DOCUMENT RESUME

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TITLE	Heating and Ventilating I, 11-2. 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.
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NOTE	126p.; For related documents, see CE 035 818-820.
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EDRS PRICE	MF01/PC06 Plus Postage.
DESCRIPTORS	Autoinstructional Aids; Behavioral Objectives; *Blueprints; Building Trades; Electrical Occupations; *Electricity; *Hand Tools; *Heating; Individualized Instruction; Learning Activities; Pacing; Plumbing; Postsecondary Education; Secondary Education; Textbooks; *Trade and Industrial Education; *Ventilation; Workbooks
IDENTIFIERS	*Insulation; Military Curriculum Project

ABSTRACT

This first course in a four-course series on heating and ventilating for the secondary/postsecondary level is one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. The four lessons in the course cover these topics: (1) Blueprints and Specifications, (2) Tools and Piping, (3) Electricity, and (4) Insulation and Refractory. Designed for student self-study and evaluation, the course materials consist of a text and a student workbook. The text contains the reading assignments and appendixes (pipefitting, valves, and piping symbols; heating symbols; and heating power symbols). 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)

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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
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The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
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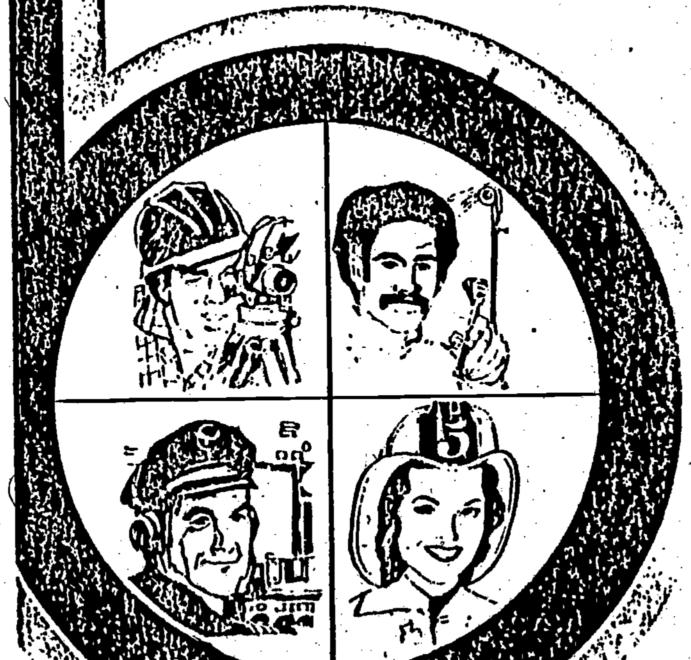
Military Curriculum Materials for Vocational and Technical Education

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

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Springfield, IL 62777
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HEATING AND VENTILATING I

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Lesson 1 - Blueprints & Specifications	Page 10
Lesson 2 - Tools & Piping	Page 24
Lesson 3 - Electricity	Page 52
Lesson 4 - Insulation & Refractory	Page 71
Workbook	Page 90

Developed by:

United States Army

Development and Review Dates

Unknown

Occupational Area:

Heating and Air Conditioning

Cost:

Print Pages:

112

Availability:

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

Suggested Background:

None

Target Audiences:

Grades 10-adult

Organization of Materials:

Student workbooks 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 I (Introduction to Heating)				
Lesson 1	–	Blueprints and Specifications	18	Flexible
Lesson 2	–	Tools and Piping	27	Flexible
Lesson 3	–	Electricity	18	Flexible
Lesson 4	–	Insulation and Refractory	18	Flexible
Workbook			26	

Supplementary Materials Required:

None

Expires July 1, 1978

Course Description

This is the first course in a four-course series designed to provide the student with the fundamentals of heating and ventilating. This course contains the following four lessons:

Lesson 1 — *Blueprints and Specifications* covers two chapters in the text. It begins with a short review of safety practices that are important to the heating specialist. Accidents, fires, fire extinguishers, burns and shock are discussed. This is followed by instruction on blueprints, blueprint views, symbols, scales, piping diagrams, heating plans, specifications and bills of materials in the second chapter.

Lesson 2 — *Tools and Piping* covers the proper care and use of common handtools; valves; pipe, fittings, and pipefitting; and welding.

Lesson 3 — *Electricity* explains the nature of matter, the structure of the atom, electrical charges, electromotive force, electric current, electrical resistance, Ohm's Law, conductors and insulators, electrical circuits, and symbols, circuit protective devices, measuring devices, magnetism, circuit troubles and troubleshooting.

Lesson 4 — *Insulation and Refractory* covers types of insulation, maintaining insulation, and the refractory.

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

MEMORANDUM 564-1

HEATING AND VENTILATING I

(INTRODUCTION TO HEATING)

U. S. ARMY ENGINEER SCHOOL

FORT BELVOIR, VIRGINIA

MOS: 51J20

EDITION 1 (NRI 110)

PREFACE

THE ARMY realizes that its building must be provided with adequate heat so that all of its people can work efficiently and live comfortably. The facilities engineer at each installation has been delegated to provide heating for buildings. He must also furnish processing steam for hospital sterilization work and cooking, for the operation of food steamtables in kitchens and dining rooms, for automotive cleaning equipment, for clothes (cleaning and pressing apparatus), and for specialized processing that may be required.

Each year the military forces use amazing amounts of solid, liquid, and gaseous fuels for heating. The cost of consuming these fuels in heating units amounts to many millions of dollars. It is therefore obvious that heating alone is a very large business. For this reason, the efficient operation of heating systems is an important factor affecting the overall cost of operation. Because of this magnitude, even small increases in efficiency can result in big savings.

Too often poor efficiency results (1) from using poor firing methods, (2) from inadequate furnace and boiler maintenance, (3) from failure to choose the best fuel for the equipment installed, (4) from improper design, and (5) from improper installation of heating equipment. The most prevalent of these are poor firing methods and inadequate preventive maintenance of stokers, furnaces, and boilers. If proper operating and maintenance practices are strictly observed by personnel, the cost of heating can be greatly decreased.

This is the first memorandum of this series, and it contains discussions on subjects designed to introduce you to the career field of heating. You will also study about layout, tools and piping, electricity, and insulation and refractory materials.

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Safety

1. Accidents

1-1. A standard dictionary defines the word "accident" as "an event that takes place without one's foresight or expectation." This definition indicates that with adequate foresight most of our accidents are preventable.

1-2. Only two percent of all accidents are caused by natural phenomena such as lightning, snowstorms, etc., and ten percent by physical hazard of falling down stairs, drowning, etc. The remaining 88 percent is caused by careless persons who, for example, leave a rake on the ground with tines turned up or who drop a banana peel on the sidewalk.

1-3. Poor housekeeping, horseplay, and improper or careless methods are the major causes of accidents on the job. Not keeping a work area clean and orderly can result in various types of accidents of major and minor importance. Broken bones, cuts, gouges, bruises, burns, and many other injuries can result from poor housekeeping.

2. Prevention

2-1. Some of the important items to consider in keeping your working and living areas in proper order are as follows:

- Keep all floors and walkways clean, dry, and free from spilled oil, fuel or other contaminants. If fuel, oil, or grease is spilled, clean it up immediately. Failure to do this may result in a serious injury to you or someone else.
- Insure that your area is properly ventilated at all times. Vapors from fuels, oils, gases, and various types of acids are injurious to your health.
- Keep all working areas well lighted. You cannot work efficiently and safely without sufficient lighting. Check the lighting system frequently and report or replace burned out lamps and fuses. Perform preventive maintenance as required.
- Don't leave tools scattered about on floors, workstands, or any other place than those cabinets and boxes especially provided for tools.
- Don't clutter your work area with unnecessary equipment. If you don't intend to use an item, store it in a safe place.
- Keep all ropes, chains, cables, hoses, and electrical extension cords properly stored when not in use.
- Provide waste containers, and insure that waste is promptly put into the right container.
- Use extra care in disposing of scrap metal, tubing, wire, glass, etc. Insure that all parts of the materials are well inside the waste containers. The sharp edges of these materials will cut and tear your skin as well as your clothes.
- Maintain adequate inspection of all electrical cables and equipment for frayed wiring insulation, exposed contacts, and the condition of switches handles and other controls.

2-2. Most any type of horseplay can result in sudden and serious injury. Some of the common varieties of horseplay are pushing, tripping, directing compressed air toward a fellow worker, using an electric shock, applying a "hotfoot" and, perhaps the most dangerous of all, "goosing." If this is applied to a nervous person, he might leap into moving machinery or into contact with high-voltage electricity. To cause injury by this sort of play is simply a crime committed by persons who will not take the trouble to think.

2-3. Safety manuals recommend that objects weighing more than 50 pounds should not be lifted by only one person. In doing heating work, it is often necessary to move material which may weigh more than 50 pounds. Be guided by the following advice when you handle materials.

- Avoid insecure positions or those in which your back is bent or twisted. Keep the feet apart in order to have a solid foundation, and squat over the object being lifted or lowered, keeping the back as upright as possible.

- Use the arm and leg muscles and not the back muscles for lifting and lowering. If there is any doubt about your ability to lift and lower a load without strain, then be sure to get help.

- If more than one person is handling an object, the weight should be equally distributed, and the lifting or setting down should be done in unison so that no individual will be overloaded.

- At all times it is important to be aware of safety violations and unsafe conditions. These should be corrected promptly or reported to your supervisor if corrections or repairs may require special tools or trained personnel. Do not use unsafe equipment or work in a dangerous area on the presumption that "nothing will happen this time."

3. Fires

3-1. Although firefighting is the prime responsibility of the post fire department, it is your duty to help prevent fires during your work with heating tools and equipment, and to aid in extinguishing any fire that might start. Good housekeeping is essential in the effective prevention of fires. Accumulations of rubbish, waste, dust, and other residue are all sources of fires. An important precaution in fire prevention is to keep oily rags and waste in covered metal containers.

3-2. Another serious fire hazard is the accumulation of fuel and paint vapors, gases, and other hazards in this category. To eliminate them, keep your area clean and well ventilated.

3-3. Fires are grouped into three general classes. Fires in each class can be extinguished by the use of a particular action or extinguishing agent. Because all fire extinguishing agents cannot be used on all types of fires, it is necessary to know the various classes of fires, as follows:

- Class A fires are those occurring in wood, clothing, paper, rags, and similar materials. This type can be handled usually with water. Water provides the cooling and quenching effect necessary to extinguish Class A fires.

- Class B fires are those occurring in flammable liquids such as gasoline, fuel oil, lube oil, greases, some solvents, paints, etc. The agents required for extinguishing this type of fire are those which will dilute or eliminate the air feed by blanketing the surface of the fire. This action creates the needed smothering effect.

- Class C fires are those in electrical equipment and facilities. The extinguishing agent for this type of fire must be a nonconductor of electricity and must also provide a smothering effect.

3-4. In the case of any fire, there are certain actions required of the individual who discovers the fire. His first action should be to sound the alarm and to alert all personnel. Second, the installation fire department must be summoned and must be given explicit directions to the location of the fire. These first two actions must be taken quickly and, after they have been done, the personnel available should apply the most effective measures possible to extinguish or contain the fire. To be able to do this it is essential that you acquire a knowledge of the various types of portable fire extinguishers.

4. Fire Extinguishers

4-1. The pump-tank portable extinguisher is perhaps the simplest. It is merely a water tank with an attached pump. The effective range of this device is only a few feet, and it should be used only on Class A fires. To use this extinguisher, simply unhook the hose, direct it at the fire, and start pumping. If you use all the water, refill the tank from the nearest available source and continue its use.

4-2. Figure 1 illustrates the five portable fire extinguishers, described below.

- Soda-acid is a type used only on Class A fires. The use of this extinguisher is very simple. Just direct the hose toward the base of the fire and invert the extinguisher. This inversion causes a mixing of the solution inside the tank, a reaction occurs, and the solution is supplied through the hose under pressure.

- The foam type may be used either on Class A or Class B fires. The method of using this extinguisher is the same for the soda-acid type. Invert it and direct the hose so that the foam is played over the surface of the fire. This is for fire involving liquids. For a fire in a solid material the stream of foam should be directed to fall lightly on or flow over the burning surface of the material.

- The carbon-dioxide, or CO_2, type may be used on Class B and on Class C fires. To operate the CO_2 extinguisher, pull the seal locking pin and open the operating valve. The CO_2 should be directed toward the base of the fire with a sweeping motion.

