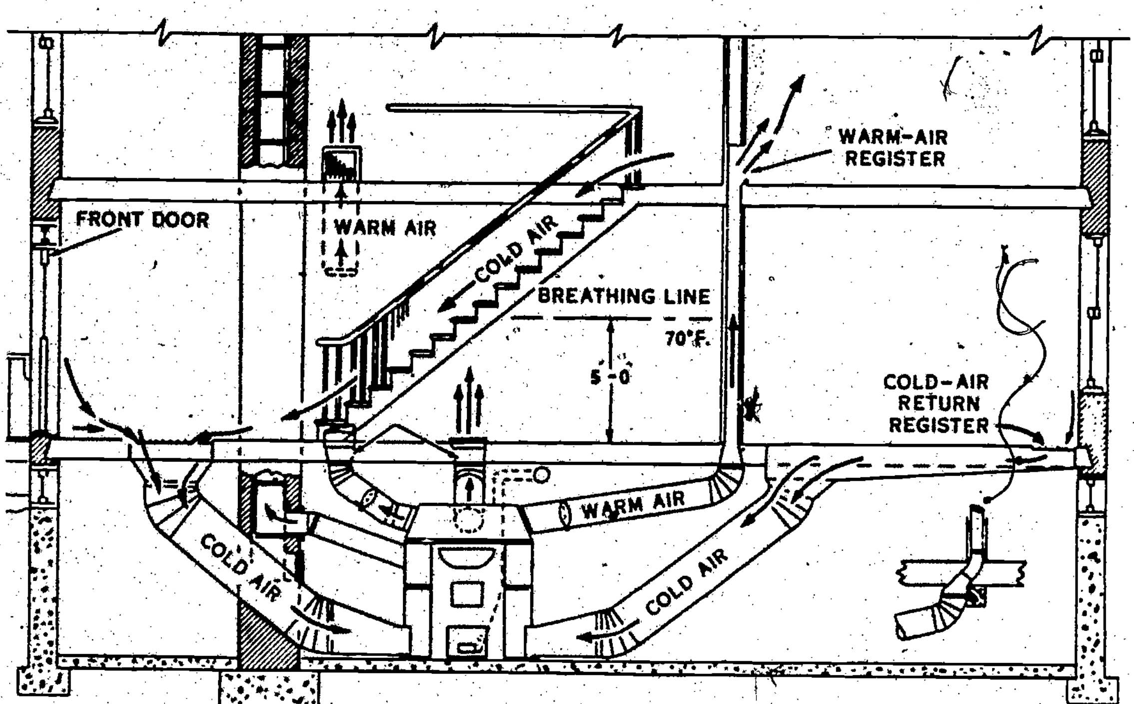


Figure 1. A typical gravity warm-air heating system.

of the warm air and cold air. The most common cause of unsatisfactory operation is insufficient duct area, usually in the cold-air return ducts. The total cross-sectional area of all the cold-air ducts must be at least equal to the total cross-sectional area of all the warm-air ducts.

1-3. The furnace for the gravity warm-air heating system must be lower than the warm-air registers. The gravity furnace is usually in the basement. It needs at least 24 inches of clearance between the plenum or bonnet and the ceiling. This minimum clearance allows ducts to be installed with at least 1 inch of upward pitch per linear foot and leaves room for proper air circulation.

1-4. **Gravity Warm-Air Furnaces.** Gravity warm-air furnaces heat air that is later distributed through ducts to warm the individual rooms. As the air is heated in the furnace heat exchanger, it expands and becomes lighter than the cool air returning to the furnace. The warmed air rises and passes into the ducts which are connected to the top of the furnace. The ducts are usually sheet metal pipes that rise continuously from the furnace to the warm-air registers from which the air is released into the space to be heated.

1-5. Gravity warm-air furnaces are constructed of either cast iron or steel. Cast iron furnaces are constructed in sections which are made gastight with asbestos-rope packing and furnace cement. The cast iron furnaces usually include a secondary heating chamber or radiator which is in the shape of a hollow doughnut and mounted on top. Figure 2 illustrates a cast iron furnace. Steel furnaces are made of welded heavy-gage steel with a firebrick lining in the combustion chamber to

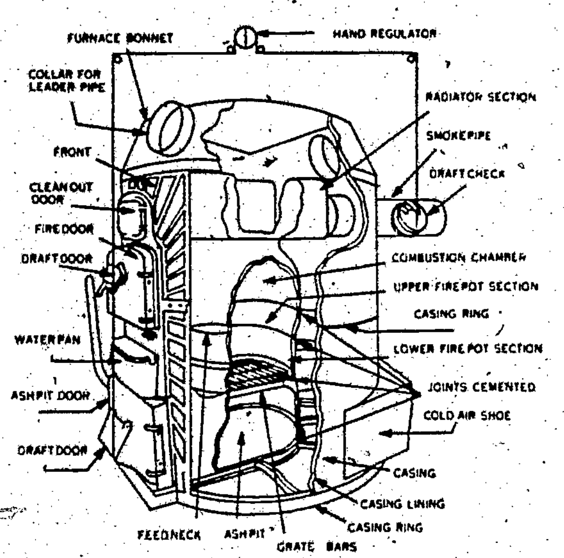


Figure 2. A cast iron furnace.

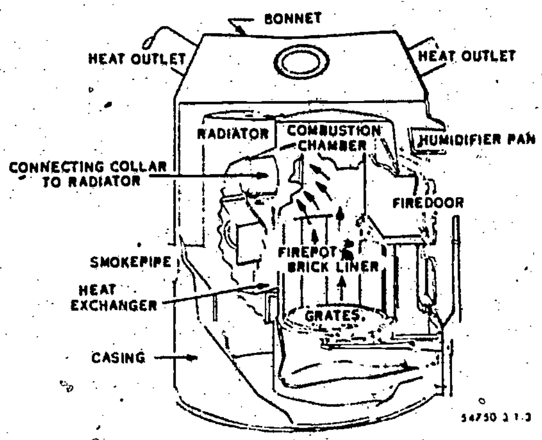


Figure 3. One type of steel furnace.

protect its wall. They also have one or more secondary heat exchangers at the back or side. The heat exchangers may surround the furnace. These furnaces can be designed to burn all types of fuel. One type of steel furnace is shown in figure 3.

1-6. A major concern of proper heating, next to temperature, is that of humidity in the air. Consequently, an important device called the humidifier is used to keep the heated air moist. The unit is an important part of every warm-air heating system. Unless you add moisture to the air during the operation of a warm-air furnace, the air is very dry when it enters the spaces being heated. The lack of moisture has its adverse effect on the health of the people in these heated areas. The dry air draws moisture out of the wood furniture and equipment, causing them to crack. Manufacturers install humidifiers on their furnaces as standard equipment to eliminate the lack of moisture in warm-air heating systems. These humidifiers are usually of the pan type. They consist of a pan and a float-operated needle control valve. This float and needle valve control the water level in the pan. The dry warm air passing over the surface of the water in the pan absorbs some of the moisture. This action causes the air to be more humid.

1-7. With this increase in humidity, the people are more comfortable in the heated rooms at lower temperatures than if the air is dry at higher temperatures. You will note that the furnace in figure 3 has a humidifier pan. Unless the water used in these humidifiers is comparatively free from minerals and other foreign matter, the humidifier pans will require frequent attention. The minerals and foreign matter collect on the float assembly and needle valve, causing the valve or the float to stick open and cause flooding. The float or valve may stick closed and prevent water from entering the pan.

1-8. *Installing gravity warm-air furnaces.* **You should install gravity warm-air furnaces in accordance with the blueprints, diagrams, and other instruction furnished by the manufacturer with each furnace. You should also be sure that the furnaces are installed so that they comply with pertinent post directives. Because there are many types and makes of coal-, oil-, and gas-fired furnaces on the market, detailed assembly instructions to suit all of these makes and types are not published in this memorandum. However, paragraphs 1-9 through 1-20 give you some general installation requirements that apply to all warm-air furnaces.**

1-9. Read and study the assembly instructions that come with the furnace. Each piece of casting is manufactured to fit in its proper place. Parts of one type of furnace are seldom interchangeable with parts of other types of furnaces.

1-10. The furnace must be level and on a solid masonry base. Do not install the furnace on a base constructed of wood or other combustible material. If the masonry base is uneven, level the furnace with steel or cast iron wedges (shims), or with the leveling bolts on the furnace. Always use a spirit level to make sure the unit is level.

1-11. There should be enough clearance for easy access for making repairs. Leave at least 18 inches between the furnace and a wall constructed of wood or other combustible material. It is a good practice to install asbestos boards on a wooden wall next to a furnace. This reduces the fire hazard. With masonry walls, the units may be installed nearer the walls; however, leave enough room to permit proper servicing. Give special attention to ceiling clearance. Cover the ceiling above the furnace with asbestos sheets or asbestos paper when the top of the furnace is close to the ceiling.

1-12. Joints should be sealed with liberal amounts of furnace cement between the sections to insure that the furnace is gastight. Furnace cement is furnished with each cast iron furnace. Asbestos rope is also furnished with many furnaces for certain applications. Follow the manufacturer's instructions covering its use. See to it that projections from the furnace, such as smokepipes or cleanout doors, extend through the outside of the casing.

1-13. Bolts must be tightened with care. Tighten each bolt until almost tight. Then, after you have installed all the bolts, gradually tighten each one until all are uniformly and properly tight. Drawing bolts too tight cracks or breaks a casing or buckles a steel plate.

1-14. When the furnace is assembled, all doors must be checked for free operation and a tight fit. Air leaking around the doors reduces combustion efficiency. Check the grates in coal furnaces for free movement. To install firebrick, follow the manufacturer's instructions.

1-15. The furnace casing, bonnet, and gravity-return air shoe must be installed according to the manufacturer's instructions. Fasten the casings or panels securely. If they are interlocking, you should see that they are set properly in place and are airtight. If there is no bottom floor panel (gas or oil), grout the casing to make it airtight. Do this by chipping and wetting the floor and then using a liberal amount of cement mixture. If you use a circular casing, strip the joints with asbestos paper to make them airtight. Use asbestos rope or a draw-band collar to make the connection between the flue and the cleanout airtight. If baffles are furnished or recommended, install them in accordance with the manufacturer's recommendations. When installing baffles, take care to provide the proper distribution of air over the combustion chamber and radiator. Check the heat exchanger before installation for leaks and cracks.

1-16. Only the downdraft diverters that come with the equipment should be installed. Diverters are developed for individual furnaces, so you should never use diverters of local manufacture unless they have been calibrated for the specific heating unit. Downdraft diverters are built into the furnace or more commonly installed in the gas flue close to the furnace. These diverters prevent excessive chimney drafts from going through the furnace and affecting combustion or even extinguishing the flame. They also prevent downdrafts from reaching the flame and interfering with combustion. Air is taken into the flue through the diverter in the case of excessive draft, and expelled from the flue through the diverter in the case of a downdraft without ever getting into the combustion chamber. A view of the downdraft diverter can be seen in figure 30.

1-17. Vents or smokepipes should be at least as large as the smokepipe outlets on furnaces. Install all horizontal smokepipes so that they have a pitch of not less than 1 inch per linear foot, as illustrated in figure 4. Fasten a vent or smokepipe to the furnace with at least three sheet metal screws.

1-18. There should be a tight fitting cleanout for coal furnaces at the point where the smoke collar extends through the furnace casing, as show in figure 4. Usually the cleanouts for this location are provided by the manufacturer. Install a checkdraft in the smokepipe, usually 18 to 36 inches from the smokepipe outlet of the furnace. Also, install the checkdraft with its hinges at the top of the pipe for easy lifting by a motor damper chain.

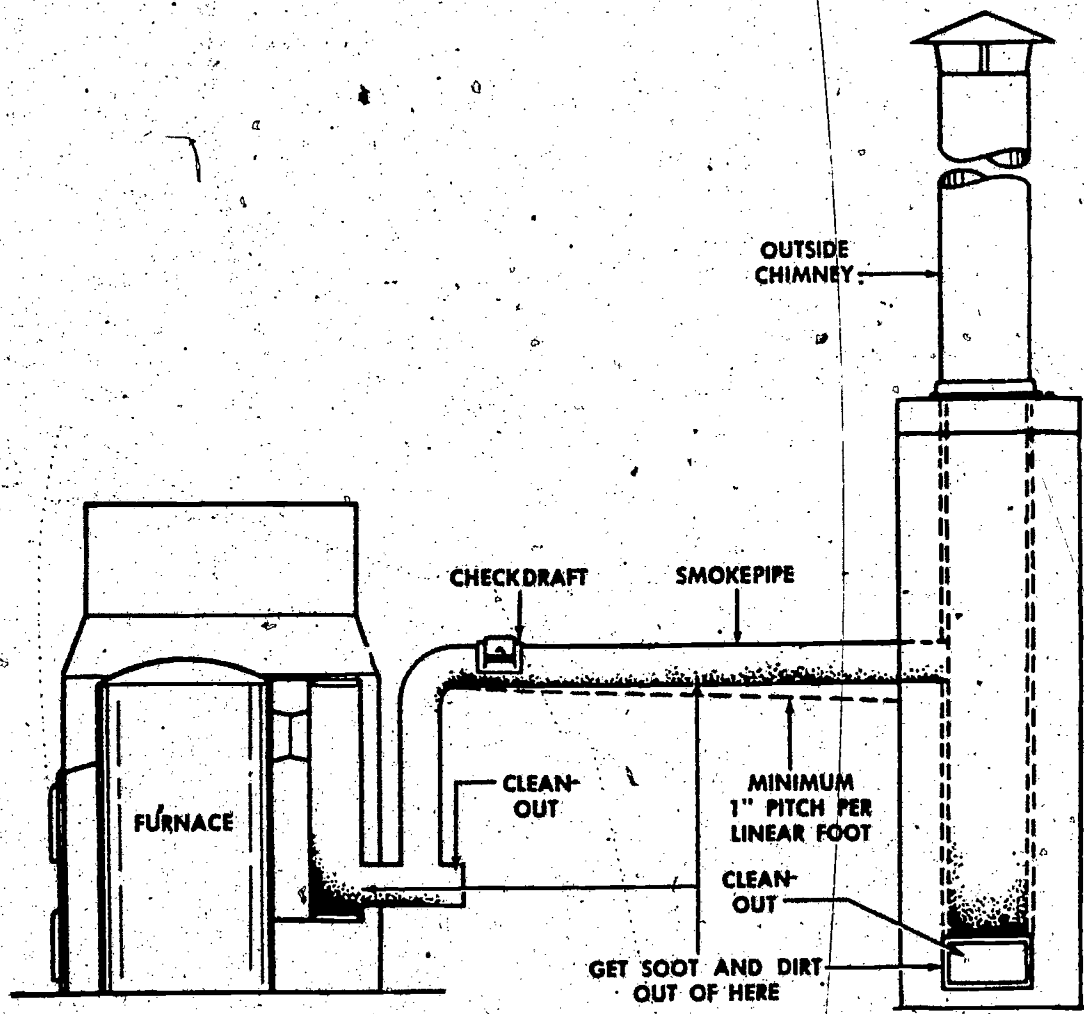


Figure 4. A typical smokepipe installation.

1-19. The furnace must have an adequate chimney. Good chimneys are built of steel, brick, or other material approved by the office of the Facilities Engineer. Measure to insure that the chimney has a cross-sectional area equal to or larger than the flue outlet of the furnace being installed. The smaller dimension of a rectangular chimney must be at least two-thirds the furnace flue diameter. To be satisfactory above sea level, the area of the chimney must be increased 4 percent for each 1,000 feet of altitude above sea level. Figure 4 shows one type of outside chimney. You should make sure that the chimney is equipped with a soot and dirt cleanout at the base. The upper part of the chimney is often constructed of a metal section that terminates with an appropriate hood. You must check to see that the chimney height at least meets manufacturer's recommendations. Even so, the chimney must never be less than 15 feet high, and always extend at least 3 feet above the peak of the roof.

1-20. The furnace room must be adequately ventilated to supply enough air for combustion. An opening having 1 square inch of free-air area must be provided for each 1,000 Btu per hour of furnace input rating with a minimum of 200 square inches. Locate the opening at or near the floorline whenever possible. In addition, you should provide two louvered openings in the ceiling, one as close to each end of the furnace room as possible, to expel flue gases. These openings should have a free-air area of at least 200 square inches each.

1-21. *Firing gravity warm-air furnaces.* Gas- and oil-fired gravity warm-air heating systems usually have automatic controls for both the furnace and fuel supply, and consequently they do not require firemen for operation.

1-22. *Maintaining gravity warm-air furnaces.*

You should inspect and maintain gravity warm-air furnaces according to a schedule prescribed for such furnaces by AR's or the local command. Inspect the roofjacks as well as the smokepipes from the inside as well as the outside of the building. Replace any noticeable deterioration, such as a rusted hood, roofjack, or fluepipe. Replace the roofjack guy wires if they are badly rusted. Check the chimney for cracks and holes, and repair any defects to eliminate air leaks. When cold air enters the chimney and dilutes the warm air, it reduces the draft. All soot and fly ash must be removed from the chimney and flue cleanouts. Inspect the draft dampers for proper operation, and check the draft diverter for soot accumulation.

1-23. You should check the heat exchanger surfaces for warping and rusting. Replace the units if they are unserviceable. The firebox doors, door hinges, and latches should be checked for damage, and any broken parts should be replaced. Seal all of the casing joints with asbestos type calking compound. The grouting around the base of the furnace should be inspected and repaired if necessary. Clean the furnace heat exchanger and the fluepipe surfaces with a vacuum cleaner. Deposits on the heat exchanger insulate it and reduce its ability to transmit heat.

1-24. You should inspect the furnace room for cleanliness and notify your superior of any combustible materials found there, such as rags, papers, and boxes. Also, see that the performance chart is posted and that it is readable.

1-25. If the furnace has a humidifier, inspect the float for water leaks. If there is water in the float, replace the unit. Check the needle valve for scale deposits and other obstructions. The valve seat is cleaned with a sharpened wooden match or similar soft material. Replace the valve stem and the valve seat if the valve does not close tightly after you clean it.

1-26. You should check all electrical switches to see if they operate correctly and inspect the electrical wiring. Make out a work order for any electrical adjustments or repairs.

1-27. **Air Ducts for Gravity Heating.** The air ducts of a warm-air gravity heating system carry the warm air from the furnace and cold air to the furnace. The air ducts are large sheet-metal pipes constructed of lightweight galvanized metal to reduce weight to a minimum. The metal pipes are covered with a thin layer of asbestos paper to reduce heat loss through radiation.

1-28. *Installing air ducts for gravity heating.* Space warm-air ducts or leaders coming from the furnace evenly around the bonnet of the unit for efficient heat distribution. A leader usually has a damper in the first length of pipe attached to the bonnet, as shown in figure 5. The warm air is taken from the casing hood or bonnet of the furnace through the leaders to the register box for the first floor, as shown in figure 1. The warm air for the second floor flows through a vertical, rectangular wallstack, inside the wall partition, and also terminates at the register box. Install the register boxes either

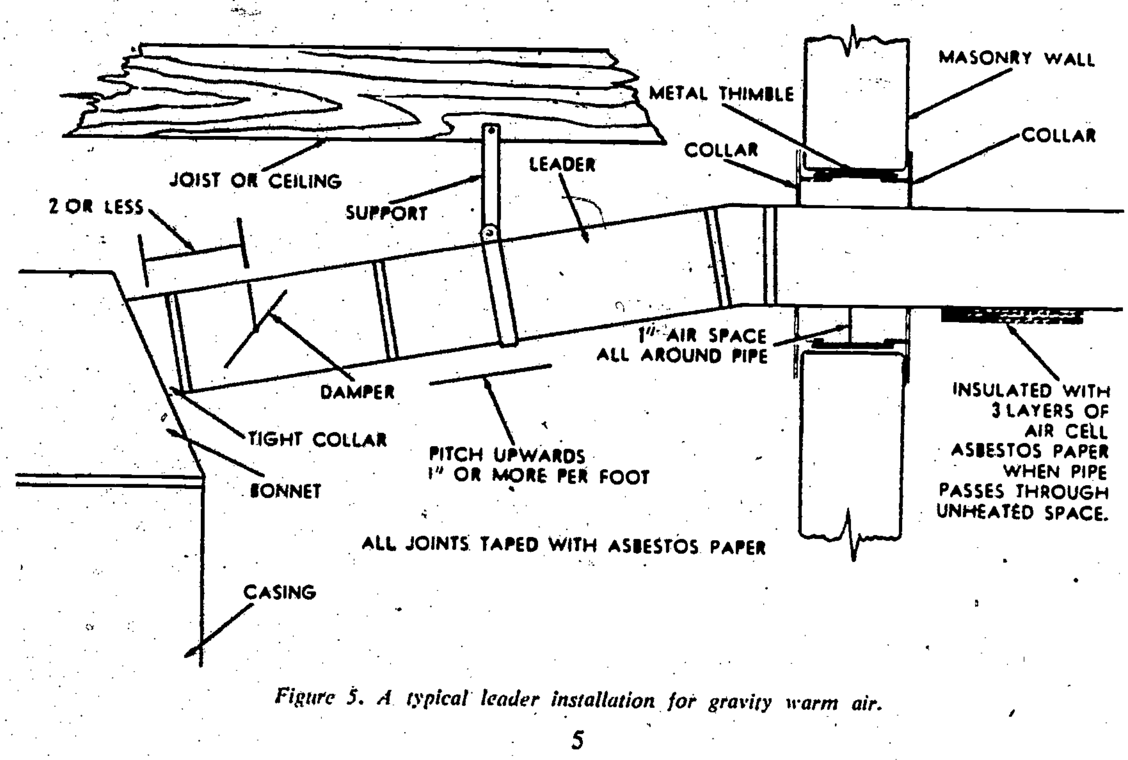


Figure 5. A typical leader installation for gravity warm air.

in the floor or the inside wall near the baseboard. The warm-air is discharged through the warm-air registers, which are set in the register boxes. The registers usually have some type of shutoff mechanism. Leaders and fittings can be mass produced or fabricated specifically for each job. Use prefabricated leaders and fittings made of asbestos to reduce the danger of fire.

1-29. The air supply for the furnace is the cool air that comes from the area inside the heated building. The air is usually picked up before it spreads and causes objectionable drafts. The air is then conveyed to the base of the furnace through one or more cold-air ducts, also shown in figure 1. These ducts are sometimes referred to as cold-air returns, and they are usually much larger than the warm-air ducts. In some cases, where the ventilation requirements are high, some of the air is brought in from outside the building.

1-30. Air passages that form portions of cold-air returns can be included in the building plans, and you can construct them on the job from other materials. When you construct them, however, make the construction reasonably airtight. As a general rule, you should not equip the cold-air returns with dampers, since the cold-air returns are normally constructed in correct proportion to the warm-air ducts.

1-31. Almost every warm-air heating system requires adjustment and balancing of the airflow going to various outlets before the heat is evenly distributed. You can balance the heating system by adjusting the dampers in the duct branches while the furnace is in full operation. Continue balancing until the desired temperature is obtained in each room. You can also use a velometer or anemometer to balance the gravity warm-air system by following the manufacturer's instructions. If you ever need to furnish additional heat to some portion of a building at the end of a long duct, balance the butterfly valves in the other warm-air pipes to favor the deficient one. If this does not work, install a booster fan in the deficient duct to force the airstream.

1-32. *Maintaining air ducts for gravity heating.* Gravity cold-air and warm-air ducts require very little maintenance. So that the warm air flows properly, clean the ducts with a vacuum cleaner once each season. Replace the asbestos covering which has loosened. Check the dampers and the register shutoffs for proper operation. All air leaks in the ducts should be repaired. You should make a check to see that each pipe is in true alinement, and insure that it is fastened rigidly to some portion of the construction.

1-33. The gravity system with warm-air and cold-air return pipes or ducts is not generally used in military installations. It is not recommended except under unusually favorable conditions, such as in a building with a basement which has adequate headroom and which is arranged so that the furnace can be centrally located. Because of the advantages of the forced warm-air system, it is more common.

2. Forced Warm-Air Heating System

2-1. The principle of design used for developing the forced warm-air heating system is primarily the same as that for the gravity heating system. Both systems require a heating unit or furnace, warm-air pipes, cold-air returns, and registers. The difference between the two heating systems is in the method of circulating the air. Gravity causes the air to circulate in a gravity system, while an electric blower or fan causes the air to circulate in a forced warm-air heating system.

2-2. One common type of forced warm-air heating system, which is shown in figure 6, illustrates a few other minor differences in layout. One advantage of the forced warm-air system is the smaller size of the horizontal warm-air ducts and cold-air returns. Forced air makes such a reduction in size possible. The sloping of the pipes so the warm air can rise is not necessary, because it is forced through. Each warm-air duct is equipped with a register damper that controls the amount of hot air delivered to a room.

2-3. Notice, too, that the furnace in the basement is not centrally located, as it is in the gravity

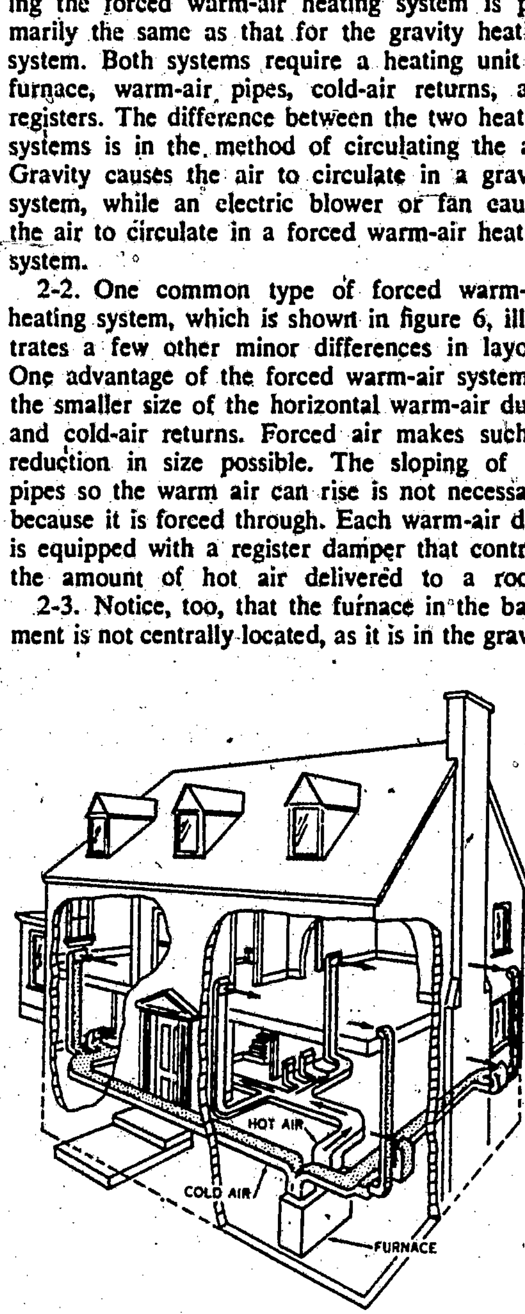


Figure 6. A forced warm-air heating system.

system. (See fig. 6.) The central location is not necessary, because the air is forced by the fan into the rooms. In fact, this advantage allows the furnace to be located on the same floor with the rooms to be heated, because the fan or blower insures that warm air reaches all of the rooms.

2-4. **Forced Warm-Air Furnaces. The furnaces for a forced warm-air heating system are manufactured in a variety of designs that are similar to the gravity warm-air units. The warm-air controls used with furnaces that burn various types of fuels were discussed in Memorandum 565. The discussions there pertain to coal-, oil-, and gas-burning equipment. The coal-fired furnaces are, in general, similar to the diagram shown in figure 7. This diagram shows the component parts of the heating unit as well as the circulation of air through the unit.**

2-5. Oil-fired forced warm-air furnaces also are manufactured in many different designs, depending upon the type of installation required. A typical oil-fired forced warm-air furnace is shown in figure 8.

2-6. A gas-fired forced warm-air furnace is shown in figure 9. This is a vertical type upflow furnace. It is frequently installed on the same level as the space it serves. Warm air is discharged vertically from the top, and cold-air return ducts are brought in horizontally near the bottom of the furnace to promote the circulation of air. Gas forced warm-air furnaces are also of the horizontal type. The horizontal type of furnace requires little space, and it is designed for installation above the ceiling or under the floor of the space to be heated. Since the furnace occupies little space, it should be located so that there is proper access for servicing.

2-7. *Installing forced warm-air furnaces.* Install forced warm-air furnaces according to the procedures and diagrams issued by the manufacturer. Since the installation procedures for forced warm-air furnaces are similar to those for gravity furnaces, we recommend that you review briefly the general installation requirements for the gravity warm-air furnaces mentioned previously in this chapter.

2-8. Most warm-air circulating blower units are built as part of the furnace by the manufacturer. You should bolt such units to a masonry base that is at least 3 inches thick and that extends at least 12 inches beyond the furnace casing. However, if the blower unit must be mounted separately, fasten the blower and blower motor to a masonry base in true alinement. Install the filters on the inlet side of the casing so that all of the air is filtered before entering the fan.