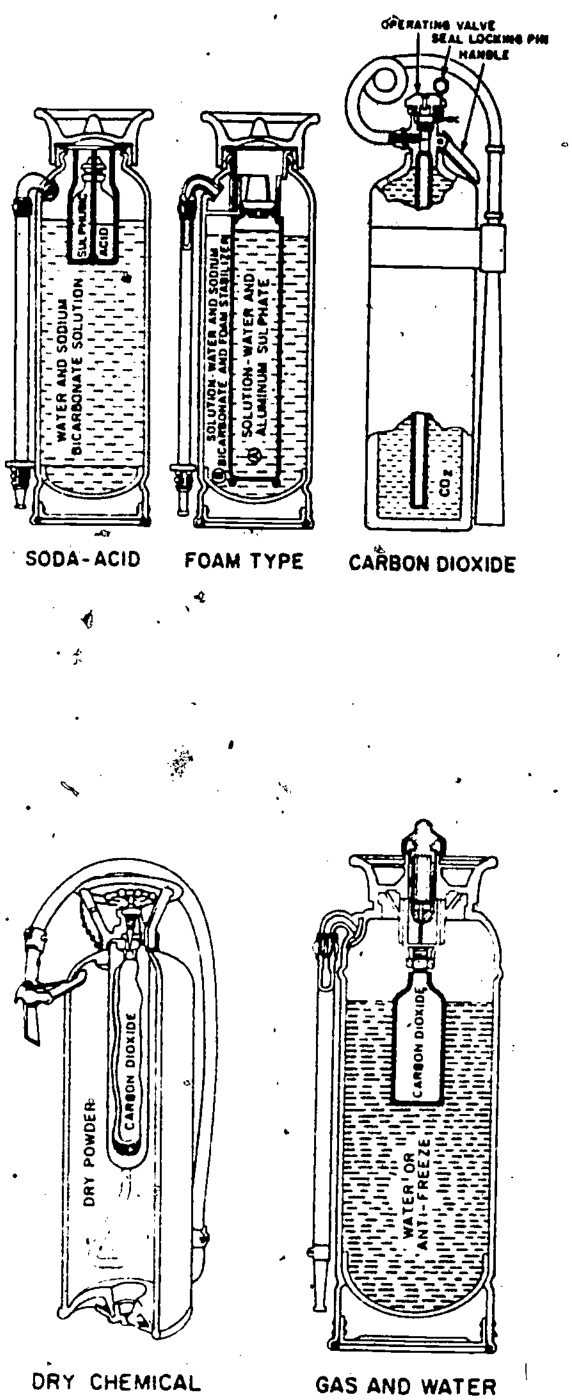

Figure 1. Portable fire extinguishers.

- The dry chemical type may be used on Class B and Class C fires. These extinguishers contain a dry powder, usually sodium bicarbonate, and an activating agent of CO_2 or nitrogen gas. This type should not be used on trash fires. To put the extinguisher to use, remove the locking pin, open the cartridge valve, and squeeze the nozzle handle.

- The gas and water type is operated like the extinguishers listed above. This is for use only on Class A fires.

5. Burns and Shock

5-1. *Burns.* Severe burns are more likely to cause shock than other types of wounds, so be sure to treat shock whenever a person has been severely burned. Infection is another great danger. To get clothing away from the burn, cut or tear the clothes and lift them off gently. Do not roughly pull the clothing from the wound and do not try to remove pieces of cloth that actually stick to the burned area.

5-2. If large sterile dressings are available, the burned surface may be covered, but in the case of severe burns it is best to leave the burn exposed. Never break the blisters or touch the burn.

5-3. The victim should drink a lot of water because of the loss of body fluids. If possible, add salt to the water. Three or four quarts of water should be consumed by the burned victim every 24 hours. Summon medical personnel at the earliest possible moment.

5-4. *Shock.* Treat an accident victim for shock whether or not he shows symptoms of shock. The following may characterize a person suffering from shock:

- He may tremble and appear nervous.
- His pulse may become rapid and weak.
- He may become excessively thirsty.
- He may become pale and wet with sweat.
- He may gasp for air and may even faint.
- He may vomit or complain of nausea.

5-5. Make the patient comfortable. Remove any bulky items that the patient has been carrying. Loosen his belt and clothes. Do not move him more than is absolutely necessary. If he is lying in an abnormal position, make sure that no bones are broken before you attempt to straighten him out. If there is no head wound, lower his head and shoulders or, if possible, raise his legs to increase the flow of blood to the brain.

Use a blanket, coat, etc. to keep him from becoming chilled. Put something under him as protection from the cold ground. If he is unconscious, place him face down with his head turned to one side. This position helps to prevent choking should he vomit. Once you have the patient in the proper position, don't move him, because to do so might make his blood pressure drop.

5-6. If the patient remains conscious, replace body fluid by giving him coffee, cocoa, or tea to drink. Do not give fluids to a patient who is unconscious or to one with a stomach wound. In some cases, it may be advisable to apply breathing oxygen if available.

Blueprints and Specifications

THE FIRST THING most of us do when we plan a trip by automobile is to obtain a map of the roads of the area in which we are to travel. A pleasant and successful trip is usually assured when we know our final destination and the best route to it. Similarly, the heating specialist must have some type of layout, some accurate diagram, to follow if he is to be successful in his job of installing, operating, and maintaining heating installations. Layouts are translated into permanent directives.

6. Blueprints

6-1. A diagram which will serve as a chart to show the heating specialist how to do the best possible job is called a blueprint. If he does not already have the skill to interpret the information such a chart presents, the apprentice heating specialist must straightway acquire it. The purpose of the information presented in this and the following sectons of this chapter is to help you to learn and perfect the skill of blueprint reading.

6-2. *How blueprints are made.* Blueprints are exact copies of mechanical drawings, which are generally drawn accurately to scale. Blueprints, or just *prints* as they are often called, are made from drawings in much the same way that photographs are made from negatives.

6-3. The negative for the blueprint is known as a tracing. It is made by placing a sheet of special translucent tracing paper or cloth over the drawing. Every line, symbol, and item of information on the drawing is then traced on the tracing paper or cloth with black waterproof ink or a special black pencil. After the tracing is completed, it is checked and the original drawing is filed for future use. Some drawings are made directly on the tracing material in pencil; then they are traced with the ink or with a special black pencil. This shortcut saves time and material, and the product is satisfactory for most jobs.

6-4. Now, the tracing is placed on the sheet of clear glass, mounted in a special frame, and covered with a sheet of sensitized light green blueprint paper. The padded back of the frame is secured behind the blueprint paper to keep the two sheets together. The front of the frame is then exposed to a strong light, which penetrates the tracing except where the lines are drawn and causes chemical action to take place in the coating on the print paper. There is no chemical action under the lines of the tracing because the black lines block off the light.

6-5. After the proper exposure, the print is removed and washed in clear water to remove the unexposed chemical. The exposed portions of the print paper turn a deep blue during the washing; of course, the lines are white. Sometimes the print is first washed in a weak solution of bichromate of potash to intensify the blue color. If this solution is used, the print must again be washed in clear water.

6-6. Any number of prints can be made from one tracing, if it is handled carefully. When large numbers of prints are required, they are made in a special blueprint machine, but the same principle is involved.

6-7. *Color of blueprints.* "Blueprints" are not always blue. All kinds of reproduced drawings are commonly referred to as blueprints or just prints. They can be white, brown, black, gray, or other colors. The differences lie in the kinds of sensitive papers used in the development processes used.

6-8. You should be able to recognize other prints, because you may be working with some of them. Black and white prints have black lines on a white background. Ammonia prints have black, maroon, purple, or blue lines on a white background. Van Dykes have white lines on a dark brown background, and negative photostats have white lines on a dark gray background.

6-9. *Handling blueprints.* Blueprints are not just scraps of paper. They are valuable permanent records that can be used again and again if you take care of them. There are a few simple rules for getting the best results from them. The prints must be kept out of the strong sunlight; otherwise they will fade. They must not be allowed to get wet or grease-smudged, and pencil or crayon notations must not be made without the proper authority. When instructions to mark a blueprint are given, a yellow pencil is used. Ordinary (black lead) pencil marks are hard to see on a colored background. Distances should not be measured on a blueprint! If you cannot find a dimension on one view, look at another view. If you still cannot find it, ask someone who knows. Why not measure? The original mechanical drawings might not have been drawn absolutely to scale. Perhaps the print paper has shrunk or stretched. You cannot take chances! You should take care of a blueprint just as you would the picture of your wife or girl friend so that the prints will be in good condition and ready to look at the next time.

7. Blueprint Views

7-1. A blueprint is a guide for the heating specialist. It is the copy of a drawing including dimensions of the structure or equipment. It contains most of the information needed by the heating specialist to install a heating system. A blueprint is usually made up of three views: the top view, the front view, and the side or end view. These views are made up of lines and symbols which are visible when the structure is viewed from these particular positions, as shown in figure 2.

7-2. For example, in figure 2, the front detail (A) illustrates how an object would appear to an observer who views it from the front. The side detail (B) shows how the object appears when viewed from the side; the top detail (C) shows how it would look from the top. When all of these views are placed on a single sheet, they are laid out as shown in figure 3. The front and side views are called elevations; the top view is the plan view, or architectural drawing.

7-3. *Elevations.* Elevations are merely pictures of an object, as viewed from positions directly in front of each of the four sides. Figure 4 shows an elevation plan of the four sides of a cottage. This blueprint gives us a general idea of what the structure looks like. Such elevations are relatively simple and are almost self-explanatory even to one who knows very little about blueprints. The heating specialist uses elevations to clarify other views. Each elevation gives additional information, such as the type of roof, kind of siding, and the dimensions. Figure 5 is a front elevation plan of a small cottage. Note the information and dimensions on the elevation plan.

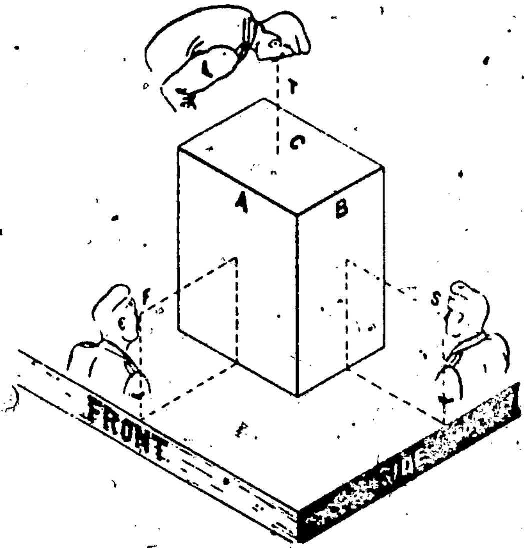

Figure 2. Three views of an object.

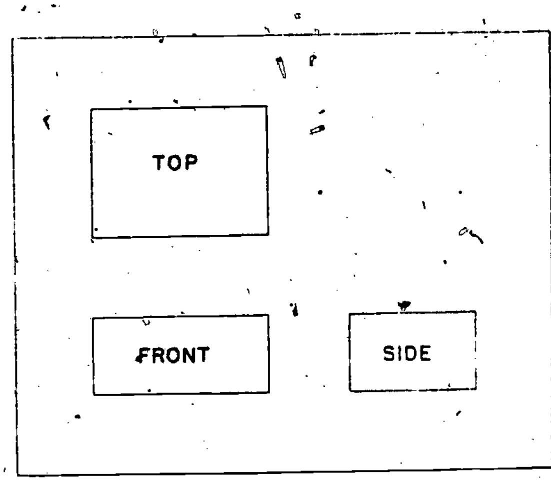

Figure 3. Three views of an object placed on one sheet.

7-4. *Plan view.* Plan views, or architectural blueprints, show the interior arrangement of a building. These blueprints are made looking down on the building from a point directly above.

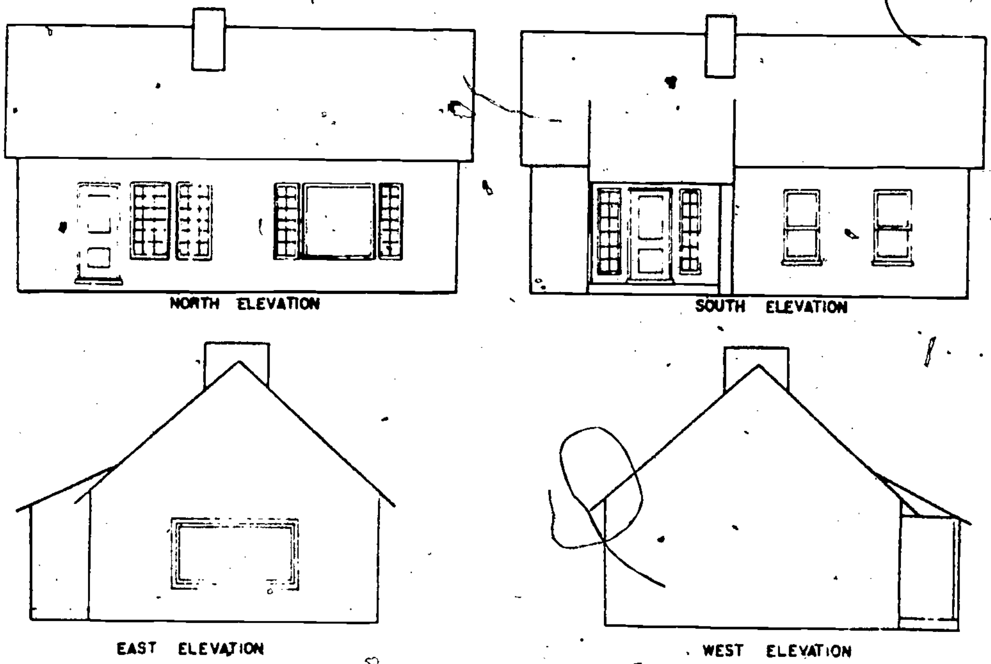

Figure 4. Elevation plan of a cottage.