2-9. The cabinet, housing the blower unit, should have doors so that you can easily oil, adjust and repair the motor and blower, and

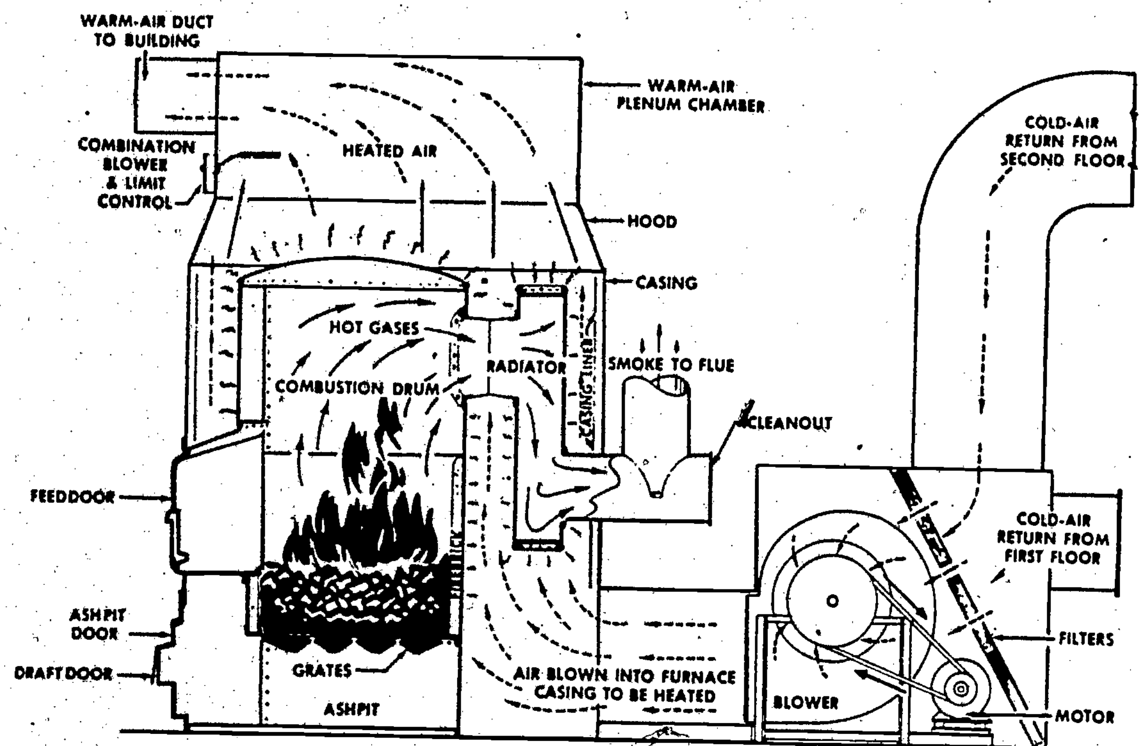
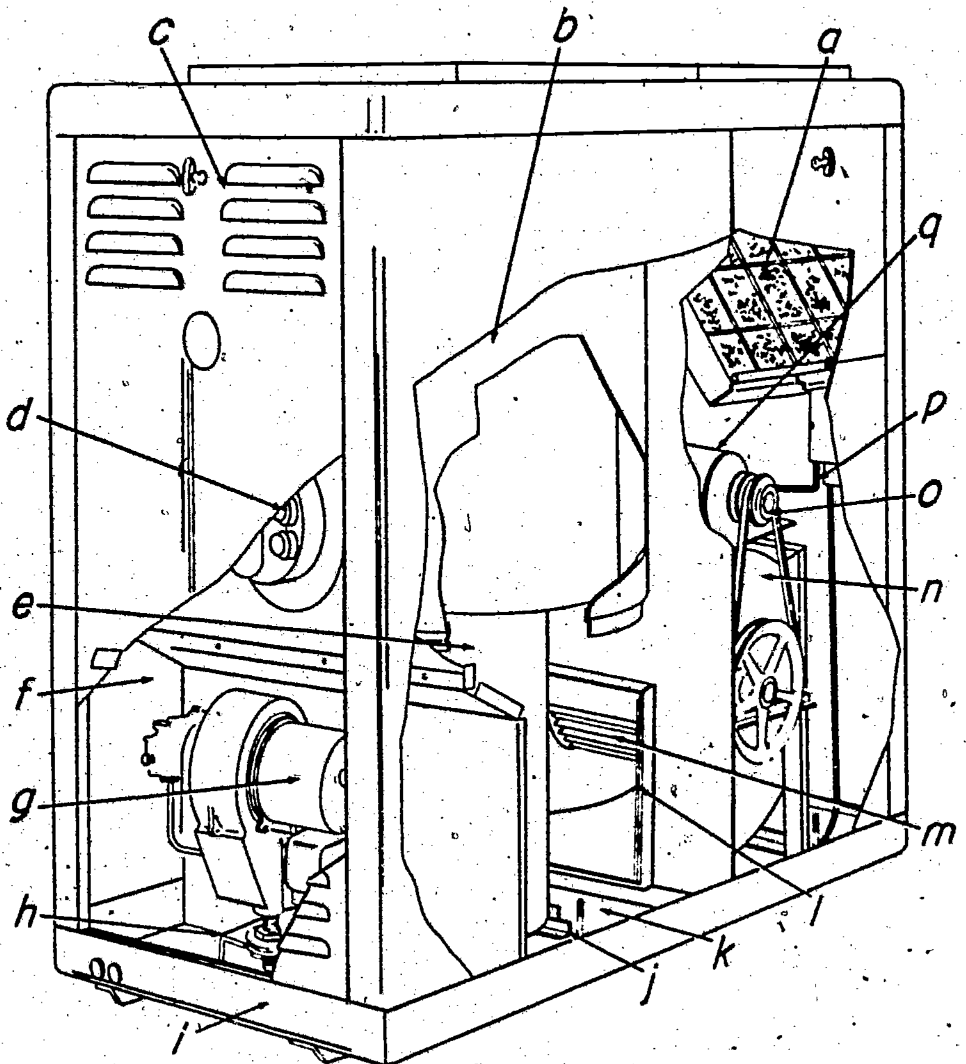


Figure 7. A coal-fired forced warm-air furnace.



a. Filters
b. Baffle liner
c. Cabinet
d. Flame observation door
e. Radiating surface
f. Burner compartment
g. Oil burner
h. Oil burner base
i. Furnace base
j. Combustion chamber mounting
k. Airtight steel floor
l. Asbestos cloth seal
m. Blower fanwheel
n. Blower
o. Adjustable speed pulley
p. Electric wiring (underwriters laboratory approved)
q. Electric motor

Figure 8. A typical oil-fired forced warm-air furnace.

replace the air filters. The complete unit must be reasonably well constructed to prevent air leakage.

2-10. *Firing forced warm-air furnaces.* Forced warm-air furnaces are fired in the same manner as the gravity warm-air furnaces. We mentioned the methods used to fire gravity warm-air furnaces previously in this chapter.

2-11. *Maintaining forced warm-air furnaces.* Since we discussed maintaining stokers, oil burners, and gas burners in the memorandum covering these units, this discussion of maintenance that follows pertains to the furnace as a unit. Forced warm-air furnaces should be inspected and maintained in accordance with the manufacturer's recommendations, pertinent Army regulations, and local post directives to comply with the mandatory requirements and obtain efficient operation. Since the maintenance requirements for forced warm-air furnaces are almost identical to those for gravity warm-air furnaces, we recommend that you review the paragraphs covering these requirements. However, instructions that pertain primarily to the maintenance of forced warm-air furnaces follow:

a. Seal all blower casing joints with asbestos tape or caulking compound. Inspect the grouting around the base of the blower and furnace casing to see if it is damaged or missing, and make any necessary repairs.

b. Inspect air filters at least once each week. You should clean or replace them whenever they need cleaning or replacing. Dirty filters reduce airflow, impair heating performance, and increase fuel consumption.

c. Check throwaway filters. Hold the filter against the light; when little or no light shines through the filter, replace it. You should not wash and recoat these filters. They usually consist of a graduated filtering medium most densely packed on the outlet side to increase the dirt-holding capacity of the filter. When you install this type of filter, make certain that you place the filter with the denser filtering medium on the outlet side. These filters are usually marked to indicate the proper direction of airflow through them.

d. Renew cleanable filters. Wash them in a strong nonflammable solvent and allow them to dry thoroughly, as shown in figure 10. You should then recoat them by using a hand sprayer. Filters are recoated only with an adhesive specified for this purpose. The adhesives, which are available through filter manufacturers, should be odorless and fire resistant. The coatings should have a high capillary attraction or ability to become wet, hold dust at all operating temperatures, prevent mold formation, and evaporate moisture slowly.

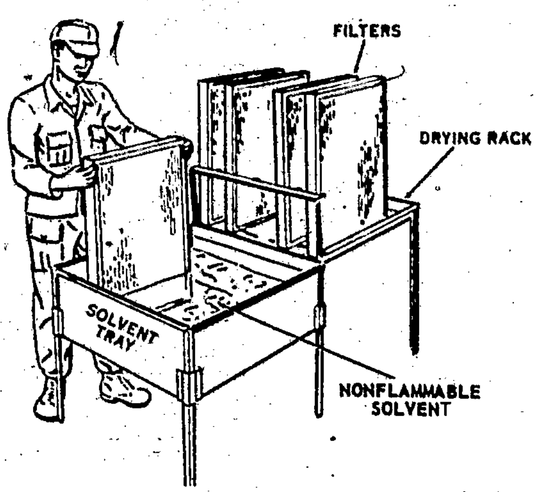


Figure 10. A typical filter washing and drying station.

e. Oil the blower and electric motor bearings regularly, at least twice each heating season. These bearings are usually fitted with oil cups. Use the oil recommended by the manufacturer. Do not overoil the bearings, but oil the bearings sufficiently; otherwise the shaft will seize in the bearings and stop the motor and blower.

f. The electric motors are mounted on adjustable bases to permit better adjustment of the blower belt tension. Unless a manufacturer specifically recommends a tighter adjustment for this purpose, adjust the base of the motor so that there is 1½ inches to 2½ inches of play in the belt, as illustrated in figure 11. You should make certain that both pulley wheels are in perfect alinement.

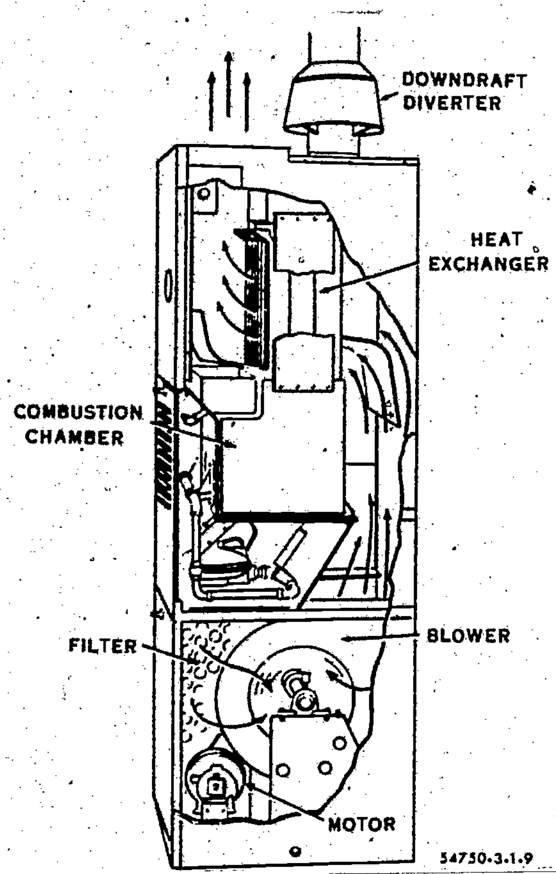


Figure 9. A typical gas-fired upflow forced warm-air furnace.

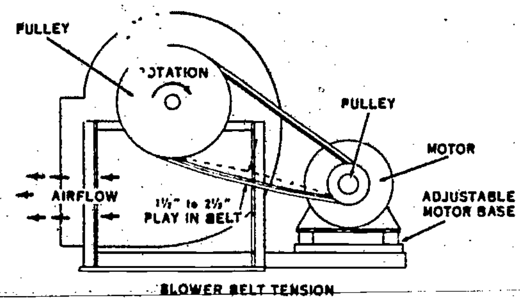


Figure 11. A forced air blower fan belt installation.

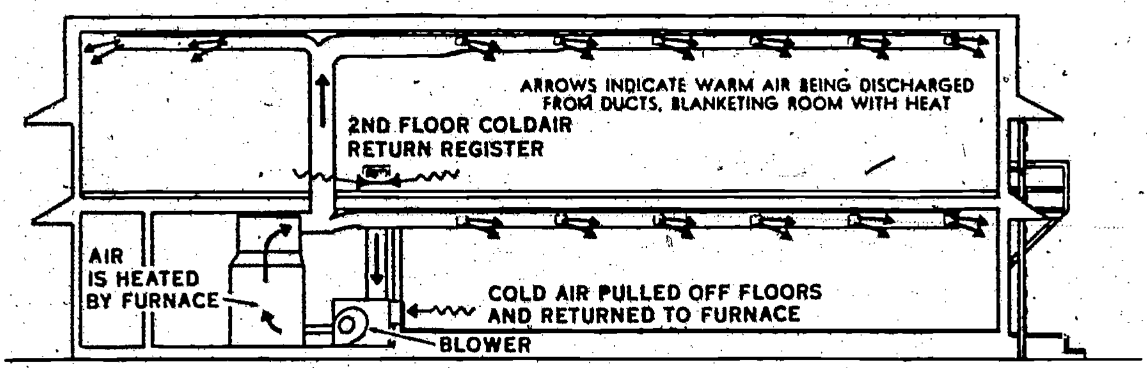


Figure 12. A typical forced warm-air duct layout for a two-story barracks.

2-12. In actual operation, an electric motor turns the blower by means of a V-belt. As the blower turns, the cool air flows through the filters which remove the dust and dirt. From the filters, the air flows into the fan which forces it past the firebox to the heat exchanger of the furnace where it is heated. The heated air is then forced into and through the warm-air ducts and into the various rooms. As more air is forced into the rooms, the cold air there flows back to the furnace through the cold-air returns and starts another cycle.

2-13. **Air Ducts for Forced Warm-Air Heating.** The air ducts for forced warm-air heating systems are usually rectangular in shape. However, you may use round ducts whenever they are necessary. With a positive-pressure blower, you may use smaller ducts and extend the system to heat larger areas without sloping the warm-air ducts. A forced warm-air duct layout for a two-story barracks is shown in figure 12.

2-14. *Installing air ducts for forced warm-air heating.* Air ducts for forced warm-air heating systems, like the ducts for gravity warm-air systems, are constructed of sheet metal. They are normally constructed in the sheet metal shop in accordance with given specifications. The cross-sectional area of rectangular warm-air ducts is large at the furnace, but it gradually tapers at the end. Air ducts usually run from the furnace through partitions and along the ceilings of hallways and rooms. The cold-air return ducts for a forced warm-air heating system are rectangular and much larger than the warm-air ducts. They are usually short since the hallways of the buildings serve as a cold-air return. Both the warm-air and cold-air ducts are usually hung from the ceiling with metal strapping. When you install air ducts for forced warm-air heating, leave an air space between the ceiling and the ducts to reduce the possibilities of fire. Equip warm-air ducts for forced warm-air heating systems with dampers, shutoffs, and registers to control the flow of warm air. Figure 13 shows a diagram of a volume damper. You must, of course supplement these instructions by reference to the pertinent specifications and blueprints.

2-15. *Maintaining air ducts for forced warm-air heating and balancing the system.* The air ducts for a forced warm-air heating system are quite trouble free and require very little maintenance. Vacuum clean the ducts once each season. Check the dampers and other air controls for proper operation. Figure 14 shows a diagram of an air duct with a splitter damper.

2-16. When the splitter damper handle is bent or the damper shaft is twisted, it is difficult to determine the exact position of the damper, because it cannot be seen. In such a case, the damper may be inadvertently positioned to shut off the flow of air to one of the ducts. During maintenance services, check such dampers for correct alinement. All of these dampers should have a locking device and some means to indicate their true position.

2-17. After you check the dampers for proper operation and true alinement and the system is in full operation, you should balance the system

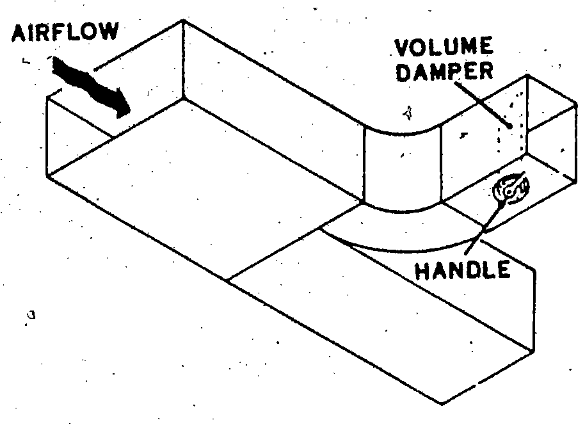


Figure 13. A diagram of a volume damper.

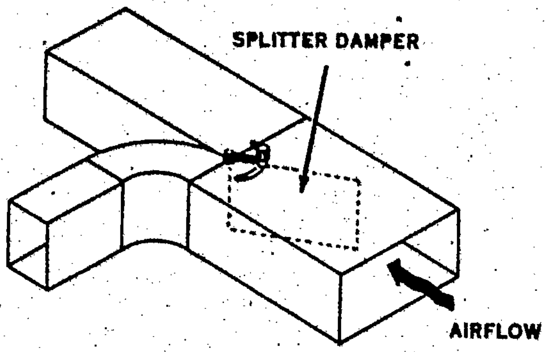


Figure 14. An air duct with a splitter damper.

by adjusting the dampers in the duct branches and stack leads. Continue balancing until you obtain the desired temperature in each room. This process is referred to as the trial and error method.

2-18. You can also balance the system by using a velometer or an anemometer. You should regulate the dampers until the air from the register is about 50 feet per minute. Take this measurement about three-fourths of the distance away from the register to the opposite wall.

Domestic Hot-Water Heating

ALTHOUGH THE hot-water system does not replace the warm-air system we discussed in the previous chapter, it has many advantages over the warm-air system. Air is not the most efficient heat carrying medium; both hot-water and steam carry more heat than air. Like air, water and steam may be heated at a central source and carried throughout the building in pipes. But unlike air, the water and steam are never open to the atmosphere. The hot-water system, then, is better for buildings such as hospitals where the air may be contaminated and should be circulated as little as possible.

2. The military uses both cast iron and steel hot-water boilers as sources of heat for domestic hot-water systems in residences and other buildings. Small hot-water heaters heat the hot water for domestic and for limited industrial uses.

3. In this chapter we tell you how cast iron and steel hot-water boilers work. We discuss two types of hot-water distribution systems with you—gravity and forced-circulation systems—the installation, operation, and maintenance of the boilers and the distribution systems. Finally, we discuss the hot-water heater, how it works, and lighting and maintaining it.

3. Hot-Water Boilers

3-1. Hot-water boilers come in many shapes and sizes. They are constructed with a firebox for burning fuel and have provisions for passing the hot gases over the heat-absorbing surfaces of the boiler. In most cases, baffles guide the gases over the most effective route. These baffles also retard the flow of the gases from the furnace so that the water can absorb as much of the heat as possible. Both ends of the boiler have openings for cleaning the boiler tubes and for washing the interior of the boiler. Since most boilers are stationary units that are permanently installed at the site, they have specified fittings and accessories for a specific heating job. Some boilers, however, called package boilers, are complete units, including the fittings and accessories. These boilers are normally mounted on skids so that they can be moved to different sites.

3-2. Some types of hot-water boilers may be classified as package boilers. Most package boilers are steam boilers. Package boilers have most of the boiler accessories mounted on the same skid or platform with the boiler, and they are already hooked to the boiler. The package boiler is generally one with a self-contained firebox and is somewhat portable. This accounts for the term "package boiler." Package boilers usually have the same accessories and controls as the comparable stationary type of hot-water or steam boiler. Cast iron boilers are seldom used as package boilers because of the danger of cracking the boiler sections during transportation. You read about automatic controls for boilers in Memorandum 565 of this course. They are discussed in the sections on burners, because the burners are directly what they control. You also read about draft, air fuel ratios, ignition, safety shutdown, and pressure controls.

3-3. **Cast Iron Hot-Water Boilers.** Cast iron hot-water boilers vary in size from small domestic units to moderately sized units capable of developing about 30 horsepower. These boilers are usually constructed of several sections joined together by some form of connection. Push nipples are one kind of connection. Push nipples are normally round pieces of metal pipe tapered at both ends. The boiler sections are ordinarily also connected by pipes known as header connections.

3-4. Cast iron boilers normally do not have brick settings. Usually, the only bricks used in connection with these boilers are those which are sometimes used as a base for the boilers. In most cases the bases are made of cast iron. Cast iron boilers can be further classified as round and square types.

3-5. *Round cast iron type boilers.* Round cast iron type boilers vary somewhat in construction. In general, however, they are typified by the unit which is shown in figure 15. This unit consists of a top section, in which the outlets and safety valve tappings are located; a number of intermediate sections, depending upon the amount of heating surface required; a firebox section, in which the return water tappings are located; and

41

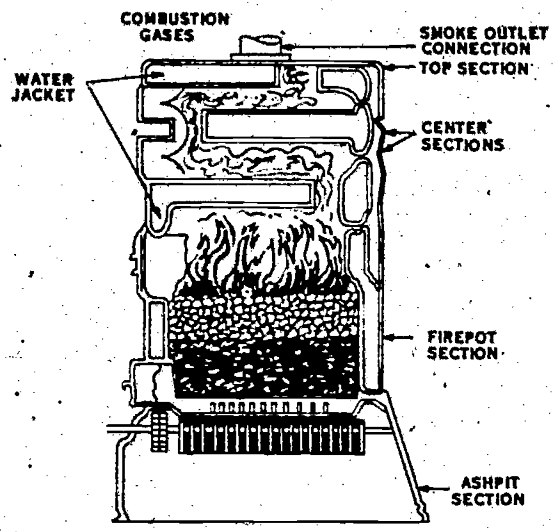


Figure 15. A typical round cast iron boiler.

a base and an ashpit. Round cast iron type boilers are small and compact and are built in sizes capable of supplying up to 1,700 square feet of radiation.

3-6. *Square sectional cast iron type boilers.* Square sectional cast iron-type boilers are similar to the typical unit shown in figure 16. This boiler consists of a front and rear section and a number of intermediate sections, depending on the size of the boiler. The sections are connected on each side at the top and bottom either by push nipples or by an outside header. When nipples are used, these sections are held firmly together by rods and nuts.

3-7. The boiler shown in figure 16 has a separate base which does not contain water and, therefore, requires a floor of fireproof construction. Boilers which have water in their bases are referred to as wet-bottom boilers. These boilers are relatively small water units which may be installed on floors constructed of combustible materials. This method of installation, however, is not desirable.

3-8. The construction of square sectional boilers is ordinarily such that the sections can be taken through regular sized doors for assembly inside the boilerroom. This is a distinct advantage from the standpoint of both installing new equipment and replacing broken sections. Cast iron boilers resist the chemical action of corrosive agents much better than steel boilers.

3-9. The disadvantage of cast iron hot-water heating boilers is the danger of the sections cracking or breaking when improperly handled or fired.

3-10. **Steel Hot-Water Boilers.** Most steel hot-water boilers are constructed in two sections. One sections consists of the water jackets, combustion chamber, and smoke passages. These components are either welded or riveted together as a unit. The other section consists of the base and either the grates or burner, and is constructed according to the type of fuel used.

3-11. Another steel boiler is a horizontal unit of the portable type having an internal firebox surrounded by water lanes. It rests either on a cast iron or a brick base. The front part of the boiler rests on a pedestal. A disadvantage of this one-piece steel boiler is that it is heavy and requires special equipment to lift it.

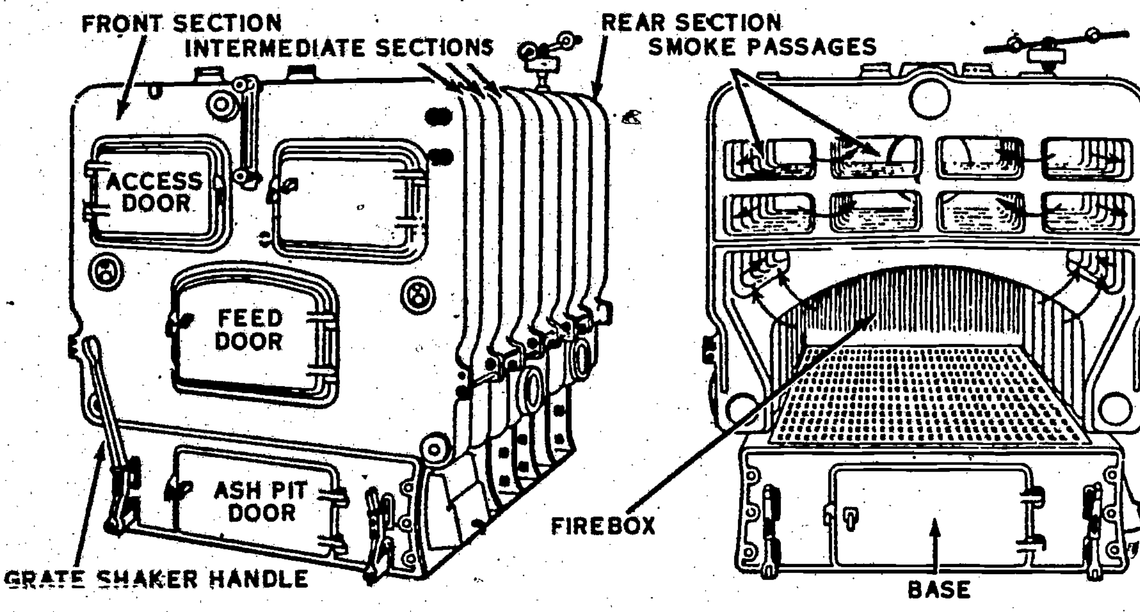


Figure 16. A square sectional cast iron boiler.

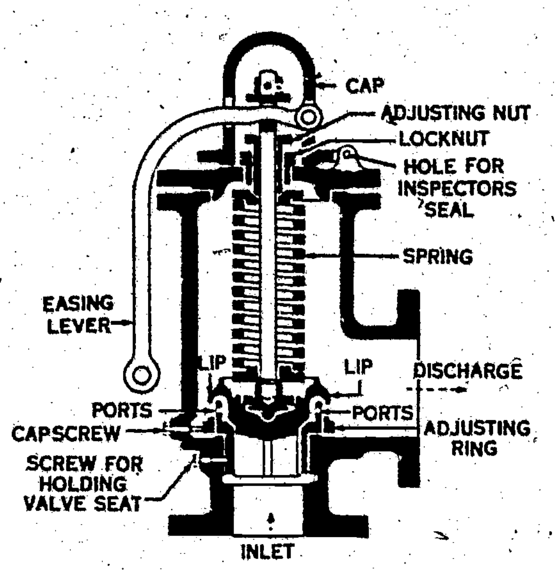


Figure 17. A typical pressure relief valve.

3-12. **Boiler Fittings and Accessories.** All boilers have certain accessories for safety and ease of operation. These accessories are pressure relief valves, pressure gages, water level control valves, and automatic controls.

3-13. *Pressure relief valve.* In a closed hot-water heating system, there is always the possibility of building up a dangerous pressure. Consequently, a pressure relief valve is installed to allow this pressure to escape. A typical pressure relief valve is shown in figure 17. This valve is usually on the top of the boiler. It contains a springloaded valve which unseats when the pressure in the system increases to a predetermined value, thereby allowing water to escape until the pressure drops to a safe point. A valve of this type can be adjusted for different pressures.

3-14. Pressure relief valves may eventually corrode and stick if they are not forced to operate occasionally. It is good practice, once each month, to increase the pressure to a point that operates the valve. When the relief pressure on the gage exceeds the setting of the valve, check the valve pressure with an accurate gage and adjust to the required amount. However, do not exceed the maximum safe pressure of the boiler.

3-15. *Pressure gage.* The operator must know the water pressure in the boiler at all times. A water pressure gage similar to the one shown in figure 18 makes this possible. The gage is connected to the top of the boiler. It shows the water pressure in the boiler and in the system in the pounds per square inch. This gage is usually a combination gage which also indicates boiler water temperature and altitude. The type shown in figure 18, however, indicates pressure only.

3-16. Very little maintenance is required for this unit, other than to clean the glass so that the gage can be read. Some types of pressure gages are constructed so that they can be recalibrated, but the proper equipment to do this is not always available. To properly calibrate a pressure gage, you must have either a master gage set or a dead-weight tester.

3-17. *Water level control valve.* Water is added to a hot-water heating system by either a manually operated water valve or an automtic valve, which is controlled by a float mechanism. Both valves are nearly identical to those used in the free-water system of a steam boiler.

3-18. *Airflow switch.* The airflow switch, or "sail switch" as it is sometimes called, is in the stack, breeching, or the air inlet to the boiler. This switch shuts down the firing equipment in event of an induced or forced draft failure. To check the operation of this switch, you restrict or shut off the draft. When you have done this, the switch should shut off the burning equipment.

3-19. *Automatic controls.* Automatic controls applicable to hot-water heating systems were discussed in Memorandum 565 of this course.

3-20. **Installing Boilers for Hot-Water Heating.** It is very important that a boiler has a good foundation. The top surface of the foundation should be level to insure proper alinement of the boiler sections, and thus eliminate undue strain on the boiler castings. The furnace foundation should be poured separately from the finished floor. It should be of sufficient width and depth to afford ample support for the boiler without any settling, and it should extend 2 inches above the finished floor.

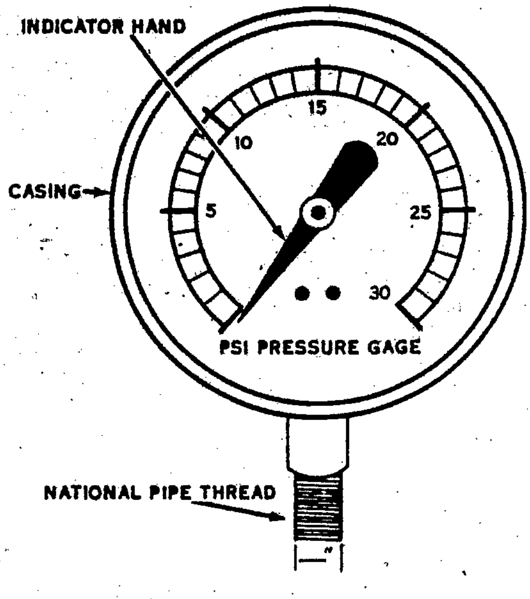


Figure 18. A typical water pressure gage.