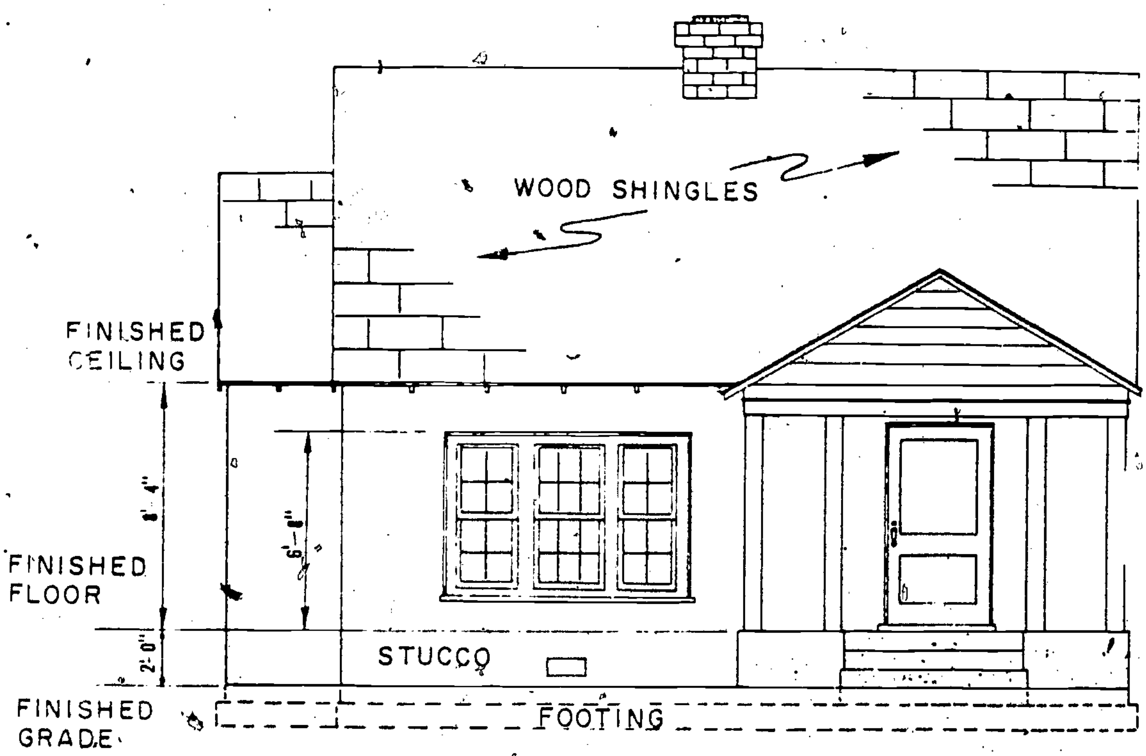

Figure 5. Front elevation of a cottage.

7

Horizontal surfaces, such as floors, appear without distortion. All vertical surfaces, such as walls, appear as lines. A plan view of the same cottage is shown in figure 6.

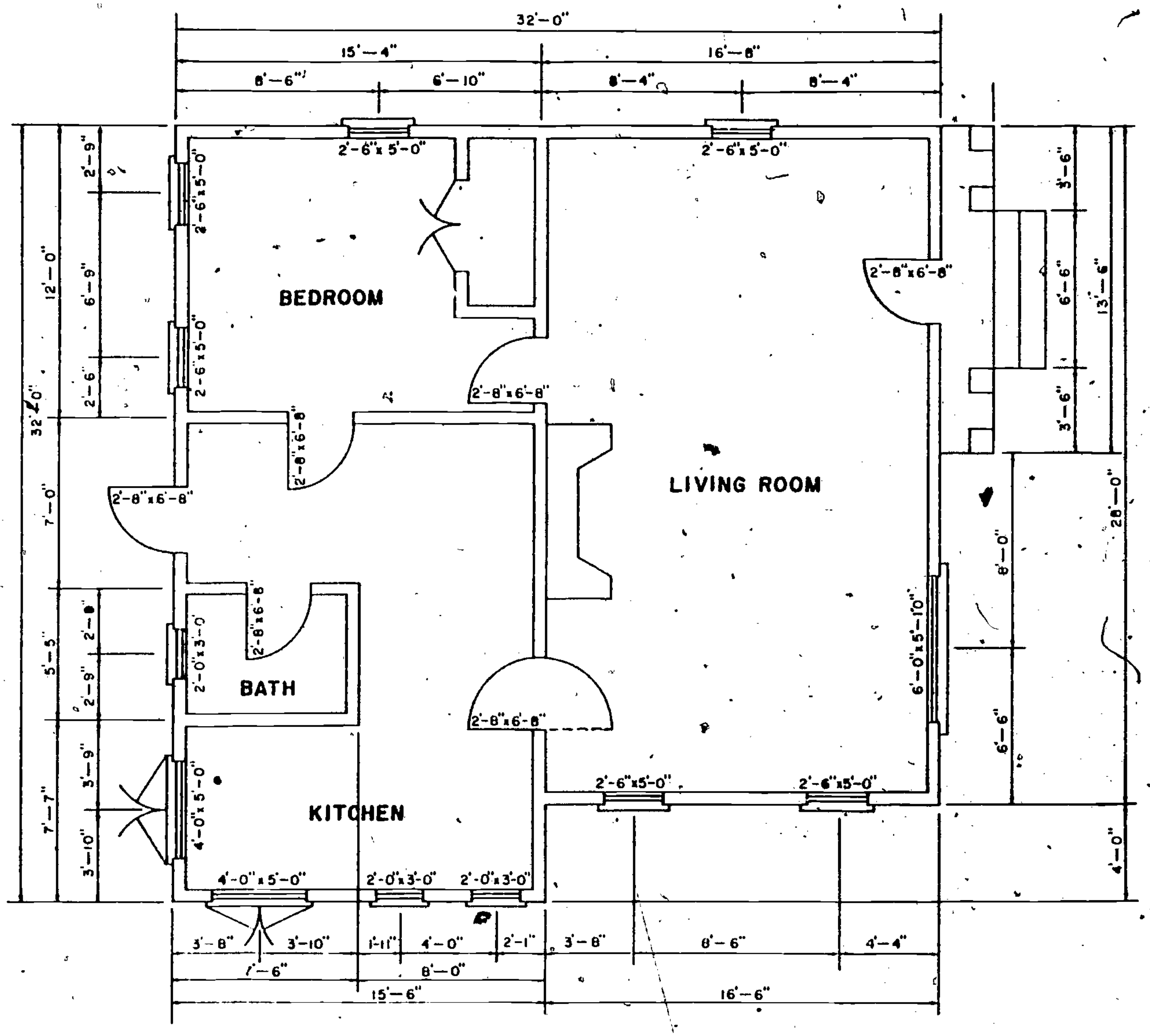

Figure 6. Plan view of a cottage.

7-5. Plan views usually show the outside shape of a building, the arrangements of the rooms, and the sizes and the shapes of rooms. They often give the types of materials to be used; the thicknesses of walls and partitions; and the types, sizes, and locations of doors and windows. They provide details of framework and structure; and they show the type, size, and location of mechanical equipment, such as heating plants, radiators, plumbing, electrical fixtures, and appliances. Also included are the instructions concerning the construction and the installation work. The plan view that is illustrated in figure 6 is quite easy to read and understand once you know what each line and symbol means.

7-6. *Blueprint details.* The lettering in figure 6 shows you that the cottage has a bedroom, living room, porch, etc. But what about the lines and symbols? To help interpret the meaning of these, the following paragraphs are devoted to a discussion of the various lines, symbols, and figures found on blueprints.

7-7. Full lines represent the visible edges on the outlines of an object, as shown in figure 7.

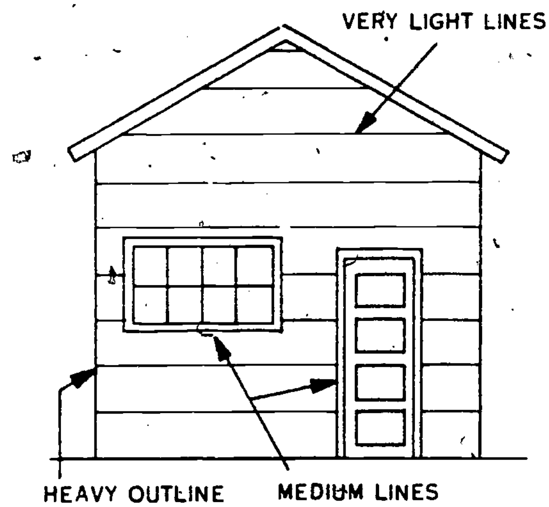

Figure 7. Illustration of full lines.

7-8. Hidden outlines are made of short dashes about ⅛-inch long and represent hidden edges of an object, as shown in figure 8.

7-9. Center lines are made with alternate short and long dashes. A line projected through the center of an object is called a center line, as shown in figure 9.

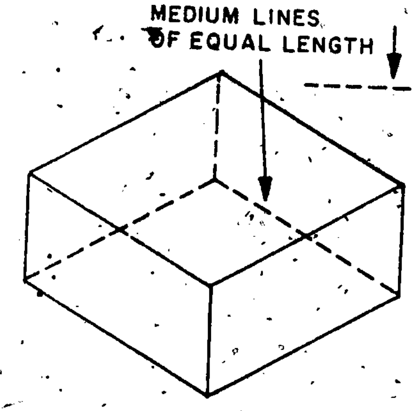

Figure 8. Illustration of hidden lines.

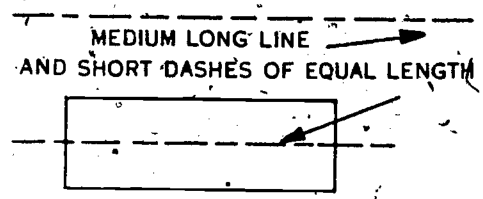

Figure 9. Illustration of center lines.

7-10. Cutting-plane lines are solid lines, generally of the same width as the visible lines, through the area being cut. Short-wing lines at each end of the cutting-plane line project at 90° to that line and end in arrowheads which point in the direction of viewing. Figure 10 shows cutting-plane lines.

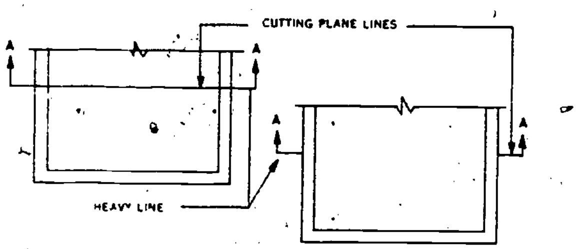

Figure 10. Illustration of cutting-plane lines.

7-11. Dimension lines are solid lines of fine width that end in the arrowheads used to indicate the measured distance between two points. On architectural drawings, the dimensions are shown in feet and inches. On engineering drawings, the dimensions are designated in feet, and in tenths and hundredths of a foot. Figure 11 shows dimension lines.

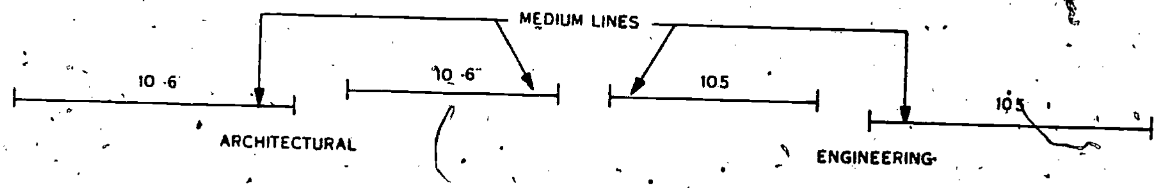

Figure 11. Illustration of dimension lines.

7-12. Extension lines are lines of fine width that are drawn from the outside edges or intermediate points of a drawn object. They indicate the limits of the dimension lines. Figure 12 shows an example of extension lines.

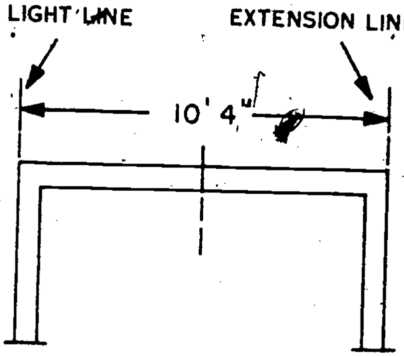

Figure 12. Illustration of extension lines.

7-13. Break lines are used to show a break in a drawing, as illustrated in figure 13. These lines are used when it is desired to increase the scale of a drawing of uniform cross section and at the same time show the true size by dimension lines.

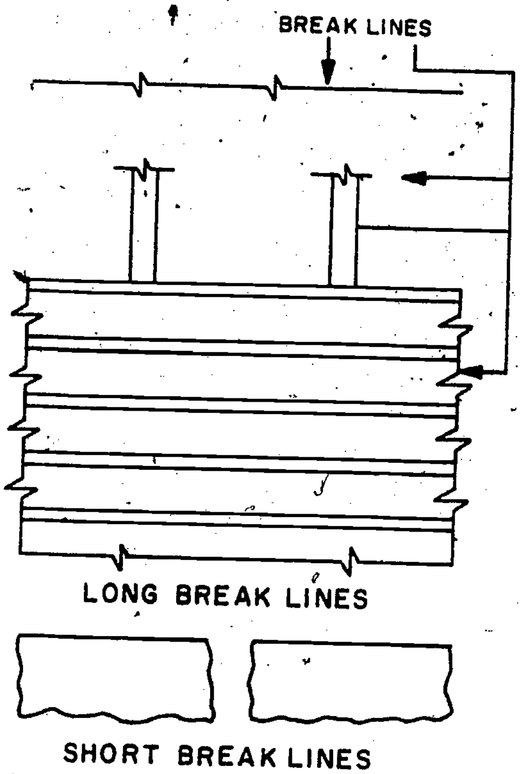

Figure 13. Illustration of break lines.

7-14. Short break lines are usually heavy, wavy lines cutting off the object outline across a uniform section. Long break lines are long dashes (parallel lines), each long dash in the line being connected to the next by a "Z" or sharp wavy line.

7-15. Leader lines are used to indicate all lines and items on a blueprint which need additional explanation. Leader lines, to which a note or dimension is attached, have arrowheads touching the edge of the surface of an object, as illustrated in figure 7. These lines cannot be mistaken for dimension lines, since leader lines are irregular lines or drawn at an angle.

7-16. *Sectional views.* Frequently, a view does not give a clear impression of an object. The difficulty lies with the invisible object lines, in which case a view into the interior of the object would help clarify the blueprint. Such a view is called a sectional view, and it is obtained by imagining that a portion of the exterior of the object has been removed to expose the internal construction. This type of section is determined by the amount of the exterior removed. A sectional view is obtained by imagining that the object is cut away, as if by sawing, and the path of the saw is considered to be the cutting plane, that is, the plane upon which the cut is made.