Assembly procedures vary in detail for various boilers. However, manufacturers furnish detailed procedures for the assembly of their boilers. Usually, the plans for the foundations can be procured from them.

3-21. **Operation of Hot-Water Boilers.** Hot-water boilers, regardless of their design and type, operate on the same basic principle. The fuel burns in the combustion chamber and produces heat. The resultant heat is radiated and conducted to the water in the water jackets surrounding the combustion chambers and pass through the boiler tubes, heat is liberated by the flue gases and absorbed by the water surrounding the tubes. The amount of heat transferred into the water depends on the rate of heat conduction through the metal in the boiler tubes and the rate of water circulation in the boiler. For this reason, boilers are designed with baffles to hold the hot gases as long as possible. They give up maximum heat before passing into the chimney.

3-22. **Maintaining Hot-Water Boilers.** The maintenance of steel boilers is a continued operation. For efficient operation keep the inside and outside of the boilers free from scale, slag, and soot. Keep the grates and the combustion chamber clean. Remove the ashes from the ashpits and the clinkers from the grates. When the boiler is to be closed down for the summer months, remove the manhole plates as well as the cleanout plugs, and wash out the boiler thoroughly. Also, remove the scale and sediment that may have collected in the boiler, and wash the inside of the boiler with a stream of water from a hose. Then dry the boiler internally by burning a small kerosene stove in the firebox. Never dry out a boiler with the burner which operates the boiler. The burner dries the surface too fast.

3-23. The smokepipe, flues, firebox, and any part of the boiler which has been in contact with the hot gases, must be thoroughly cleaned during the summer overhaul. Corrosion and rust form to a greater degree when the boiler is idle. The door hinges and other similar units should be greased or oiled.

3-24. Sometimes it is necessary to replace one or more sections of a cast iron boiler because of a leaking nipple or a cracked wall. To remove the section, you loosen and remove the bolts holding it in place. Then drive wooden wedges between the damaged section and the one next to it, both at the top and bottom, to separate the sections. Repeat the procedure for removing other sections.

3-25. When steel boilers develop a leak, weld or rivet them. When boiler flues are unserviceable, replace them.

3-26. Plugs and handholes are on the outside of the boiler so that you can reach the various parts of the boiler for cleaning. The drain valve and rod-out openings are usually at the lowest point of the boiler, so that sediment, rust, and like foreign matter can be washed out readily.

4. Hot-Water Heating Distribution Systems

4-1. In hot-water heating systems, water is heated at a central source and circulated through pipes to radiators, convectors, or unit heaters. There are two general types of low-temperature hot-water heating systems. The first type is the gravity system in which water circulation depends upon the weight difference between the hot column of water leading to the radiators and the relatively cooler, heavier column of water returning from the radiators. The second type is the forced-circulation system in which water is circulated by a power-driven pump.

4-2. **Gravity Hot-Water Distribution System.** The distribution systems and piping for hot-water heating systems and for domestic hot-water supply systems are simpler in design than those for steam, because there are no traps, drips, or reducing valves. Several items such as supports, insulation, and some valves and fittings are the same for both steam and hot-water distribution.

4-3. Gravity hot-water distribution systems operate because of the gravitational pull on the heavier cool water, which sinks as the heated water becomes lighter and rises. At this point, we discuss some of the types of gravity systems that are currently used.

4-4. *One-pipe open-tank gravity system.* The one pipe open-tank gravity distribution system, shown in figure 19, consists of a single distribution pipe which carries the hot water to all of the radiators and returns it to the boiler. This system is easy to install and moderate in cost.

4-5. The water which flows into the radiators at the end of the system has a lower temperature than the water entering the first radiators. A system of this type should be designed so that the water reaching the last radiator is not too much cooler than the water reaching the first radiator. Because of this progressive temperature drop in the distribution system, larger radiators should be installed at the end of the system to equalize the amount of heat radiation per radiator. It is difficult to get enough circulation by gravity to give the system small radiator temperature drops; consequently, we do not recommend the one-pipe open-tank gravity system.

4-6. *Two-pipe open-tank gravity system.* Many hot-water gravity distribution systems are two-pipe open-tank systems, such as the one illustrated

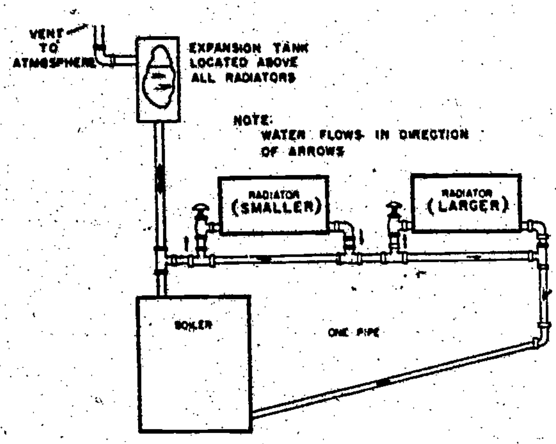


Figure 19. A one-pipe open-tank gravity hot-water distribution system.

in figure 20. This heating system is constructed with separate water mains for supplying hot water and returning cold water. The radiators are connected in parallel between the two mains. In the two-pipe open-tank gravity system, the distributing supply mains are either in the basement with upfeed to the radiators or in the attic. When the system is in the attic, it has overhead downfeed supply risers. The return mains are in the basement. Return connections for the two-pipe system are usually made into a gravity return, which pitches downward to the return opening in the heating boiler. The water temperature is practically the same in all radiators, except for the allowance to be made for the temperature drop in the distribution supply mains occurring between the boiler and the end of the circuit. Water temperatures are the lowest at the end of the circuit. The amount of temperature drop between the beginning and the end of the line depends upon the length of the main and upon the heating load.

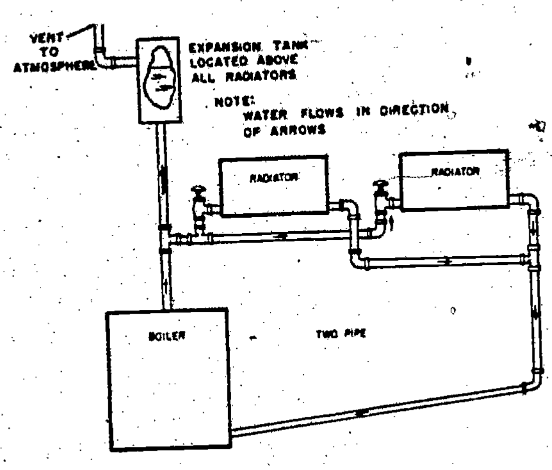


Figure 20. A two-pipe open-tank gravity hot-water distribution system.

4-7. A tank with its vent open to the atmosphere is installed in the system above the highest radiator, as shown in figures 19 and 20, for water expansion. The water level in the expansion tank rises and falls as the system is heated and cooled, and the system is full of water and free from air at all times. In the open-tank gravity hot-water heating system, the expansion tank is installed on a riser directly above the boiler so that the air liberated from the boilerwater will enter the tank and not be retained in the system.

4-8. *One-pipe closed-tank distribution system.* A one-pipe closed-tank gravity hot-water distribution system, like the one shown in figure 21, is similar to the one-pipe open-tank gravity hot-water heating system except that the expansion tank is a pneumatic compression tank not open to the atmosphere. When the water in a closed-tank system is heated, it expands into the pneumatic compression tank. This action permits system operation at a much higher water temperature, without boiling, than the temperature in the one-pipe open-tank gravity system. This also results in higher heat emission from the radiators.

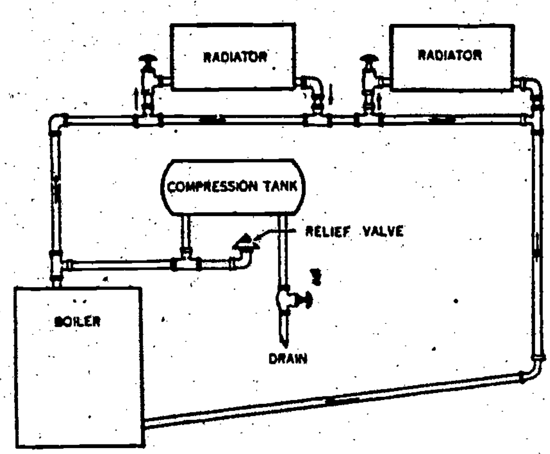


Figure 21. A typical one-pipe closed-tank distribution system.

4-9. A gravity open-tank system with an average boilerwater temperature of 170° F. has a radiator emission rate of 150 Btu psf, whereas a gravity closed-tank system, with an average boilerwater temperature of 190° F., has a radiator emission of 180 Btu psf. Higher boilerwater temperatures permit higher temperature drops through the radiators; consequently, smaller pipe sizes can be used. The closed pneumatic compression system requires a relief valve, usually set for the relief of water pressures over 30 psi, depending upon the height of the building. A pressure-regulating valve automatically maintains the system full of water. The installation of the radiators and piping for an equivalent two-pipe closed-tank gravity upfeed or overhead down feed system is the same as that for the open system except that the sizes of both the pipe and radiators are uniform and can be smaller. The open-tank system may have a reversed return main which does not go directly back to the boiler.

4-10. A reversed return main does not go directly back to the boiler. It doubles back from the last radiator and parallels the supply main back to the boiler entrance. Reverse return systems allow equal length of heating circuits for all radiators. Friction and temperature losses for all radiators are nearly equal. In most cases, the reversed return system involves no more piping than other piping arrangements. With the correct size of piping and radiator supply tappings, the reversed return system provides even heat and circulation to all radiators, even those near the end of the circuit.

4-11. *Expansion in gravity hot-water distribution systems.* In the gravity and forced-circulation systems, open and closed expansion tanks allow the water in the distribution system to expand as the temperature rises. An open tank must be mounted at the highest point in the system; a closed tank can be located at any point. If the air cushion leaks out of the closed expansion tank, it fills with water. At times, you must recharge the tank by draining part of the water out of the tank and allowing air to fill the space.

4-12. In the open system, an expansion tank open to the atmosphere allows the system to expand. The open system is normally designed to operate at the maximum boiler temperature of 180° F. This gives an average radiator temperature of 170° F., or a radiator output of 150 Btu per square foot (psf). The closed system, in which the expansion takes place against a cushion of air in the tank closed against the atmosphere, can be operated at temperatures above 212° F., because the pressure built up in the system prevents the water from boiling. Radiator temperatures then become equal to those of low-pressure steam systems.

4-13. When a hot-water system is first filled with water, it is normally necessary to bleed the air out of the system at the same time. You can remove the air by opening an air vent on a radiator or by breaking a union near the end of the line. The temperature of the water that is distributed is from 150° to 250° F. The higher temperatures are used with the forced circulation systems.

4-14. **Forced-Circulation Hot-Water Distribution System.** Forced-circulation hot-water distribution systems have several advantages. They permit the use of smaller pipe sizes and allow the installation of radiators at the same level as the boiler, or below, without impairing water circulation. By using a circulation pump, a positive flow of water is assured throughout the system. In larger installations, especially where more than one building is served, forced circulation is almost invariably used. With the development of the circulation pump of moderate cost, the forced-circulation system is being used more extensively in small heating installations.

4-15. Even as in gravity systems, forced-circulation systems can consist of a one-pipe or a two-pipe, upfeed or downfeed, and can be equipped with a direct or a reverse return. Although these systems usually have closed expansion tanks, they may have open tanks.

4-16. *One-pipe, closed-tank, forced-circulation system.* The general arrangement of a one-pipe, closed-tank, forced-circulation system, shown in figure 22, is similar to the one-pipe gravity system, but with the addition of a circulating pump.

4-17. The circulation to individual radiators is improved by special supply and return connecting tees. These tees, by an ejecting action on the distribution supply main and an ejecting action on the return, combine to use a portion of the velocity head in the main to increase circulation through the radiators. Tees of this type also aid stratification of hot and cold water within the distributing main. They are designed to take off the hot-test water from the top of the main and to deposit the colder water on the bottom of the main.

4-18. *Two-pipe, closed-tank, forced-circulation system.* The general arrangement of the piping and radiators for two-pipe forced-circulation distribution systems is the same as that for the two-

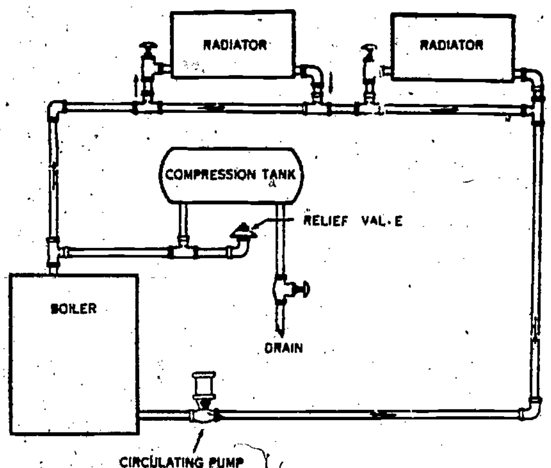


Figure 22. A one-pipe closed-tank distribution system with a circulating pump.

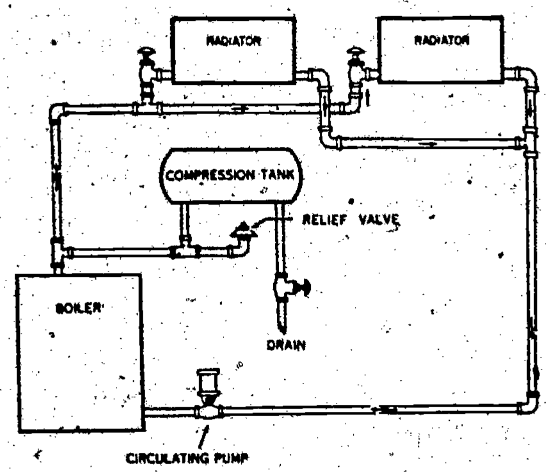


Figure 23. A two-pipe, closed-tank, forced-circulation system.

pipe gravity systems. The relative locations of the compression tank relief valve and the circulating pump are shown in figure 23.

4-19. **Distribution System Components.** The component parts of a hot-water distribution system include: pipelines, radiators, unit heaters, circulating pumps, reducing valves, flow-control valves, and special flow fittings.

4-20. *Pipelines.* The piping system constitutes the closed passageway for the delivery of hot water to the points where it is used. Pipelines are made up of lengths of pipe fastened by screwed, flanged, or welded joints. They have valves and fittings such as tees, unions, and elbows, according to the needs of the installation. Pipelines are supported by hangers and fastened by anchors. Expansion joints or loops allow for expansion.

4-21. Mains and branches of the pipeline should be pitched so that the air in the system can be discharged through open expansion tanks, radiators, and relief valves. The pitch is generally not less than 1 inch for every 10 feet. The piping arrangements for a new system should include provision for draining the entire system.

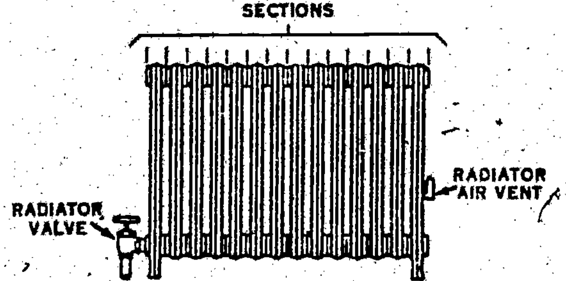


Figure 24. A typical cast iron sectional radiator.

4-22. *Radiators.* The radiator transfers heat from the hot water in the pipes of a hot-water heating system into the air in a room. A radiator is usually constructed of cast iron and assembled in sections, as shown in figure 24. Damaged radiator sections can be replaced without replacing the entire radiator assembly.

4-23. Radiators usually rest on the floor. However, they can be either mounted on a wall or hung from the ceiling. The location of a radiator depends on the type of room to be heated and its location with respect to the location of the boiler. For instance, in a forced-circulating hot-water distribution system, the radiators may be on the same level with the boiler.

4-24. Hot water heating system radiators and high points in the distribution lines must have some type of vent that releases air from the system. Air trapped in the system prevents the circulation of water. For this purpose, a manually operated key type air vent, like that illustrated in figure 25, can be used.

4-25. Manually operated key type air vents can be replaced by automatic air vents. One type of

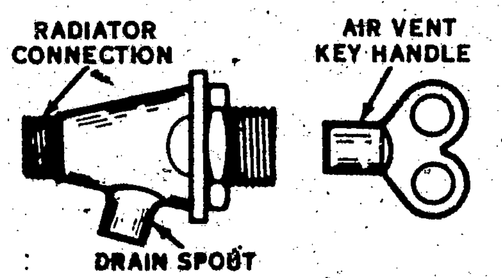


Figure 25. A manually operated key type air vent.

automatic vent is illustrated in figure 26. It automatically allows the air that forms in the system to escape. When air vents fail, replace them.

4-26. Radiators also have shutoff valves, such as the one illustrated in figure 27, which reduce or stop the flow of hot water through a radiator. They are installed in the piping adjacent to the inlet side of the radiator. Occasionally, you must tighten the packing nut on these valves to prevent the water from leaking around the valve stem.

4-27. *Unit heaters.* A unit heater is one used to heat a localized area. The heater consists of a heating coil that is supplied with hot water. The coil is usually of the finned type, and air is circulated over it by an electric fan. A unit heater installed in a distribution main is illustrated in figure 28.

4-28. Servicing unit heaters includes a monthly inspection. Each month check for water leaks, cleanliness of the finned coils, and the operation of the fan motor. Other accessories which you also should inspect are traps, air vents, fan blades, and valves. Make any needed repairs. Lubricate the electric fan monthly.

4-29. *Circulating pumps.* A forced hot-water heating system has a water circulating pump in the return line near the boiler. This pump insures the positive flow of water regardless of the height of the system or the drop in the water temperature. Greater velocities of waterflow are obtainable with forced circulation than with gravity circulation.

4-30. Circulating pumps are free of valves and float control elements. They are operated under a sufficiently high water inlet temperature to eliminate the difficulties caused by vapor binding.

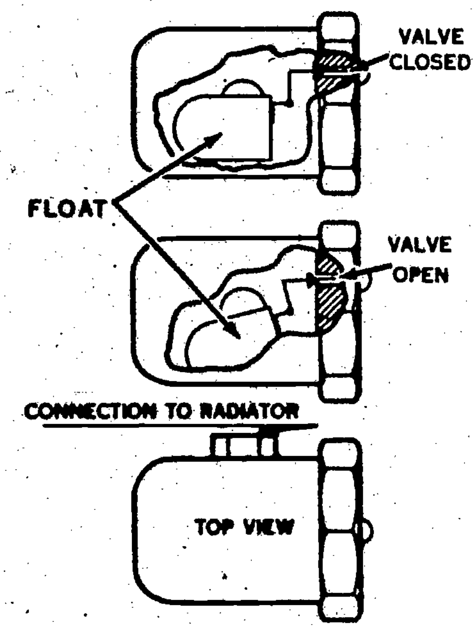


Figure 26. One type of automatic air vent.

The pumps are usually operated by electric motors.

4-31. During maintenance servicing, check the pump carefully for proper rotation, and lubricate the electric motor and pump according to the manufacturer's instructions. Also you periodically clean the pump of sand, rust, and other foreign matter which has collected in the pump casing. Be sure that the pump rotates freely and that the shaft packing glands, if there are any, are not drawn up so tight that they score the shaft.

4-32. *Reducing valves.* A reducing valve is normally installed in the cold-water line going to the boiler. It automatically keeps the closed system supplied with water at a predetermined

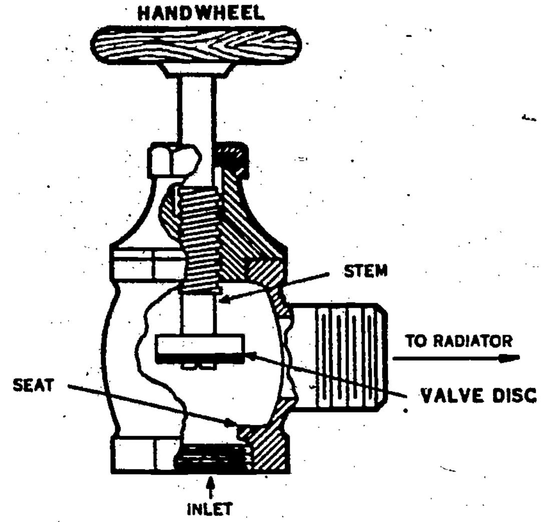


Figure 27. A typical radiator shutoff valve.

safe system pressure. These valves are usually set at the factory, but you may adjust them in the shop to a desired pressure. You should install this valve at approximately the same level as the top of the boiler.

4-33. *Flow-control valves.* Forced hot-water circulating systems use the flow-control valve, shown in figure 29, which is normally installed in the distribution main. This valve prevents gravitational flow of water through the system. The valve does not offer any serious resistance to the flow of water when the circulating pump is in operation. However, when the pump is not operating, the small gravitational head of water cannot open the valve. Each week you should check the flow-control valve for proper opera-

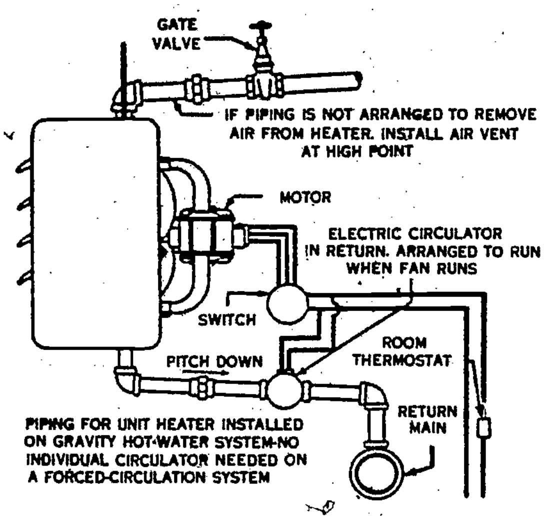


Figure 28. A typical unit heater installation.

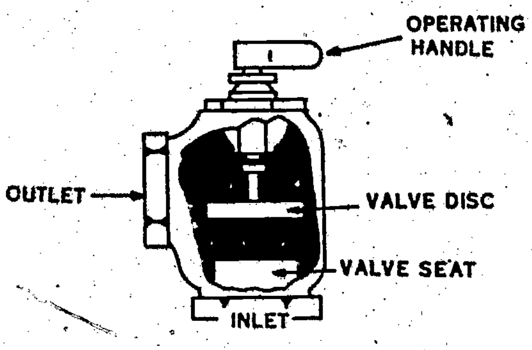


Figure 29. One type of flow control valve.

tion and free movement. Examine the valve for water leaks and repair it when necessary.

4-34. *Special flow fittings.* Various types of special tees that are designed to deflect main-line water into the radiator branches are used in one-pipe and two-pipe forced-circulation systems. These fittings are designed and calibrated to the size of the radiator and system operating temperature. Fittings of this type are required with one-pipe forced-flow systems, and they do equally well for radiators above and below the distribution mains.

4-35. **Installing Hot-Water Heating Systems.** The general information given in this chapter about installing hot-water heating systems should be supplemented by detailed installation procedures from the manufacturer of the heating equipment to be installed.

4-36. **Maintaining Hot-Water Heating Systems.** Hot-water heating systems require little maintenance other than periodic checks to make certain that all air is out of the system and all radiators are full of water. The circulating pumps should be oiled regularly, in accordance with the manufacturer's instructions, and the pressure relief valves should be checked periodically.

4-37. **Troubleshooting Hot-Water Heating Systems.** Some of the common discrepancies which you will encounter when troubleshooting hot-water heating systems are as follows:

Boiler Trouble

Symptoms	*Remedy*
Boiler smokes through the feed doors.	Clean the boiler flues and the fluepipes. Repair any chimney leaks.
Boiler heats slowly.	Increase the draft. Check on the type of fuel. Clean the boiler of scale. Blow down the boiler.
Boiler produces insufficient heat.	Clean the boiler of scale. Change to a larger boiler. Blow down the boiler. Increase the draft, and check on the type of fuel.

Radiator and Unit Heater Trouble

Symptoms	*Remedy*
Radiators will not heat.	Insufficient water in system. Bleed the air from the system. Open the radiator valves. Clean the corroded valves, and check the operation of the circulation pump.

Distribution Piping Trouble

Symptoms	*Remedy*
Distribution piping will not transfer hot water to the radiators.	Insufficient water in the system. Bleed the air from the high points in the distribution piping. Check the operation of the circulation pump. Check for corrosion stoppage in the distribution piping.

5. Hot-Water Heaters

5-1. Clean hot-water is required in many installations for domestic use and for industrial use. Since boilerwater cannot be used for this purpose, because of the chemical added, it is necessary to heat other water. The water may be heated in tanks equipped with coiled piping through which the boilerwater circulates. Or it may be heated in independent units that heat by electricity, gas, oil, or coal.

5-2. Domestic hot-water heaters are built in various sizes from 20- to 50-gallon capacities. Industrial type hot-water heaters are designed to heat thousands of gallons of water, depending upon the amount an installation uses.

5-3. Modern hot-water heaters are self-contained and require very little attention, since they are fully automatic. The diagram of a gas-operated hot-water heater is shown in figure 30. These units are cylindrical in shape, and they have diameters ranging from about 12 to 30, 40, and 50 inches, depending upon their capacity. The tank is constructed of galvanized sheet metal, which may be lined with a composition of glass to resist corrosion of the tank lining and prevent contamination of the water. The combustion chamber is in the lower section, which is vented by a baffled flue that extends through and ends at the top of the tank. The entire tank is insulated to prevent the escape of heat. It is also equipped with a thermostat which can be adjusted to maintain a certain water temperature.

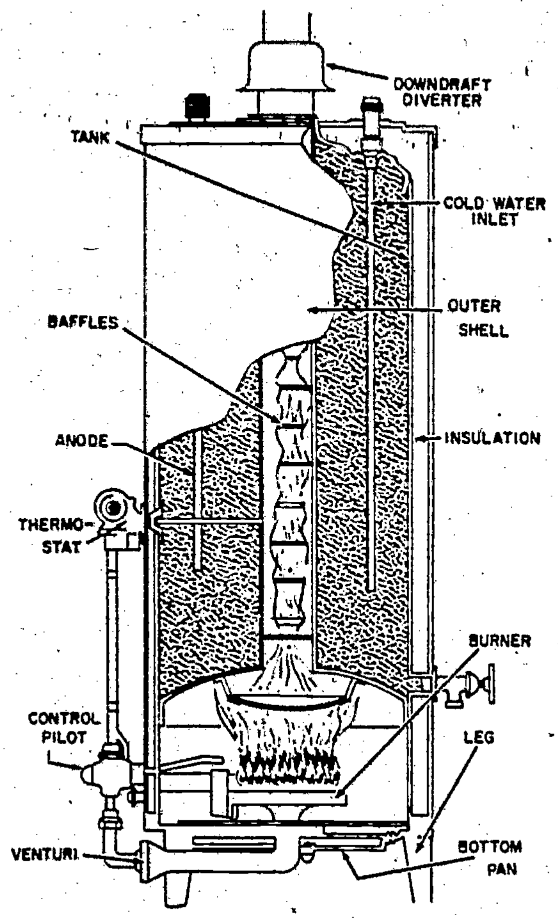


Figure 30. A gas-fired hot-water heater

Safety features which make the hot-water heater automatic are also in the unit.

5-4. Both the cold-water inlet and the warm-water outlet are at the top of the tank. These tappings are usually marked "INLET" and "OUTLET." However, if there is a question in your mind as to which is the inlet and which is the outlet, just remember that the cold-water inlet pipe extends over halfway into the tank, but the outlet pipe does not. There is usually a drain valve at the bottom of the tank.

5-5. The directions for lighting and operating a hot-water tank are usually printed on the side of the unit. The servicing required to maintain this unit is the same as that for an automatic gas burner.

CHAPTER 3

High-Temperature Hot-Water Heating

HIGH-TEMPERATURE hot-water systems came into use in Europe more than one hundred years ago. However, the first large high-temperature hot-water heating system in the United States was installed about 1940. After this, very few heating plants of this type were installed in this country until after World War II. At this time the military recognized the high-temperature hot-water system as a very good method of heating. The acceptance and successful use of this heating system by the military led to its general acceptance by industry. The high-temperature hot-water system is commonly referred to in its abbreviated form as HTHW.

2. You recall that in previous chapters of this memorandum we discussed the effectiveness of both hot-air and low-temperature hot-water heating systems. In this chapter we discuss the characteristics of HTHW heating systems, types of heat-carrying media, types of HTHW systems, pressurizing HTHW systems, HTHW system operation, safety characteristics of HTHW systems, and piping for HTHW systems. We also mention steam as a medium of heat transfer; however, steam heating is not thoroughly discussed until Memorandum 567 of the course.

3. The HTHW system is a very real and growing competitor to other methods of heating; consequently, you should familiarize yourself as much as possible with the information in this chapter.

6. Characteristics of HTHW Heating Systems

6-1. High-temperature hot-water (HTHW) systems operate at high pressure to maintain a water temperature that exceeds the normal boiling temperature of 212° F. (at atmospheric pressure) used in other types of heating systems.

6-2. High-temperature hot-water systems consist of standard and heavy-duty equipment, including boilers (sometimes referred to as generators), expansion drums, system circulator pumps, distribution piping, and heat-consuming equipment.