7-17. When an object has been cut away and one portion removed, the remaining portion is then crosshatched in the view. The term "crosshatching," or section-lining, is used to distinguish the surfaces of material theoretically cut and exposed by the cutting plane. Blueprints are crosshatched with the type of crosshatching (symbol) that represents the actual material from which the part or unit is made. Figure 14 is an illustration of a cross section in detail, as taken from an elevation plan.

7-18. *Sectional detail views.* Sectional detail views, with the aid of symbols, show in detail the construction, design, and materials used during

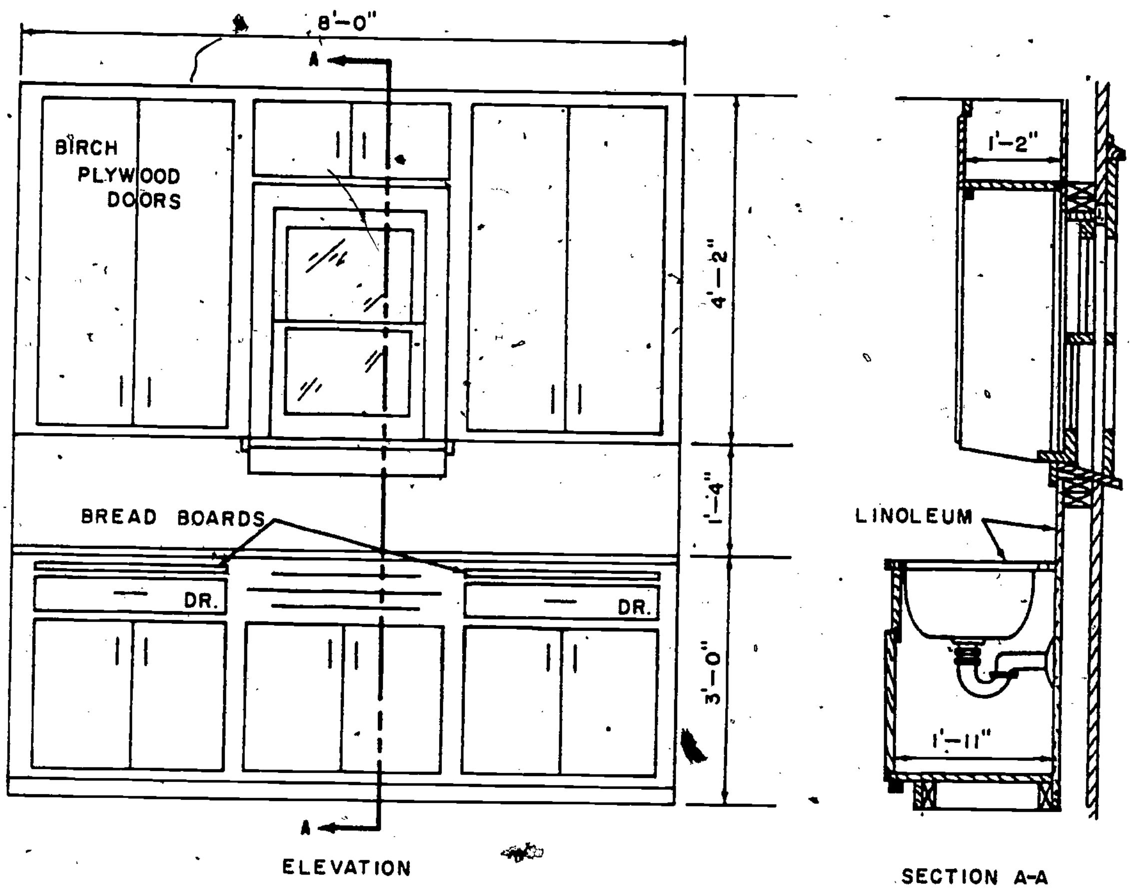

Figure 14. Elevation and cross section.

the fabrication of certain parts. Figure 15 shows the cross section of a foundation detail in larger scale than the original plan. This type of detail view and many others are commonly found on plan views. They help to determine the kind of construction and how it is to be installed. This type of drawing is one that will give the heating specialist much information which cannot be gained from just a plain view floor plan. There will be a detail sheet with most blueprints, or detail plans will be included on each blueprint sheet. If the plan has leader lines on it, it will probably have a note, "See Detail Sketch A, B, or C," etc.

8. Symbols, Scales, and Piping Diagram

8-1. To round out the information on the purpose, construction, and use of blueprints by the heating specialist, we have included in this section a discussion of symbols, scales, and a specific type of print, the piping diagram.

8-2. **Symbols.** Symbols used in blueprints are arbitrary or conventional signs, such as characters, letters, abbreviations, etc., used in place of pictured details. A few diagrams of sectional lining and outside view symbols used in blueprints are illustrated in figure 16 to show the types of materials. Common symbols used by the heating

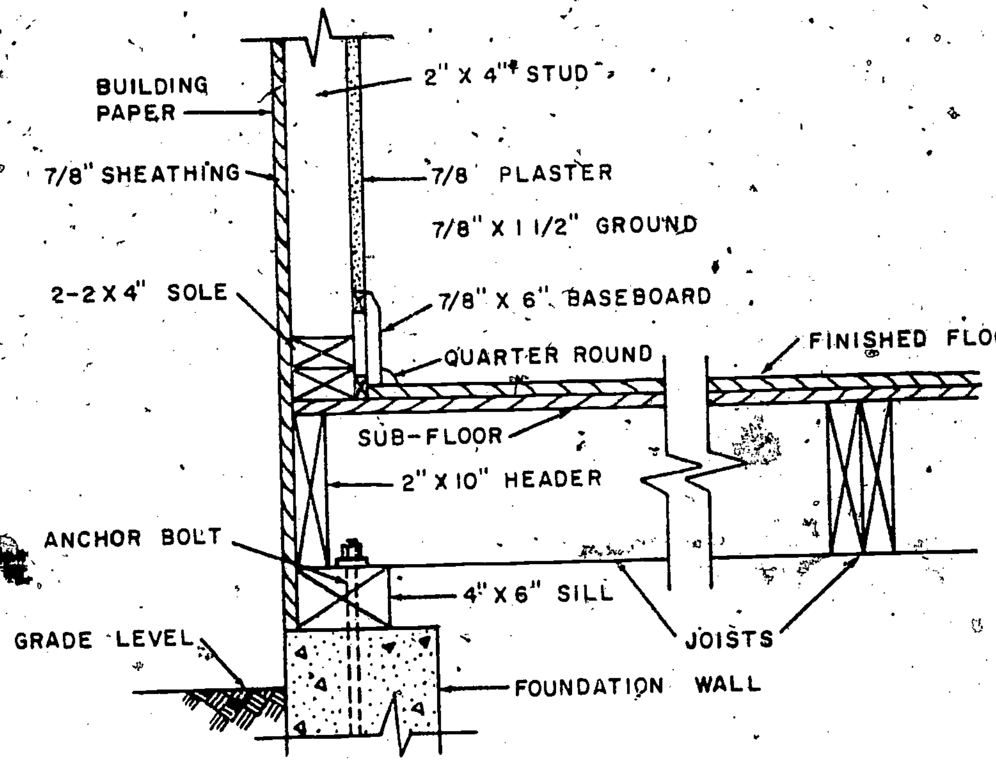

Figure 15. Foundation detail.

career field are reproduced in Appendixes A, B, and C. By referring to figure 16, you can easily tell that the foundation in figure 15 is concrete.

8-3. **Scales.** Objects are drawn full size when the details of the object are clearly shown and the size of the paper will conveniently permit. Enlarged views of sections are made when the actual size of the object is so small that full-sized representations would not clearly present the features of the object. Reduced scale prints are made of large objects that can be shown clearly in a smaller scale. The prime reason for reducing the scale of drawings is to reduce their size so that they can be placed on smaller sheets without crowding the views.

8-4. The scale of prints is generally noted in the title block and can be designated as "full size," "enlarged view," or at a reduced scale, such as 1" = 10', ¼" = 1', and others which are similar.

8-5. The process of measuring dimensions on a blueprint is called scaling. Important dimensions are normally shown on the blueprint and should not be scaled because of the possible distortion of the print on cloth or paper.

8-6. *Architect's scale.* Architect's scales are divided into proportional feet and inches. They are generally used in scaling blueprints for machine and structural work. The triangular architect's scale (see fig. 17) usually contains 11 scales, each subdivided differently. Six of the scales are read from the right end. Figure 17 shows how the 3/16-inch subdivision at one end of the scale is further subdivided into 12 equal parts, representing 1 inch; also the division of the 3/32-inch subdivision into 6 equal parts representing 2 inches each.

8-7. *Engineer's scale.* Engineer's scales are divided into decimal graduations (10, 20, 30, 40, 50, and 60 divisions to an inch). Figure 18 illustrates an engineer's scale. These scales are used for plotting, map drawing, and the graphic solution of problems.

8-8. *Metric scale.* Metric scales, shown in figure 19, and used in conjunction with drawings, maps, and the like, which are made in countries using

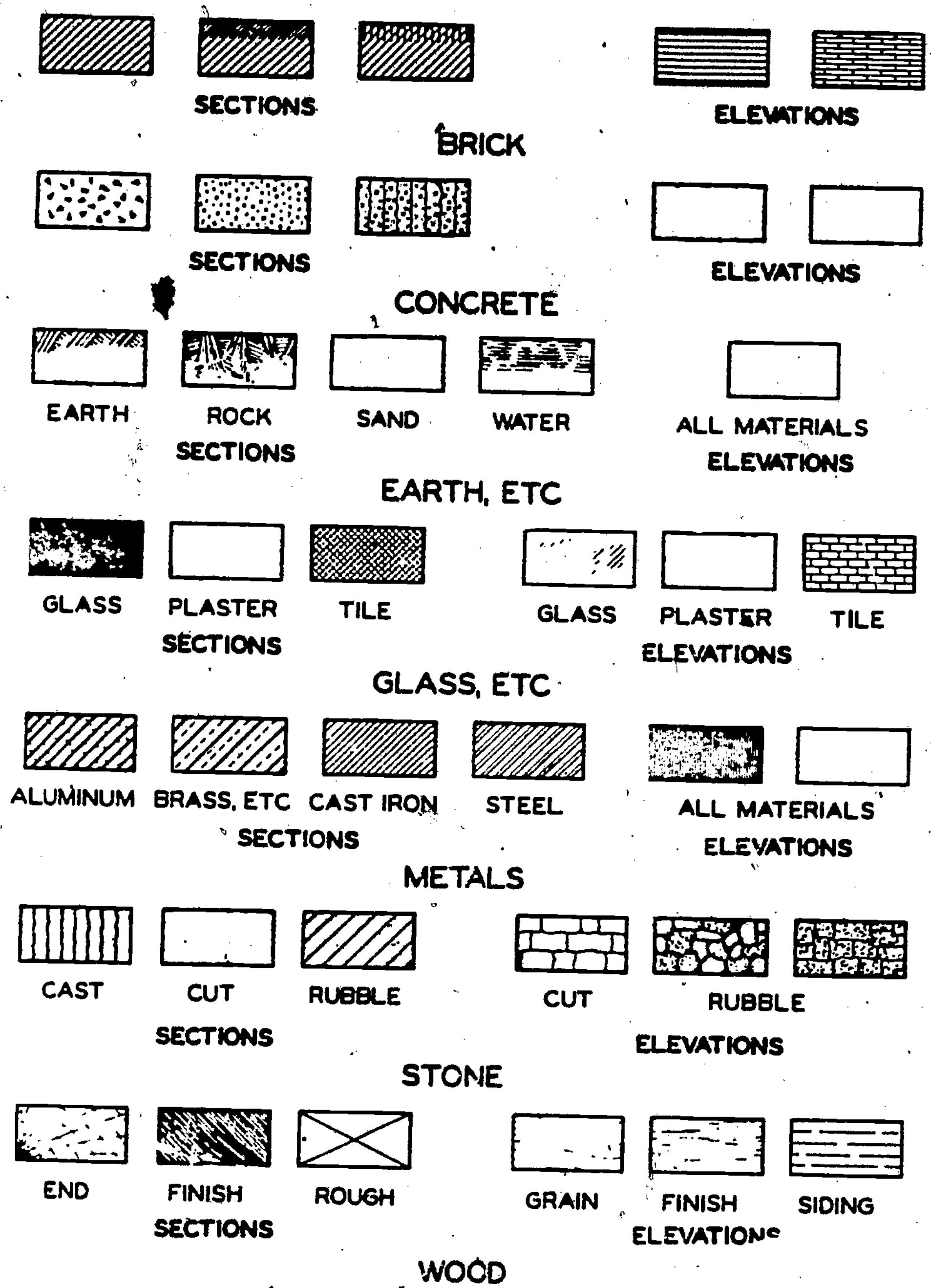

Figure 16. Symbols of materials.

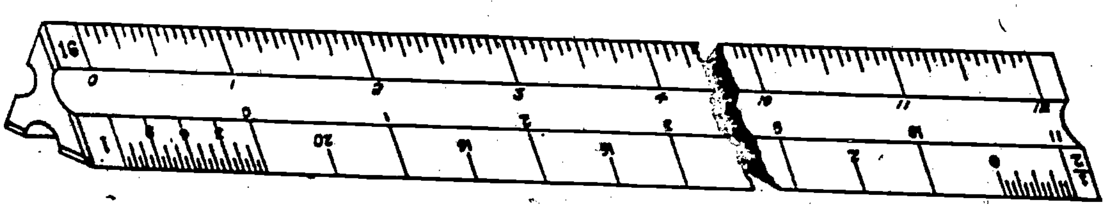

Figure 17. An architect's scale.