6-3. High-temperature hot-water systems use boilers or generators that may be heated with coal-, oil-, or gas-burning equipment. However, the water is sometimes heated by direct-contact steam heaters. High-temperature hot-water systems use either steam or an inert gas for pressurization.

6-4. High-temperature hot-water systems have the hot water pumped from the generator and throughout the distribution system. The circulator pumps are large enough to deliver the water at sufficient pressure to overcome any drops in the distribution system and the heat-consuming equipment. The major advantages of the HTHW heating system are low makeup requirements, minimum maintenance, high thermal efficiency, and safe, easy operating and control.

6-5. The HTHW system is a closed system, so the only water wastage is the normal leakage at the pump and valve packing glands. Consequently, very little water is consumed during system operation. This means that only a small amount of makeup water is used, practically eliminating boiler blowdowns. The closed recirculating system operates at high thermal efficiency. All of the heat not used by heat-consuming devices in the system or lost through pipe radiation is returned to the boilerplant. Because very few boiler blowdowns are required, the heat loss from blowdowns is kept to a minimum.

6-6. The HTHW system uses the thermal "flywheel" effect, which is characteristic of the large heat storage capacity of high-temperature hot water that permits the system to accumulate generated heat and even out the heating load on the boiler. The sudden changes in firing rates in other systems which produce poor combustion and high stack temperatures are virtually eliminated, and the boiler has higher operational efficiency. Table 1 compares the heat storage capacity of water and steam for various pressures and temperatures. At 50 psig with the temperature at 298° F., water contains 87 times the amount of heat that steam does. (15.360 divided by 170 equals 90.4). Figure 31 illustrates the variation of water density and volume at different temperatures. When the temperature of water is 100° F., the density is about 63 pounds per cubic foot. When the temperature rises to 200° F., however, the density drops to 60 pounds per cubic foot, and the percent of increase in volume rises from almost zero to 2.50 percent. Note that as the temperature of the water increases the percent of increase in volume goes up and the density per cubic foot goes down.

6-7. The HTHW system operates at low cost. The requirements for maintaining the HTHW system are comparatively lower than for other types of heating systems. The same water is recirculated, and the system is always filled with non-corrosive-treated water, and scaling and corrosion do not occur. Also, there are no traps and reducing valves to maintain, as in the steam heating system for example.

6-8. In the HTHW system, a mixture of water and steam is discharged into the atmosphere when high-temperature hot-water escapes through a leak in the line. The temperature of the water is well above the vaporization point at atmospheric pressure, so part of the water flashes to

TABLE 1

HEAT STORAGE COMPARISON OF HTHW AND STEAM

Gauge Press, Psi	Temp. °F	Total Heat Content Btu/cu. ft.		Ratio: Water/Steam
		Water	Steam	
50	298	15,360	170	90.4
60	308	15,840	203	78.0
70	316	16,260	229	71.0
80	324	16,670	255	65.4
90	331	17,000	281	60.5
100	338	17,320	306	56.6
110	344	17,600	332	53.0
120	350	17,870	358	49.9
130	356	18,170	384	47.3
140	361	18,380	410	44.8
150	366	18,610	434	42.9
160	371	18,830	461	40.9
170	375	19,040	486	39.2
180	380	19,220	511	37.6
190	384	19,400	537	36.1
200	388	19,570	562	34.8
210	392	19,750	588	33.6
220	396	19,920	613	32.5
230	399	20,080	639	31.4
240	403	20,240	664	30.5
250	406	20,390	690	29.6
260	409	20,530	716	28.7
270	413	20,670	741	27.9
280	416	20,800	767	27.1
290	419	20,920	792	26.4
300	422	21,040	818	25.7

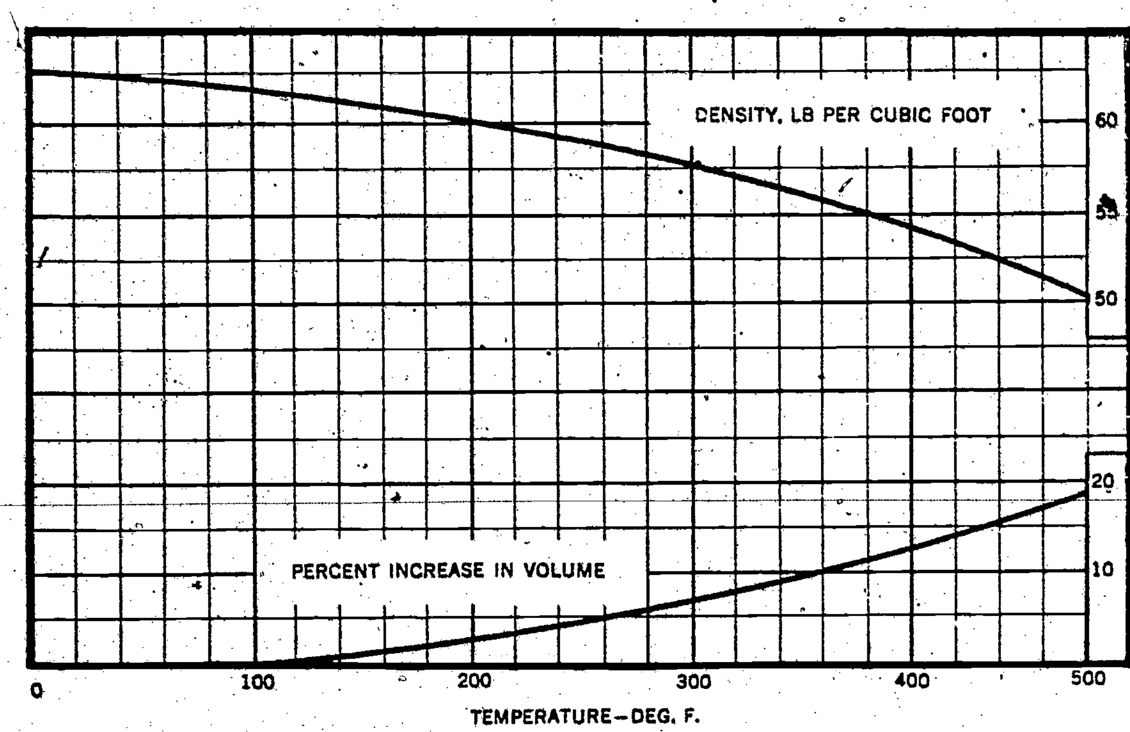


Figure 31. A comparison of water density and volume.

steam. This utilizes much of the heat from the water and makes the leak less dangerous. Later in this chapter you will be given more information regarding the safety characteristics of the HTHW system.

6-9. Another characteristic of the HTHW system is its simplicity of construction with the absence of complicated traps and valves. Now that you have completed the major characteristics of the HTHW heating system, let us compare the different types of heat-carrying media.

6-10. Types of Heat-Carrying Media. The current practice is to use a central-heating plant in preference to a number of smaller individual heating units. Advantages of the central-heating plant lie in the simplification of heating plant design and operation and in maintenance. There are, however, the problems of uniformly distributing the heat through pipelines over the heated areas of large buildings and transmitting the heated media for long distances about the post. We will, therefore, examine hot air, steam, and hot water, the three commonly used means of transmitting heat.

6-11. *Hot air.* Hot air carries heat from the heating plant to the place of use. Due to the low specific heat of hot air, 0.24 Btu/lb or 0.018 Btu/cu ft are required to provide available heat of 1.8 Btu/cu ft for a temperature change of 175° F. at the plenum chamber to 75° F. at the heated area. A very large volume of hot air is required to transmit the heat from the central-heating plant to the place of use. If the heat load is small and the distance the heat travels is short, as in homes and small buildings, the hot-air method of heating is often an ideal arrangement. However, if the heat load is large or the distance the hot air must travel is great, or both, the size of the air transport ducts and circulating fans would be expensive and too large.

6-12. *Steam.* Steam often is used to transmit large quantities of heat over great distances. Steam has a latent heat of vaporization (the amount depends on the pressure). This latent heat is potentially available for heating. For a given volume, steam contains from 38 to 70 times more heat than air. Therefore, we must definitely recognize steam as a good medium for transporting large quantities of heat over great distances.

6-13. *Hot water.* Hot water also carries heat. With hot water, as with hot air, the heat available for heating is represented by the water temperature and is not represented by a change of state such as the latent heat of vaporization in steam. Let us assume that the temperature of water leaving a generator is 400° F. and that the water returning to the generator is 250° F. Here, the difference in temperature of 150° F. represents 158 Btu/lb or 9,000 Btu/cu ft transmitted to the heat load. For a given size of line about 30 times as much heat can be transmitted

53

by water than by steam. The actual relative amount depends on the water temperature and the steam pressure. Since the water must be returned to the heating plant, the distance that it must travel will be approximately twice the distance steam travels. This does not take into account the condensate return line for steam which is only about one-fifth the capacity of the HTHW return line. On the volume basis, water is a very good carrier of heat as compared to other heat-transporting media. The weight of the circulating water, however, is quite large and should be taken into account when the installation cost is figured.

6-14. **HTHW Versus Steam.** It is evident that steam or high-temperature hot water can be satisfactorily used for transporting and distributing heat from a central-station heating plant to the heat load. Therefore, we should examine the features of both systems.

6-15. *Advantages of HTHW.* The piping arrangement for the HTHW system is simple. The parallel supply and return lines can be located at any elevation or grading. But with steam, it is necessary to slope all of the lines for proper system drainage and collection of condensate. which must be pumped or drained back to the heating plant. In the HTHW system the arrangement of valves and fittings is simple. Pressure-reducing valves. and steam and water traps are required for steam systems, and they are difficult and expensive to install.

6-16. High-pH (potential of hydrogen) alkaline water is circulated throughout the entire HTHW system and practically eliminates internal corrosion. This potential of hydrogen ion concentration is expressed in gram atoms per liter of a concentration expressed in gram atoms per liter of a solution. The pH values from 0 to 7 (low) indicate acidity, pH 7 indicates pure water, and 7 to 14 (high) indicates alkalinity. In the steam system, pure but wet steam and low-pH water are in contact with the piping, heaters, etc. This provides a corrosion problem. In the HTHW system, the water is always under pressure and is seldom exposed to the atmosphere. This process virtually eliminates any possibility of absorbing oxygen or other noncondensable gases. The condensate in the steam heating system is usually collected in an open hot well where the water is exposed to the atmosphere and can absorb oxygen. To eliminate the oxygen, it is necessary to pass all the return condensate through a deaerating heater, an air ejector vacuum vessel, or use chemicals to remove the oxygen. There is also the tremendous "flywheel" effect in heat storage for the HTHW system, as compared to steam, because of the comparatively heavy weight of the water in the system. For systems of equal volume, the heat in the HTHW is about 30 times greater than for steam. The actual amount depends upon the steam pressure and water temperature.

6-17. *Advantages of steam.* A given volume of steam is capable of containing a great amount of heat (38 to 70 times that of air) and like HTHW is a good means of transporting heat for long distances. However, steam does have some advantages that HTHW does not have.

6-18. Steam is readily available for use where it may be required, such as for kitchen and for laundry use. In HTHW systems, steam must be generated by installing water-to-steam heat exchangers.

6-19. Steam is a compressible gas that requires no tolerances for expansion. The HTHW system, however, requires expansion drums to allow for changes in water volume caused by temperature changes.

6-20. Steam, by taking advantage of the available pressure drop, flows throughout the heating system without a pump. Water, which is about five times as heavy as steam, must be pumped through the system. The circulating pump horsepower requirement is partially offset by the boiler feed pumps and return condensate pumps of the steam system.

6-21. Since both steam and HTHW are suitable heat transportation media, an evaluation of the features of each system has its place. Steam would surely be preferred for hotels and skyscraper office buildings with a vertical and concentrated heat load. For groups of buildings, spread out over a large area where heat must be transported over a considerable distance and at varying elevations, HTHW should have the advantage.

7. Types of HTHW Systems

7-1. The high-temperature range for most military and federal heating plants is 350° F. to 450° F., which corresponds to saturated pressures of 135 psi to 425 psi. However, some types of plants operate at higher pressures and therefore have higher water temperatures. The installation of HTHW plants that operate at temperatures above 400° F. must be approved by the Chief of Engineers. Costs usually determine the maximum water temperature used, because the types of HTHW systems utilizing the higher pressures require more expensive piping, valves, fittings, and heat exchangers.

7-2. The degree of complexity of HTHW systems varies according to the size, type, and heat load requirement of the installation. Since methods used to maintain pressure and to assure uniform flow rates depend upon the amount of heat load, they affect the complexity of the heating system. There are two methods of circulating the HTHW through the system—the one-pump and the two-pump systems.

7-3. The one-pump system uses only one pump to circulate the hot water throughout the system, which includes the generator. The two-pump system uses one pump to circulate the water through the distribution system, and a second pump to circulate the water through the generator for positive circulation. Figure 32 shows some typical pumps that are used for circulation in the HTHW system. Note that the pumps are of the centrifugal type. Each pump shown in figure 32 would be used to circulate the water to different areas in distribution systems.

7-4. There are two common ways of heating the water in the HTHW system. One way is to use hot-water boilers or generators; the other way is to use the cascade or direct contact heater. The water in the HTHW generator is heated in much the same manner as low-temperature hot-water is heated. In the cascade heater, however, the water is forced through spray nozzles and comes into direct contact with the steam. The steam condenses into the circulating water. A typical spray nozzle head is shown in figure 33. The spray nozzles are installed in a combination cascade heater expansion drum. A typical cascade heater expansion drum installation is illustrated in figure 34. Let us discuss some ways of pressurizing the HTHW system.

8. Pressurizing the HTHW System

8-1. Since water volume varies with changes in temperature, the extra water must be taken care of when the water is heated. It is desirable to operate with the water above the boiling temperature of 212° F.; therefore, the pressure in the system must be maintained equal to or greater than the corresponding saturation (steam or vaporization) temperature. An expansion tank is required because the water, which is not compressible to a smaller volume, expands when it is heated. Also, the pressurization prevents the formation of saturated steam or vaporization when the water temperature is raised. There are two basic designs employed for pressurizing HTHW systems: first, the "saturated-steam cushion," and second, the "mechanical-gas cushion." Although both designs have a variety of modifications,

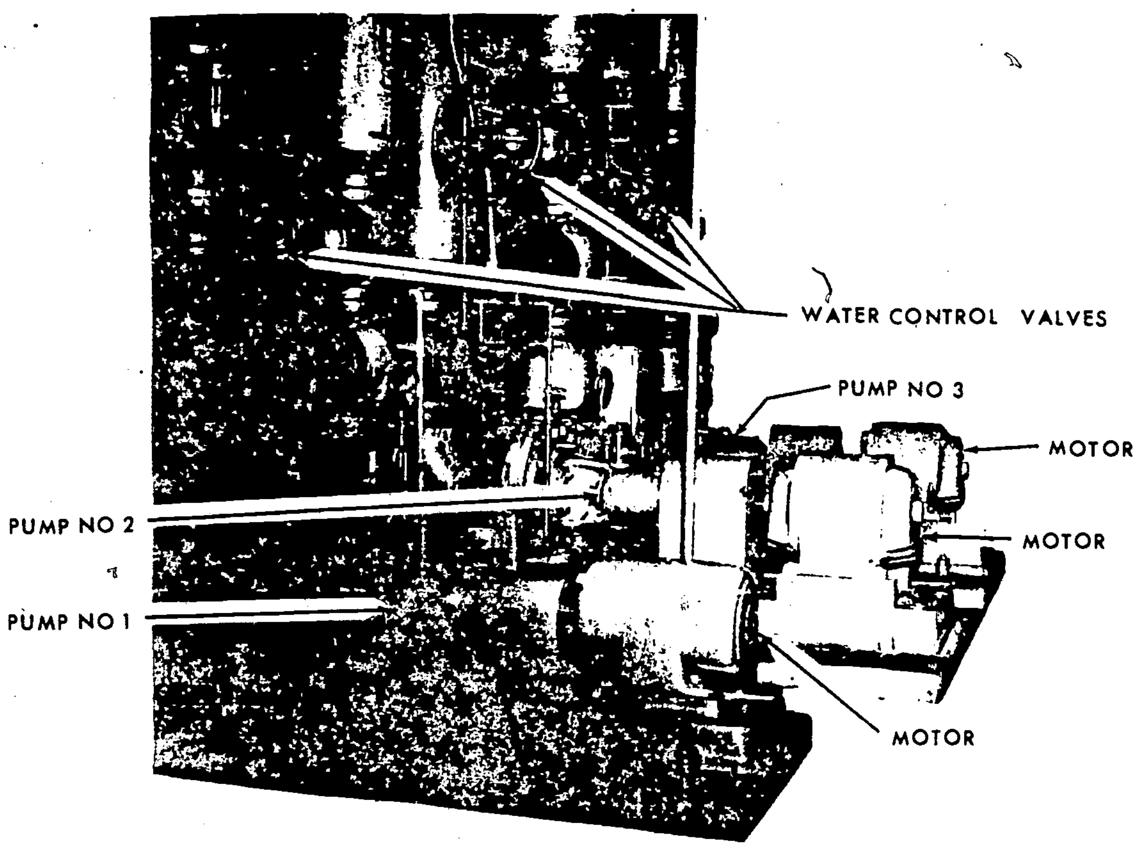


Figure 32. Typical high-temperature hot-water circulation pumps.

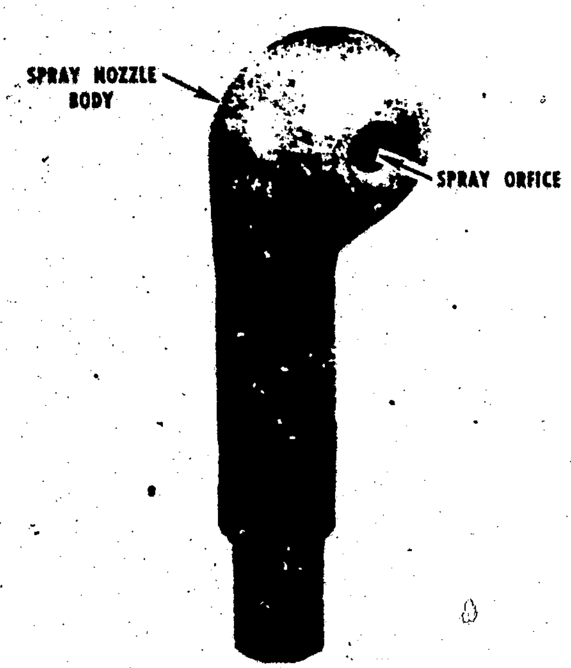


Figure 33. A typical cascade heater spray nozzle head.

their characteristics are still typical of the basic pressurized system design.

8-2. **Saturated-Steam Cushion.** Pressurizing the heating system with steam in the expansion tank is a natural method. Firing the HTHW generator to maintain the system pressure corresponding to the required saturation (steam or vaporization) temperature pressurizes the system. Excess heat is generated to offset the radiant heat loss from the expansion tank. All of the HTHW in the steam-pressurized system flows through the expansion tank and thereby maintains the saturation (steam or vaporization) temperature there.

8-3. The steam in the space in the expansion tank provides the pressure or cushion for the system. The pressure maintained is that of the saturated steam. The water in the lower portion of the tank will be approximately saturation (steam or vaporization) temperature corresponding to this pressure. The water to be used in the HTHW heating system is drawn from the lower part of the expansion tank, mixed with the system return water, and circulated throughout the system. The mixing is necessary to prevent cavitation (steam flashing) at the pump suction.

8-4. Here are some conditions that are typical of the saturated-steam cushion design. The expansion tank, either integral or separate, is a part of the HTHW system. The entire hot-water flowing in the heating system passes through the expansion tank and exposes the tank to the maximum system heat and any form of contamination that is in the water. The heat and contamination, in turn, subject the expansion tank to thermal stresses and corrosion. There are explosion hazards typical of a steam boiler in the system, and good water-level control is important in maintaining proper operating conditions. Load variations causing supply pressure changes create flashing of the saturated liquid in the system and produce water hammer.

8-5. **Mechanical-Gas Cushion.** The expansion tank contains the mechanical-gas cushion and is connected to the HTHW system return line just ahead of the circulating pump suction connection. The tank contains an inert gas (usually nitrogen) and is the source of pressure in this method. When the system has been pressurized by the nitrogen, pressure in excess of saturation must be maintained. That is, the water temperature throughout the system must always be less than its saturation temperature. In the nitrogen-pressurized system, the expansion tank is installed in the system as a standpipe arrangement so that the water does not flow through it. The water in the lower part of this tank is stagnant, except for the changes caused by expansion and con-

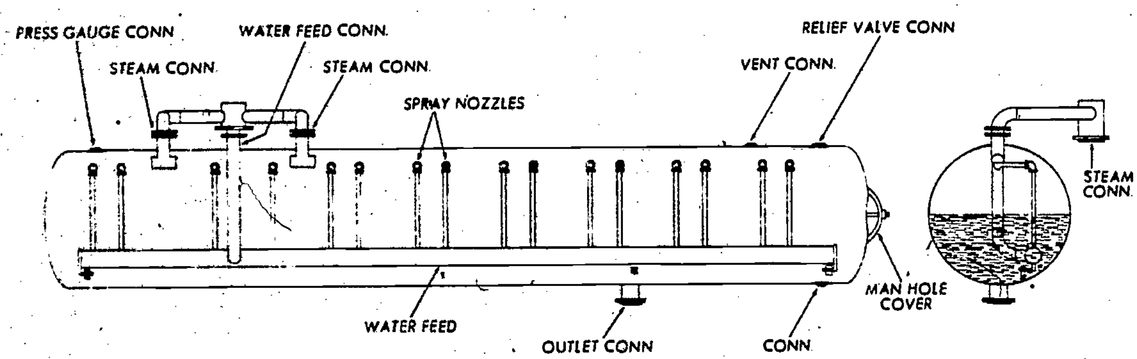


Figure 34. A combination cascade heater expansion drum installation.

traction brought on by load fluctuations. If you assume that the water is virtually incompressible, the tank provides the space available for these changes in the system's water volume.

8-6. Here are some characteristics that are typical of this design. The expansion tank is independent of the generator and remains cool. Corrosion is practically eliminated because the heating system is flooded, with the exception of the nitrogen space in the expansion (cushion) tank. When properly designed, the system is sealed with its fixed charge of water and nitrogen. However, this design does not contain a steam drum or any steam spaces which will permit the accumulation of steam. The generator tubes are the weakest link in this entire system. An explosion caused by the dissociation of hydrogen and oxygen cannot occur. The formation of steam cools the otherwise red-hot metal surfaces. Low-water conditions do not allow the flashing of steam.

9. Operation

9-1. To insure normal operation, you fill the system with treated water taken from the water softener. To prevent oxygen corrosion, add the chemicals for treating the water to furnish 20 to 40 parts of sodium sulfite per million parts (ppm) of water. You thereby maintain a pH value of 9.3 to 9.9. While the water is circulating in the generator and in the system, you should fire the boiler at about 25 percent of its rated capacity to bring the system up to normal operating temperature. You should allow the expansion drum vent in steam-pressurized systems to blow for about 1 hour to rid the system of all oxygen and other noncondensable gases.

9-2. The startup and firing of HTHW boilers or generators are done in much the same manner as for domestic hot water and steam boilers, depending upon the type of fuel-burning equipment used. The specific startup and operating procedures vary with different installations. Therefore, this information is furnished by your local supervisor and the manufacturer of the equipment.

9-3. Coal, oil, and gas are the types of fuels normally used to fire the boilers of HTHW systems. The specific type of fuel used will depend upon the type of firing equipment installed in the plant. Each type of fuel requires that designated inspections be made and that certain precautions be taken to eliminate fire and safety hazards.

9-4. The inspection of fuels and material storage areas for fire and safety hazards was covered in some detail earlier in the course. The inspection and storage of coal was discussed earlier. It is desirable, however, at this point to review some of the important aspects of the fire and safety precautions related to fuels.

9-5. On receipt, you inspect coal to insure that it is relatively free of impurities. Spontaneous fires and slack create hazards to the coal piles, which require watching. When you are transferring fuel oil from one tank to another, be sure that both tanks are grounded. Checks must then be made to insure that excessive oil pressures are not generated in the tanks by expansion of the fuel. Although natural gas is not normally stored on a military post, liquid petroleum (LP) gas is often stored near the heating plant. You should often check the areas where this gas is stored to insure that there is no leakage. Liquid petroleum gas is heavier than air and settles in low areas and creates explosive hazards. When checking for gas leaks, use a standard soap solution.

9-6. Because of the large heat storage capacity of HTHW systems, the load demand change for the boiler is slow and smooth. This characteristic provides for improved and safer operation than that provided by the saturated-steam cushion. This brings us to the discussion about the safety characteristics of HTHW.

10. Safety Characteristics of Steam and Hot Water

10-1. One of the significant advantages of HTHW is its relative safety, especially at the point of use. The many installations of steam and hot-water heating systems are so familiar to us that we do not normally concern ourselves with the hazards that they can present. The high-energy content of HTHW has led to the common belief that it is less safe than other heating media. In case of a break, however, this energy is used in the change of state process and is not available to create a serious hazard. Consequently, the reverse is the case. To describe what happens, we shall compare the effects upon the occurrence of a break or similar mechanical failure in each of four types of heating media which are commonly used.

10-2. **Low-Pressure Steam.** A break in a low-pressure steam line results in the forcible ejection of steam, as long as the pressure persists, at a temperature slightly below that of the steam in the pipe. Steam at 5 psi and 230° F. discharges to the atmosphere at the temperature of approximately 229° F. and at the velocity of about 1500 feet per second. This is a definite hazard, because the steam rapidly envelops the inclosure at the ejection velocity and its temperature is high enough to cause considerable bodily harm to persons in this area.

10-3. **High-Pressure Steam.** The action of a break in a high-pressure steam line is similar to that described above for a low-pressure steam line. Because of the greater expansion that takes place, there is a slightly greater drop in temperature with high-pressure steam. For example, steam at 125 psi and 300° F. temperature is discharged into the atmosphere at 290° F. and a velocity of approximately 1,600 feet per second. The energy in the steam is converted into work (kinetic energy) as it flows out of the system. Again, this is a highly hazardous condition.

10-4. **Low-Pressure Hot Water.** When a failure occurs in a low-pressure-hot-water system, scalding water is emitted for a short time until the system pressure reduces to atmospheric pressure. Since the temperature of the water is not above its boiling point at atmospheric pressure, flashing to steam does not occur. Water at 15 psi and 200° F. temperature discharges through a break to atmospheric pressure at a temperature of approximately 200° F. and at a velocity of about 175 feet per second. Less hazard is present in this case than with steam, because the lower water ejection velocity does not tend to fill the inclosure. The condition, however, is still hazardous, especially in the case of overhead piping, because water at 200° F. can produce permanent injuries.

10-5. **Pressurized HTHW.** When a break occurs in an HTHW line, a mixture of water and steam is discharged to the atmosphere. Since the temperature of the water is well above its vaporization point at atmospheric pressure, the energy in the water is used to convert a part of the water from the liquid state into the vapor state. This energy is used in the change of state process, and it is not available to do work (kinetic energy). Because the quantity of heat available is sufficient to vaporize only from 20 to 25 percent of the HTHW present, there is no energy available to produce an explosion. Due to the pressure in the system, the mixture of steam and water is ejected initially at a high velocity. Since the pressure is maintained independently by a fixed quantity of nitrogen in the compression tank, the pressure falls rapidly and the velocity of ejection drops to a low value in a very short time.

10-6. When 25 percent of the water vaporizes, it obtains its heat energy from the other 75 percent of the water. Therefore, the heat content of the 75 percent of the water is reduced by that amount of heat which is used to vaporize the 25 percent. The resulting emission temperature of HTHW at 400° F. drops to between 120° F. and 130° F.

10-7. **Boiler Versus Generator Failure.** The explosion of a steam boiler can be the result of excessive steam pressure created inside the steam drum. When this happens, considerable damage is sustained by the heating plant. Severe steam boiler explosions, however, can also occur from the dissociation of hydrogen and oxygen in the tubes or drums. Dissociation takes place whenever water comes into contact with a red-hot metal surface, such as would happen in a boiler if the water level were allowed to drop too low and then be suddenly raised. When substantial amounts of hydrogen and oxygen accumulate in the steam drum, they blow the boiler and perhaps the building apart.

10-8. Forced circulation HTHW generators consist only of tubes and headers, and they have no pressure vessels such as a steam or "mud" drum. The tubes (convectors) in the convection section of the furnace portion of the generator are the weakest link in the system's circuits. The thin gage metal of the tubes collapses from overheating when liquid contact is lost on the interior of the tubes for as short a time as 2 minutes. It is, therefore, not possible to develop high steam pressures within the system because the tube failure occurs in such a short time. The release of water and the consequent drop in pressure to atmospheric pressure upon the collapse of a generator tube prevents the formation of an explosive condition.

11. Installing the Piping System

11-1. All piping in an HTHW system should be welded. No screwed joints should be permitted, and flanges should be allowed only where necessary, such as at expansion joints, pumps, and generator connections. Only schedule 40 black steel piping or better is used for HTHW systems. Upon completion, the entire heating system is subjected to a test of 450 psi that lasts for not less than 24 hours.

11-2. The possibilities of line failure are very remote when the construction recommended above is used. The system piping material is subjected to a minimum factory test of 700 psi. The generator tubes are subjected to an ASME test of 900 psi. All valves and accessories are rated at working pressures of 540 to 1,075 psi at 400° F. The weakest link in the piping network lies within the generator tubing. The worst failure likely to occur is the loss of tubes, and therefore the generator. The safety of the piping system is maintained over the life of the installation because of the absence of corrosion in the hot-water heating systems due to boilerwater treatment.