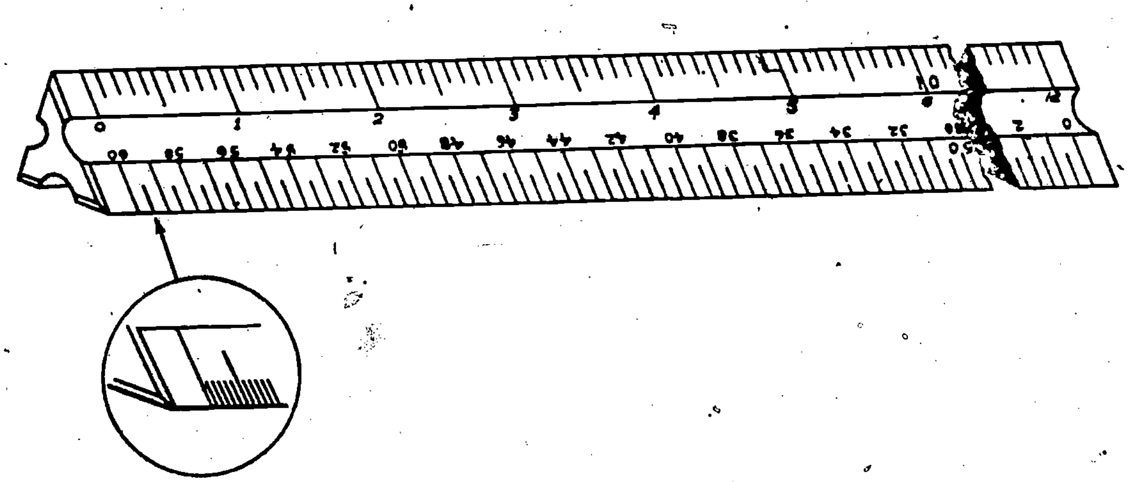

Figure 18. An engineer's scale.

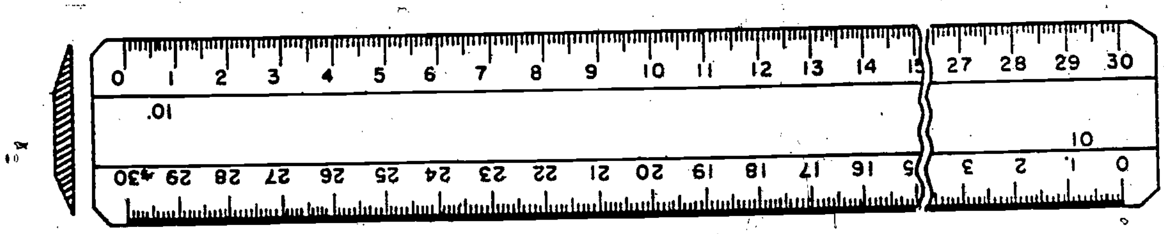

Figure 19. Metric scale.

the metric system. The metric system is also being used with increasing frequency in the United States. The scale is divided into millimeters and centimeters.

8-9. *Graphic scale.* Graphic scales, shown in figure 20, are lines divided into distances corre-

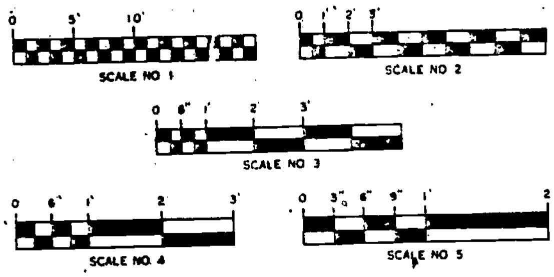

Figure 20. Graphic scales.

sponding to convenient units of length of the object represented by the print. They are placed in or near the title block of the print. Since these scales are a part of the print, increasing or decreasing the print will change the scale lengths accordingly.

8-10. *Methods of scaling.* When you are using the architect's or engineer's scale, the method of scaling is that of determining the scale of the print from the notations given, such as 1″ = 10′, ¼″ = 1′, 1″ = 20′, and the like. Then, you select the corresponding scale on the architect's or engineer's scale. While using the proper scale, measure the desired dimensions on the print. For example, if the scale of the print is 1″ = 100′, then a dimension that measures 20 divisions on the engineer's scale (10 divisions per inch) represents a distance of 200 feet.

8-11. When you are working with graphic scales, the method usually used is that of marking off the length of the dimension desired onto a slip of paper, placing the slip of paper on the graphic scale, and reading the distance of the dimension that was marked.

8-12. **Piping Diagrams.** There are two types of piping diagrams — the schematic, or flat, and the oblique, or pictorial. The schematic view shown in figure 21 is the most common. The oblique diagram shown in figure 22 is used only when the schematic drawing is not clear in itself. Notice that in figure 21 there is no way of showing the dirt pocket, unions on the various lines, or the bypass line in detail. However, in figure 22 these details are shown clearly.

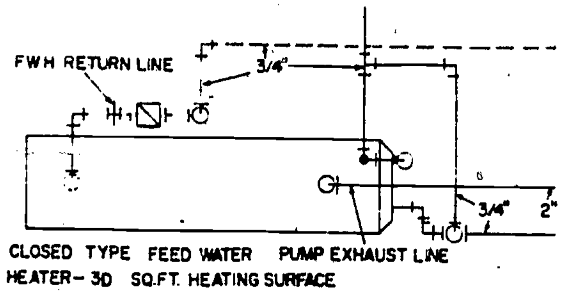

Figure 21. Schematic diagram of piping connections to a feed-water heater.

8-13. When either of these drawings is used by itself, the installation will be quite difficult to make. The installation is easily understood, however, by having both drawings from which to work.

9. Heating Plans, Specifications, and Bill of Materials

9-1. The heating specialist should make every effort to familiarize himself with all procedures required to complete a heating installation under all climatic conditions. Three documents should be in his hands before any type of heating equipment is installed or modified. These are the heating plans, the heating specifications and the bill of materials.

9-2. **Heating Plans.** After studying this chapter to this point, you should be able to easily interpret the heating plan of the hospital clinic and surgery unit shown in figure 23. This plan view shows the plan of the rooms, including the windows and doors, size of the building, location of the heating pipes, and location of the hot and cold water lines and sewer lines.

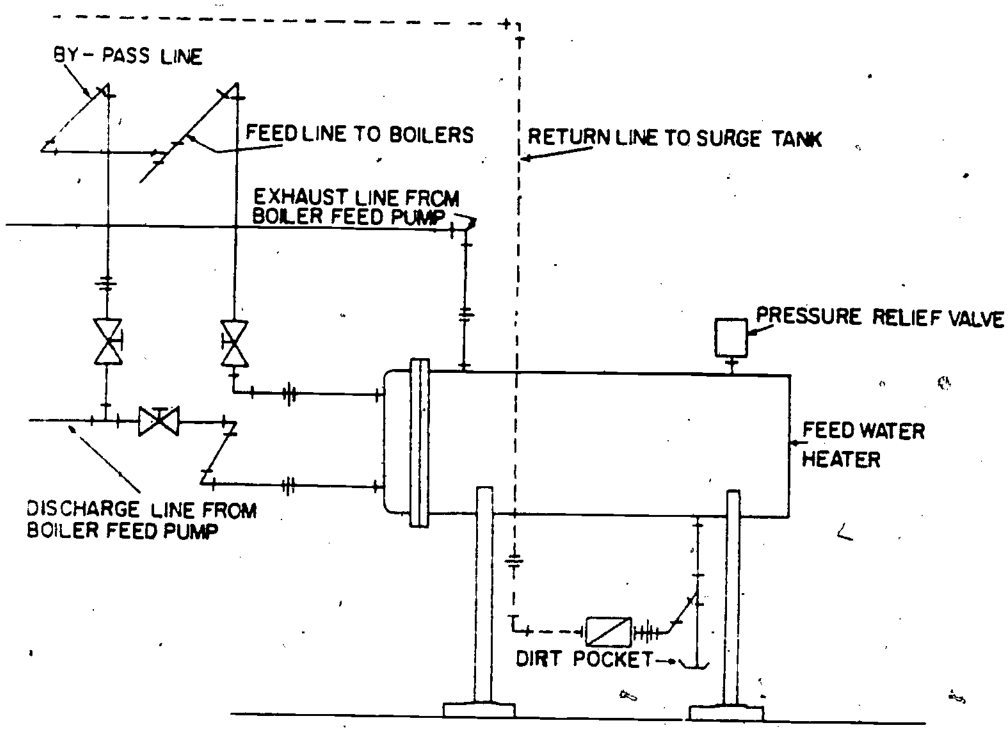

Figure 22. Oblique diagram of a piping connection to a feed-water heater.

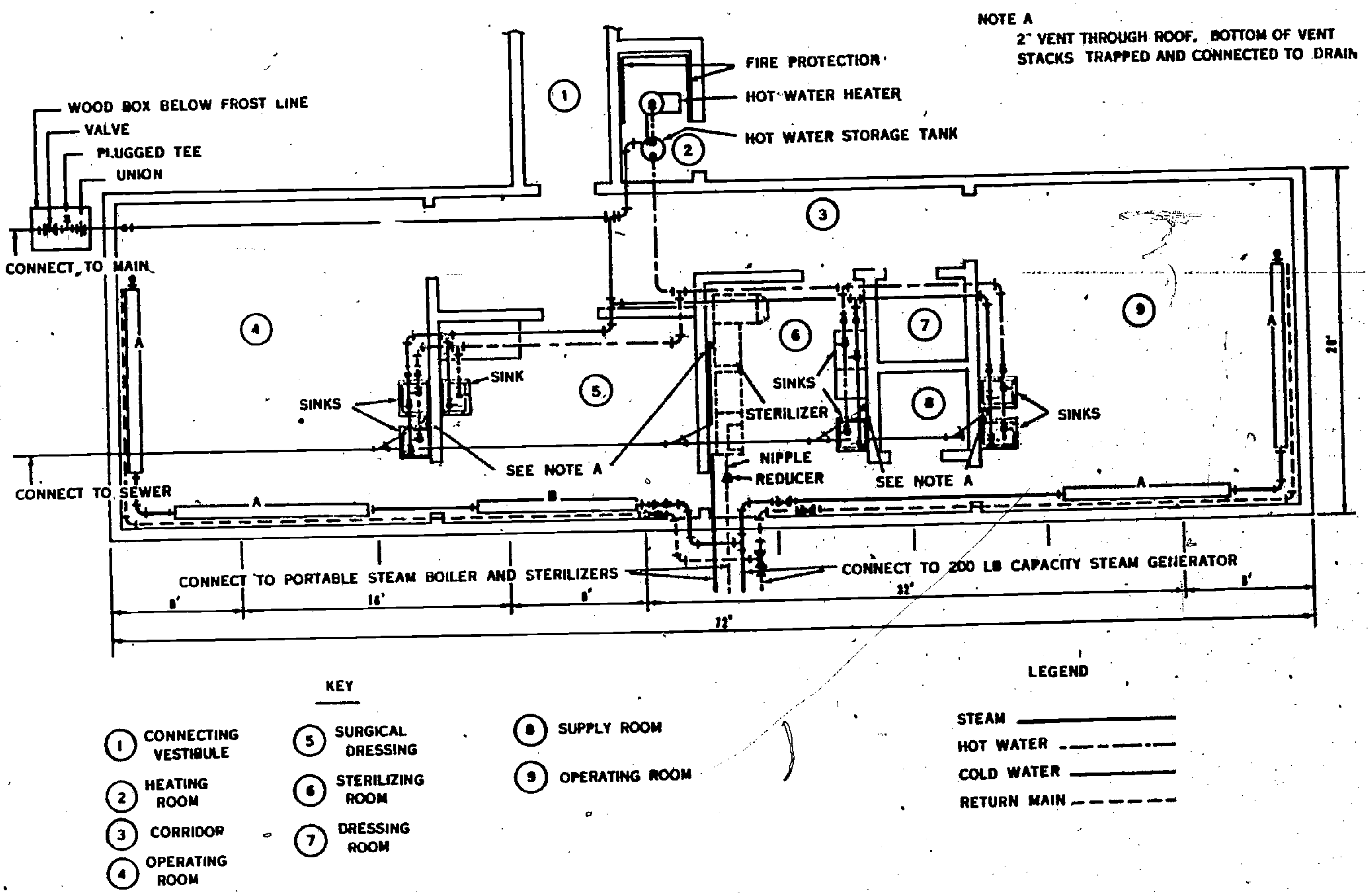

Figure 23. Heating plan of a hospital clinic and surgery unit.

9-3. A typical gravity warm-air heating system plan for a two-story dwelling is shown in figure 24. This heating system plan shows the location of the furnace, furnace flue and chimney, and the arrangement of the warm-air ducts in the basement of the dwelling. The warm-air ducts used to heat the second story pass through the walls of the first story. Only part of the cold-air ducts are shown in this plan.

9-4. **Specifications.** Specifications are details of construction or installation not shown on an architect's drawing. They contain all the information pertinent to the construction of a structure, including labor, types of building materials to be used, methods of construction, and the like.

9-5. **Bill of Materials.** A bill of materials is usually included with heating plans and specifications. The bill of materials is a list of all materials and equipment necessary to complete a heating installation or to modify an existing system. In addition to quantities, it must include the correct and complete nonmenclature, the stock number and the status and unit of issue. Such information is obtainable from applicable stock-lists.

9-6. The quantities listed in a bill of materials do not normally include overages for wastage, and damage. Overages for expendable materials are usually added to the quantities required when the bill of materials is filled.

Summary

IF YOU ARE TO DO accurate and competent work as a heating specialist, you must have special training to enable you to follow and comprehend the directions given for the completion of specific jobs — initial installations, repair, and troubleshooting, for example. The directives that you will use most are three in number: heating plans (blueprints), specifications not shown on the architect's drawings, and a bill of materials.

As a heating specialist you must know, first of all, how to interpret the information shown on the blueprints — in other words, how to read a blueprint. In addition, you should know how "prints" are made; the meaning of the symbols drawn into them (types of lines, for example); the use of the elevation, the plan view, and the sectional view; the types of scales used in architect's drawings from which blueprints are made; and that blueprints cannot be used for making accurate measurements, even though the scale of the original drawing is given.

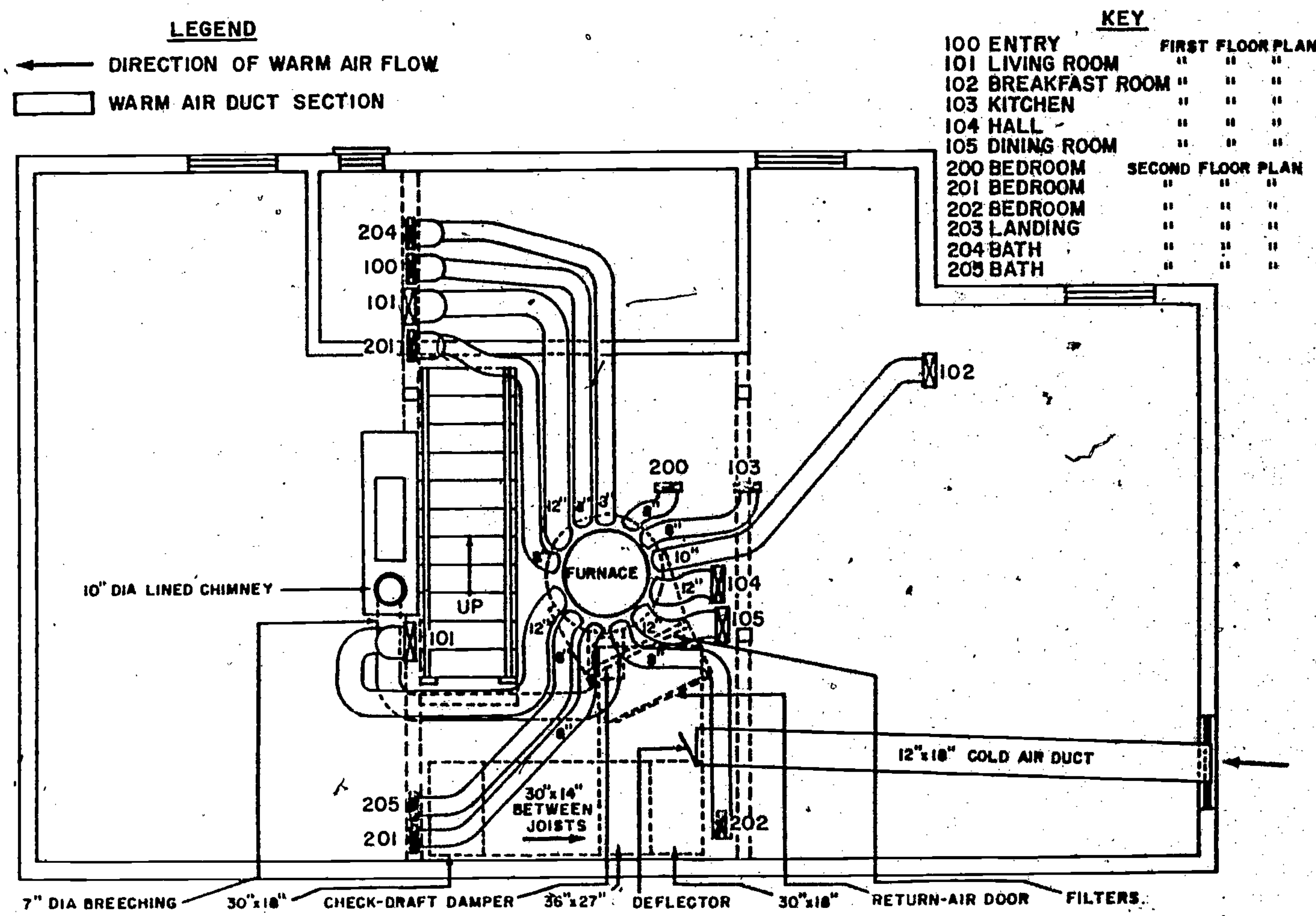

Figure 24. A typical gravity warm-air heating system plan.

Tools and Piping

TOOLS ARE THE mechanic's best friend, and without them he is helpless. In this age of machinery there are many jobs still being done in the military with handtools. Regardless of the job to be done, the good mechanic must have, choose, and use the correct tools to do the work properly. Without them, and the knowledge of how to use them, the mechanic wastes time and cuts down his efficiency. Besides, without proper tools, he may injure himself.

Statistics show that handtools in use are responsible for a large portion of the accidental injuries to mechanics. The knowledge of the proper use of handtools will not prevent an accident, but if know-how is used, the accidents and injuries will be greatly reduced. This chapter includes the do's and don'ts of using and caring for common handtools.

10. Proper Care and Use of Common Handtools

10-1. Many of the jobs that the heating specialist does require the use of common handtools. He is required to remove, repair, and replace heating units and assemblies. This work requires the ability to use and care for the various tools. He also needs to know what pipe fittings to select and how to use them in accomplishing a good repair job. The tools discussed in the pages that follow, and your proper use of them, will make your job easier and more likely to pass inspection. The following are a few sensible tips on the care and use of tools:

- Place each tool in its proper place in the toolbox or rack. Then, perhaps, the next time you want the tool, you can find it without pulling a major inspection of the shop.
- Tools should be kept clean. Oil helps to prevent rust, but in excess amounts it makes for a messy toolbox, dirty clothing, and slippery hands. Slippery hands are an invitation for bruised knuckles.
- Toolboxes are designed to hold tools, not to be used to stand or sit on. It is an unsafe practice to place a toolbox on elevated stands, especially stepladders. Place toolboxes on the floor to prevent injuries to personnel.
- Handtools should not be carried in your pockets. The only place to carry tools is in the toolbox or properly constructed tool pouches. Tools carried in a workman's pocket may be the cause of puncturing equipment and even injuring the workman himself.

10-2. **Screwdrivers.** The screwdriver is one of the most common handtools, but because it is so common, everyone thinks he knows how to use it properly. It usually winds up by being the most abused tool used. Do you know that a screwdriver is meant only for driving and removing screws? It is not designed to be a chisel, punch, pry, nailpuller, or hammer. Jackknives, wire-cutting pliers, and chisels have fairly sharp cutting edges — screwdrivers should not have, the point should be squared.

10-3. The most common types of screwdrivers are the standard, offset, spiral ratchet, and Phillips, as shown in figure 25. The standard screwdriver is suitable for most ordinary work. The offset screwdriver makes work possible in tight corners where the standard tool will not enter properly. The spiral ratchet screwdriver is used to drive or remove small screws rapidly. The Phillips screwdriver is made with a specially shaped blade to fit Phillips type cross-slot screws. This type of screwdriver should not slip off the screw head when held at a slight inclination to the screw. The other screwdriver types should be held squarely and firmly against the screw and in the slot. Here are some common sense do's and don'ts about screwdrivers:

- Never use an oily or greasy screwdriver; dry it off before using it.
- Never use screwdrivers that have split or splintered handles, or chipped blades.

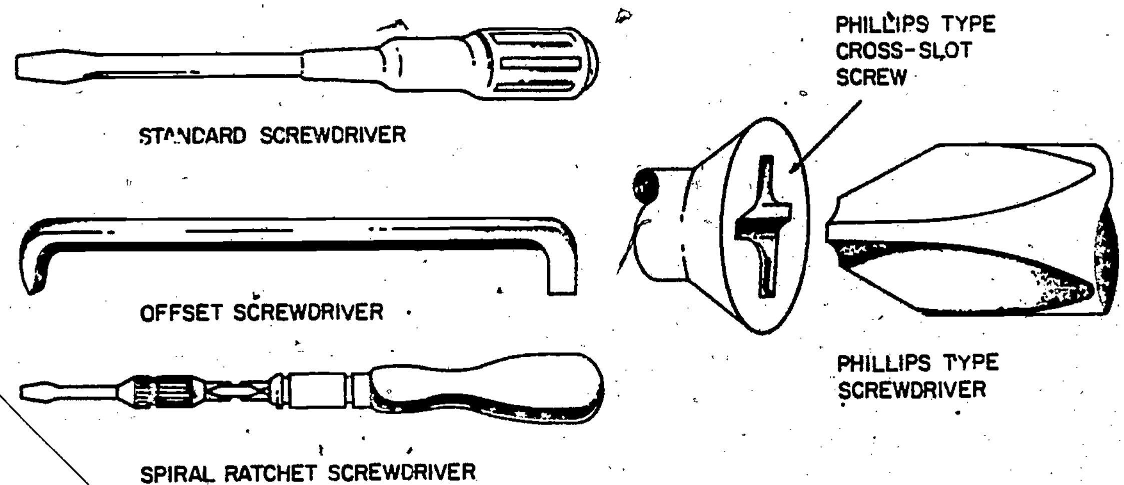

Figure 25. Types of screwdrivers.

• Never use a screwdriver as a chisel; it doesn't work very satisfactorily. It can be ruined for further use as a screwdriver.

• Never use a screwdriver as a pry — the blade generally bends or breaks.

• Since a screwdriver is not to be used as a chisel or pry, there is no reason to hit its handle with a hammer.

• The handle of a screwdriver should not be used as a hammer. The handle, being of softer material than a nail or bolt, winds up a poor second best.

• Always select the screwdriver that fits the slot. If it is too small, the blade might break or the slot edges become curled and chewed up. If the blade is too big, the screw head might break off or the screwdriver might slip out of the screw slot and multilate the slot. Figure 26 shows how the screwdriver should fit the screw slot.

• Be sure that the screw is not cross-threaded when you start it into the hole. Otherwise, it ruins the thread on the screw, and worse yet, it can ruin the internal threads in the hole.

• Never hold the object containing a screw in your hand while tightening or loosening the screw. One slip and you can be badly cut or stabbed. Instead, place the item in a vise or support it on a solid surface that will withstand the pressure of the screwdriver and the work.

10-4. **Wrenches.** Wrenches are tools used for tightening and removing nuts, bolt heads, and cap screws. They are also used for gripping

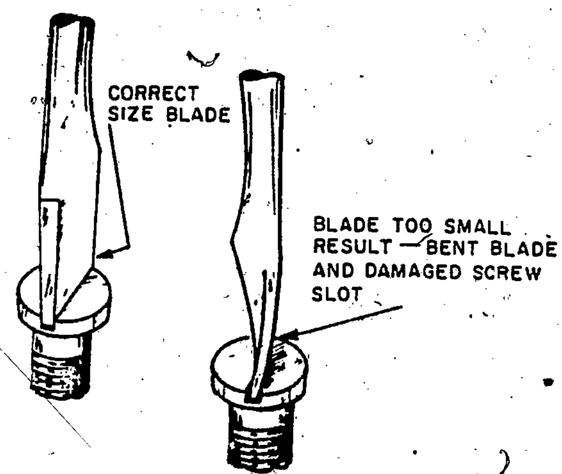

Figure 26. Correctly and incorrectly fitted screwdrivers.

round items, such as pipe, studs, and round rods. Wrenches are generally classified as adjustable jaw wrenches, socket wrenches, open-end wrenches, box-end wrenches, and pipe wrenches, and are shown in figure 27.

10-5. **Misuse of the wrench has caused many a skinned knuckle, mashed finger, strained back, and serious disabling fall.** The ways of preventing these injuries are so simple and easy to apply that it is a wonder so many occur. If the following are applied when using and handling wrenches, accidents can be greatly reduced or almost eliminated:

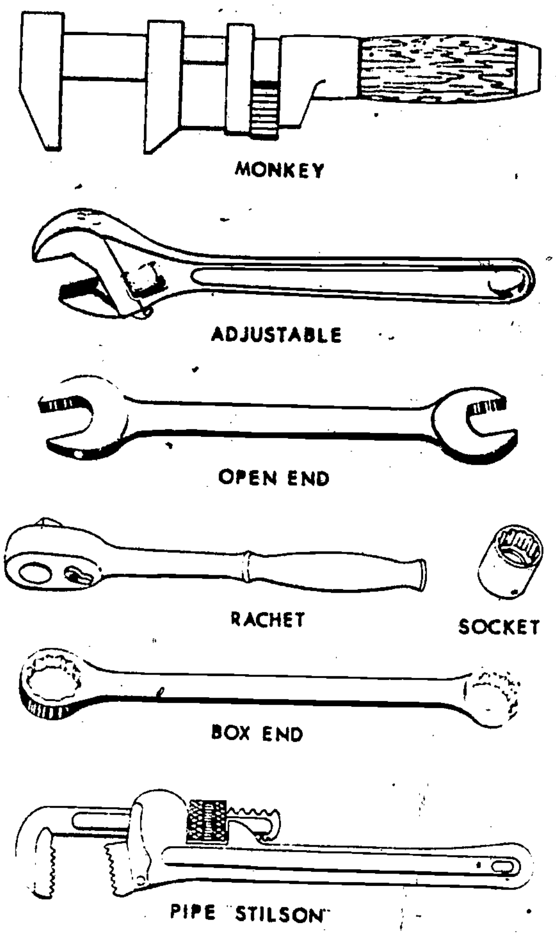

Figure 27. Types of wrenches.

• Use the proper type and size of wrench for the job. If the wrench is too large, the threads can be stripped or the corners of the nut can be broken off. If the wrench is too small, it will be strained or even broken.

• Use only wrenches that have jaws in good condition. Be sure that the wrench, the nut, and your hands are free from grease and oil.

• Never use a shim in trying to make a wrench that is too large to fit the nut. The wrench should fit the nut closely but not so tightly that it is hard to remove.

• Do not use a wrench as a hammer or crowbar.

• Always place the wrench on the nut in such a position that the pull on the handle tends to force the jaws farther onto the nut. The most effective angle for pulling is to have the arm positioned at right angles to the wrench handle and the center line of the bolt. This helps prevent the wrench from slipping off the nut. Stop pulling on the nut as soon as it is turned down tight; then use a torque wrench when a definite tightness is specified.

• Think twice before pushing on a wrench. There are ten chances to one you will find it safest to pull. If the wrench must be pushed, use the palm of the hand so that the knuckles will not be mashed in case something slips.

• See that your footing is good before you pull and acquire the habit of figuring out what is going to happen if the wrench slips, the bolt breaks, or the thread strips. Particular care should be taken when you are working on a ladder or any other elevated position.

• Never use a piece of pipe or another wrench to extend the handle of a wrench to gain leverage. Something is bound to give — but it might not be what you expect.

• Inspect all wrenches (and other tools) frequently. Do not use any that are cracked, chipped, or bent. Do not try to place wrenches (or other tools) in the toolbox from a distance of 20 feet.

10-6. Adjustable wrenches are made so that their jaws can be opened or closed to fit the flats of a nut or bolt head. The monkey wrench and the adjustable open-end wrench are also common types. The size of these wrenches is designated by their overall length.

10-7. Socket wrenches are frequently used where it is necessary to operate in close or hard-to-reach places. The sockets are supplied in sets to fit standard-size nuts and are readily fitted onto or removed from the handle. A ratchet handle is usually included in the set so that the nut can be completely tightened wthout removing the socket from the work. Another accessory for the socket wrench is the handle which measures the amount of pull you put on the wrench. This is called the torque wrench. On some makes of torque wrenches a pointer indicates on a scale the amount of force being applied. On others you set a dial for the amount of torque desired. Figure 28 shows both types of torque wrenches.

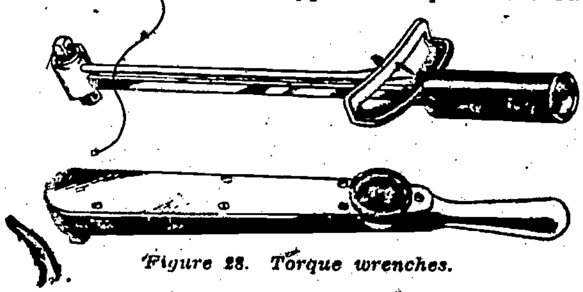

Figure 28. Torque wrenches.

Treat a torque wrench as a delicate piece of testing equipment; it cannot be treated like other handtools without losing its accuracy.

10-8. Box-end wrenches are used for general purpose work. These wrenches are well suited for operation in close quarters because their heads are small. They can be used on nuts which cannot be grasped with other types of wrenches. Most box-end wrenches have 12 points, and most nuts have six sides; therefore, as little as one-twelfth of a turn can be taken each time the wrench is shifted. The length of the wrench varies according to the size of the opening which is plainly stamped in the metal near each end.

10-9. Open-end wrenches fit standard-size nuts. They are lightweight, strong, and convenient for doing work in a limited space. Because the jaws are set at an angle, usually 15° or 90°, it is easy to increase the swing of the handle by turning the wrench over. Sets of midget open-end wrenches are available for electrical and instrument work. The length varies according to the size of the opening which is plainly stamped on the wrench.

10-10. Pipe wrenches are used for turning pipe, round rod, and smooth fittings which do not offer a gripping surface for other types of wrenches; however, the bite of the jaws mars the work. Pipe wrenches should not be used on nuts or bolts. The size of these wrenches is designated by their overall length.

10-11. **Hammers.** Hammers are handtools consisting of a head and a handle, and they are used for striking, driving, and pounding. The head consists of one or more faces that are used for striking. A striking face may be round, square, rectangular, concave, flat, convex, or combinations of these. The head is pierced by a hole called the eye which is often slightly oval-shaped and bell-mouthed at each end. This shape makes it easy for inserting and securing the handle. Some types of hammers are shown in figure 29. Hammers are generally classified as common hammers, soft hammers, and sledges. Since each hammer has its special uses, the mechanic should learn to select the right hammer for the particular work at hand.

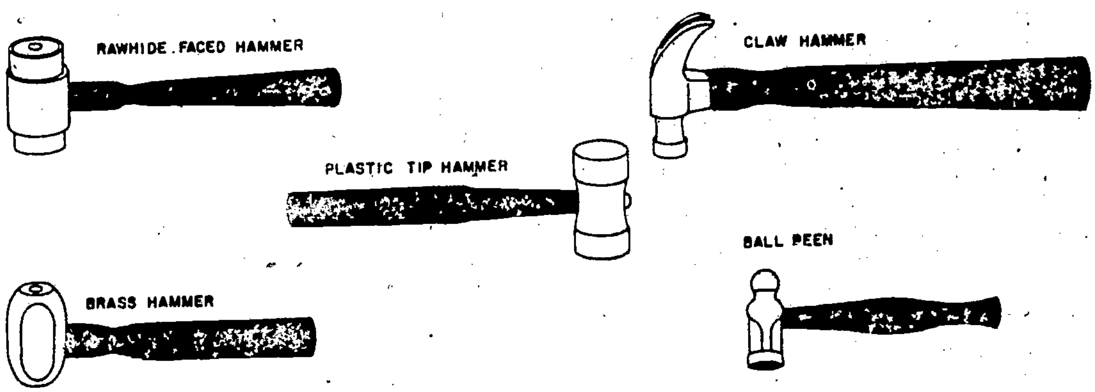

Figure 29. Types of hammers.

10-12. Common hammers have forged steel heads of various sizes and shapes. They vary in size from 4 ounces to 2½ pounds, and they are shaped and balanced to enable the operator to hit the mark squarely without difficulty. The handle, usually hickory, should be shaped to fit the hand comfortably and also to fit tightly into the eye. The ball-peen hammer and the claw hammer are the most common for the heating mechanic. The ball-peen hammer has one end ball-shaped for riveting and similar peening or drawing operations. The other end is cylindrical with a slightly convex face for striking or driving. The claw hammer has one cylindrical end for striking and driving. The other end has two tapered prongs or claws, the bases of which meet at a sharp angle. The claw end is used as a lever for pulling out nails and for similar tasks.

10-13. Soft hammers have faces or entire heads made of lead, copper, brass, babbitt, rawhide, rubber composition, wood, plastic, fiber, or the like. They are generally used for any operation in which a steel hammer might mar or damage the work. Soft hammers with short handles are usually called mallets.

10-14. Sledges are hammers weighing from 4 to 20 pounds with handles from 30 to 36 inches long. They should be used only on work requiring an exceptionally heavy blow. Probably the specialist would use a sledge more for work of a destructive than of a constructive nature.

10-15. Hammers, too, can be dangerous when improperly used. Fingers have been mashed and workers injured because the proper precautions were not taken. The hammer should be held near the end of the handle with its face parallel to the work. A grip tight enough to control the blow is best. Raise the arm straightway from the object to be struck and bring the hammer down with a quick, sharp motion. Do not hold the handle close to the hammer head and never use it as a pry or scraper. If you think that you are a hammer expert and that this advice does not apply to you, then you are in line for a set of bloody blisters, smashed fingers, and some unhappy moments. Many accidents with hammers are caused by loose hammer heads, oily or greasy handles, or sweaty hands. These conditions cause either the hammer or the loose head to leave the desired path of travel and take off on a new one. You can be reasonably certain that either one will hit a person or something else before it hits the floor. Another good way to get a painful bruise is to have grease or oil on the hammer face when the tool is used.

10-16. **Pliers and Nippers.** Pliers and nippers are tools used to hold, turn, cut, shape, or bend light materials by hand. Figure 30 shows the types of pliers that are most commonly used.

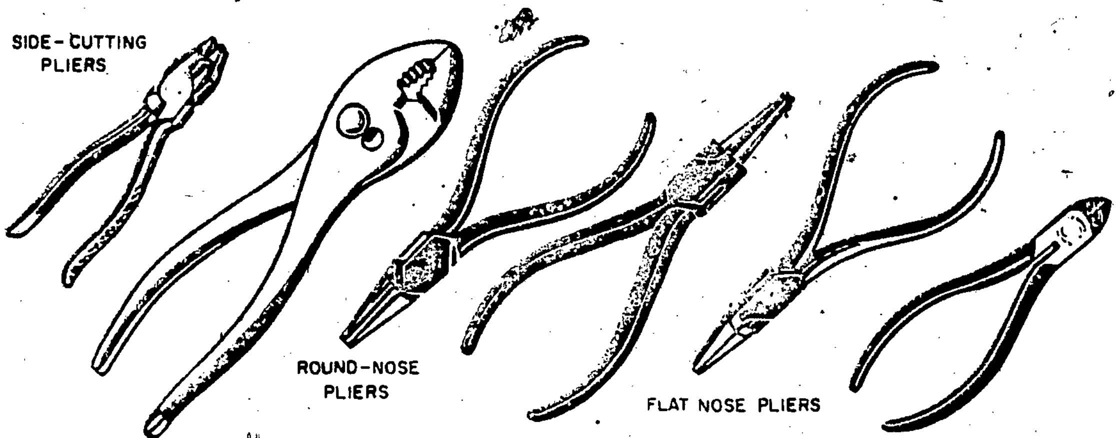

Figure 30. Common types of pliers.

10-17. Side-cutting pliers are used for holding and bending thin material and for cutting wire. Adjustable combination pliers are general purpose tools used for holding flat or round stock, and some types are also used for cutting wire. The various lengths and shapes of flatnose, roundnose, and half-roundnose pliers make it possible to bend or form metal into a variety of shapes. They allow the work to be done in close quarters.

10-18. Nippers, as shown in figure 31, are used strictly for cutting wire, light metal bars, bolts, etc. They are especially good for cutting them flush with a surface. They exert more force than pliers and should not be used as holding tools. Diagonal cutters are convenient for cutting off wire and small stock, such as cotter keys, located in tight places. Bolt cutters are classified as shears, but actually they are similar to heavy-duty nippers with compounded operating handles that increase the leverage. Bolt cutters are used

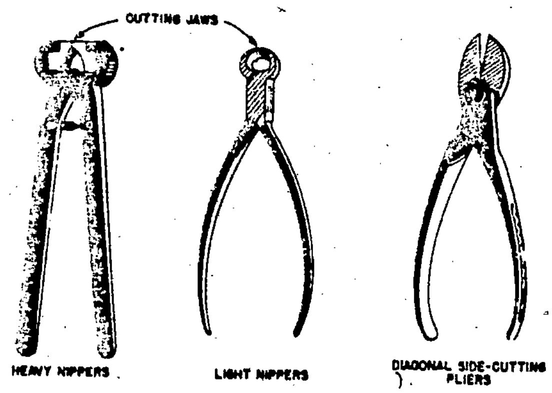

Figure 31. Types of nippers.

to cut bolts and small bars of metal that are beyond the capacity of nippers.

10-19. Pliers and nippers are made in a wide range of sizes to avoid overstraining and breaking a tool. Good adjustment must be used in selecting pliers or nippers heavy enough for the job. It is poor practice to use pliers instead of wrenches for tightening or loosening nuts; the pliers are likely to damage the flats of the nut. If dirty, greasy, or oily tools are used they can slip and cause skinned knuckles or leave scratches in the finished work.

10-20. Observe extreme caution when cutting wire that is springy or under tension. The wire can whip into your hands or face. So to avoid this, have one end of the wire securely in your grasp and keep your body away and shielded from the loose end.

10-21. **Files and Filing.** A file is a hardened high-carbon steel tool for cutting, removing, smoothing, or polishing metal. One file is shown in figure 32.

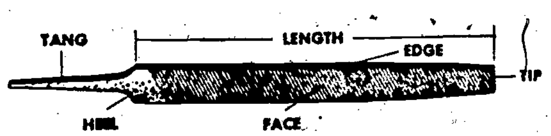

Figure 32. Flat file.

10-22. The cutting teeth of files are made by straight or diagonal rows of chisel cuts. Various cuts of files are shown in figure 33. Files are classified by name, grade, and cut. The cut may be either single or double, such as those shown in figure 33. Grade refers to the distance between

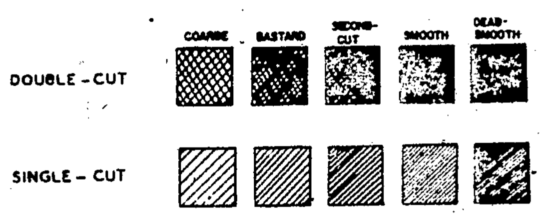

Figure 33. File cuts.

the parallel cuts. This can be listed in the order of coarseness as follows: flat, coarse, bastard, second-cut, smooth, and dead-smooth, as also shown in figure 33. Files are made in various shapes, and they vary from 3 to 24 inches in length.

10-23. *Types.* Types of common files are mill, flat, round, hand, and half-round. The mill file is a single-cut file tapering in thickness and width for one-third of its length. It is useful for fine work and is available with square, round, or with smooth edges that have no cutting teeth. The flat file is a double-cut file that often tapers in thickness and width. It is used when a fast-cutting tool is needed.

10-24. The round file is a round tapered type having various cuts, but sometimes double-cut in the larger sizes. It is sometimes referred to as a rattail file. Parallel or untapered round files are also available. The principal use of these files is to enlarge circular openings or form concave surfaces. The hand file is a single-cut file similar in shape to a flat file, but with parallel sides and only a slight taper in thickness. It has square edges, one which is a safe edge.

10-25. The half-round file is a double-cut file, which tapers in thickness and width and has one flat and one oval side. This file is for removing stock rapidly and for filing concave surfaces.

10-26. *Selecting files.* It is important that you select the correct file for the work. The following points can be helpful in making your selection. For heavy, rough cutting, a large coarse double-cut file is the most suitable; for making finishing cuts, however, use a second-cut or a smooth single-cut file. Start filing cast iron with a bastard file and finish with a smooth file; however, when filing hard steel, start with a smooth-cut file and finish with a dead-smooth file. Start filing brass or bronze with a bastard file and finish with a second-cut or smooth file; however, use a float file when filing aluminum, lead, or babbitt metal. For small work, use a short file, for medium-sized work an 8- or 10-inch file, and for larger work a file as large as can be controlled conveniently.

10-27. *Using files.* It is equally important for you to know how to use a file. Here are some important points to be observed when working with a file. You should hold the file with the handle against the palm of your hand, thumb on top, and the end of the file in the other hand with your fingers curled under it. When filing, lean your body forward with the weight evenly distributed on both feet. The file must be held straight or the surface of the work will not be flat. Not more than 30 to 40 strokes per minute should be taken; too much speed will ruin the file and the work. Use pressure on the forward stroke only, and apply only enough pressure to make the file cut evenly. The file should be lifted from the work on the return stroke to prevent it from becoming dulled by scraping action. (This does not apply when filing very soft metals, such as lead or aluminum. On soft work, pressure on the return stroke helps keep the file clean of removed metal.)

10-28. A file with a tang should never be used without a handle, as the tang may run into or cut the hand. A file with a handle is shown in the top view of figure 34. Be certain the handle is

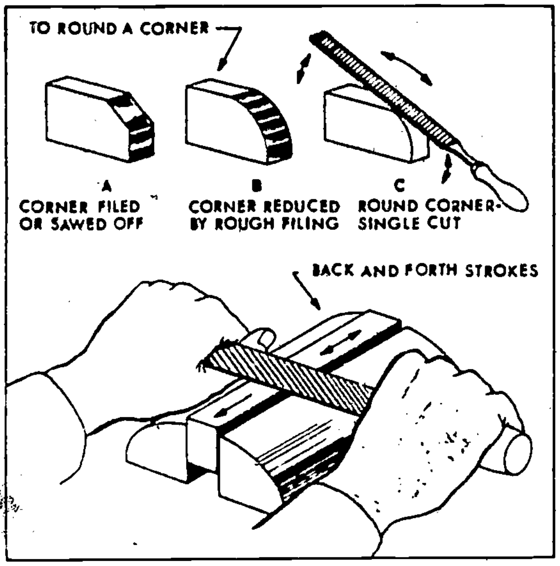

Figure 34. Drawfiling.

wedged firmly on the tang of the file. Small files, such as needle and ignition files, have handles. Hold the work firmly in a vise, with the surface to be filed projecting slightly above the vise jaws and parallel with them. If the work is loose in the vise, the file will chatter. This damages the teeth. It is poor practice to bear down hard on a new file. When the file is new, the teeth edges are very fine and will not stand much pressure.

10-29. When round surfaces are filed, the best results are obtained by using a rocking motion as the file is moved across the work. To produce a very smooth surface, work is sometimes drawfiled. When drawfiling, move the file sideways along the work, as shown in figure 34. A single-cut smooth file should be used. Pressure is heaviest on the stroke made toward the body and very light on the return stroke. For a smooth, finished surface, wrap a piece of fine emery cloth around the file and proceed as in drawfiling.

10-30. Like all other tools, a file should be given good care while it is being used. Certain precautions should be carefully observed to get maximum results from filing. When filing soft metals, narrow surfaces, or working in corners, small particles of metal sometimes clog the teeth of the file and scratch the material being filed. This is called *pinning*. It is usually the result of putting too much pressure on the file, especially if it is a new one. To avoid pinning, be certain the file is "broken in" before taking heavy cuts. Also, rubbing chalk on the file before using it will help prevent pinning.

10-31. A new file should be broken in by using it first on brass, bronze, or smooth cast iron. A new file should not be broken in on narrow surfaces, such as sheet iron, because the narrow edge is likely to break off the sharp points of the teeth. A new file should never be used to remove the fins or the scale from cast iron. Most of the damage to new files is done by using too much pressure during the first few strokes.

10-32. When a file is pinning and not cutting properly, it should be cleaned with a file card, pick, and brush, which are shown in the bottom view of figure 35. The pick is a small, pointed

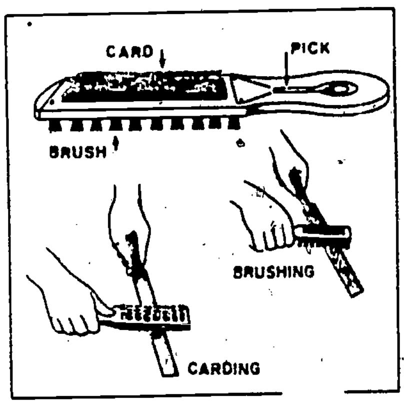

Figure 35. File card.

wire instrument, often furnished with a card file for cleaning out individual cuts in the file that are clogged too tightly with metal to be cleaned with a file card. When cleaning a file, lay it flat on the bench and draw the file card and brush back and forth across it parallel with the teeth cuts.

10-33. A file should never be used on material harder than itself or on sandy or scaly castings.

One stroke across this sand or scale will make the file useless. Apply a little oil on the surface of the file to lubricate the chips and to prevent scratching when filing wrought iron, steel, or hard fiber.

10-34. Like other cutting tools, files are easily dulled by rough or improper storage and handling. Files should not be thrown into a drawer or box where they can rub against each other or against other tools. It is best to store them in separate holders, such as clips, straps, or holes cut in a wooden block. Too rapid strokes or the failure to lift the file off the work on return strokes will quickly reduce its cutting efficiency. For best results and long file life, use the file card and brush often.

10-35. Painful injuries can be caused by the improper use of files. The following suggestions will help you use them without personal injury. You should have a firmly attached handle on the file, particularly when filing work that is rotating in a lathe. Do not salvage a small rattail file for the purpose of using it as a prick punch, for it is too brittle. Never use a file as a pry; it usually breaks and throws off tiny bits of steel which can get into your eyes. Never use a file as a hammer; this will not only injure the file but can throw steel particles into your eyes.

10-36. **Calipers.** Calipers are classified as sliding and spring, and either classification can be designated as inside or outside. Measurements taken with calipers are considered more accurate than those taken with a rule.

10-37. The pocket slide caliper (sliding caliper) has a fixed jaw fastened to the end of a bar and a movable jaw fastened to a frame which slides on this bar. The bar has a scale stamped on it and the frame has two stamped index marks labeled IN and OUT. One side of the jaws is used to take outside measurements, while the other side of the jaws is used to take inside measurements. Figure 36 shows the pocket slide caliper being used for taking inside and outside measurements.

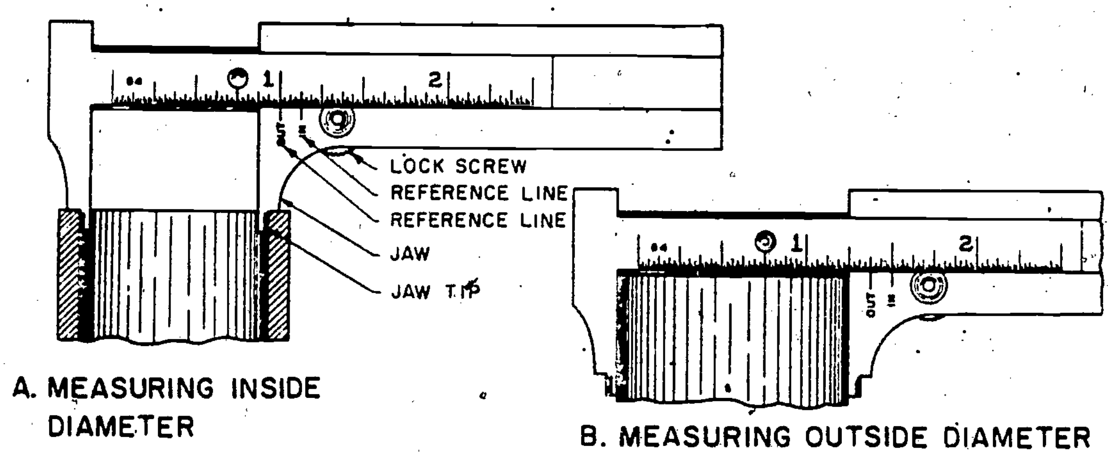

Figure 36. Measuring with pocket slide calipers.

10-38. **Rules and Tapes.** Rules and tapes are measuring tools often used by the mechanic. They usually are included in his toolkit and are used for taking all general measurements. These tools are marked with graduations indicating inches and fractions of an inch for measuring purposes. Graduations of less than 1/64 inch are not used because of the difficulty in reading them.

10-39. Rules are usually made of steel and are 4, 6, or 12 inches in length. The largest unit of measurement common to rules is the inch, and this is divided into smaller parts known as fractional parts of an inch. The graduations on a rule are the result of dividing the inch into halves (½), quarters (¼), eighths (⅛), sixteenths (1/16), thirty-seconds (1/32), and sixty-fourths (1/64).

10-40. When the total length to be measured is short, the rule should be used. It is more accurate than the tape. The rule is a precise measuring instrument and should be handled as such. It is not a screwdriver, a pry, a scraper, nor a putty knife; and it should not be used in place of one of these tools.

10-41. There are several kinds and lengths of tapes. The one that is used by the mechanic is 6 feet long and is made of flexible steel. It is coiled in a circular case and often has one end fastened permanently to the case. The tape can be easily drawn out of the case when needed and pushed back into it when not needed. Tapes are usually graduated in sixteenths (1/16) or thirty-seconds (1/32) of an inch. Most tapes have a small lip on one end which prevents them from slipping completely into the case when the tape is rolled into it. The lip also enables the mechanic to easily line up the end of the tape with the end of the piece of stock. The steel tape is used to measure distances, length of stock, and mainly for taking measurements that do not need to be very accurate. The tape should be kept free from dirt and grit and should be lightly oiled. It should not be bent at a sharp angle since this often breaks it.

10-42. **Cold Chisels.** Cold chisels are tools used for chipping or cutting cold metal by hand before its surface has been filed. They are made of a good grade of tool steel, hardened at the point and sharpened to a cutting edge at one end. In handwork, they are driven with a hammer. They will cut any metal softer than they are; in general, any material that can be cut with a file. Cold chisels are classified according to the shape of their points, the most common being flat, cape, roundnose, and diamond point. These are shown in figure 37.

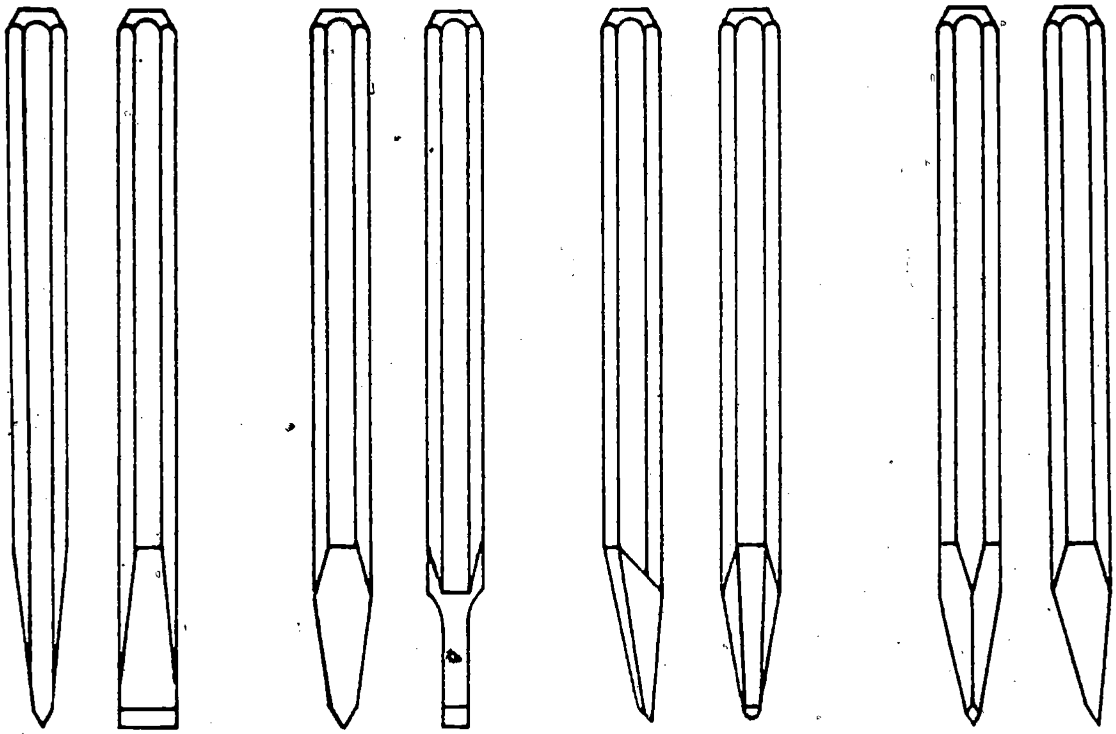

Figure 37. Types of cold chisels.

10-43. When selecting a cold chisel, you will obtain the best results if the type of cold chisel is selected for the particular work to be done. You should use a flat chisel for cutting sheet metal and for chipping (removing stock from flat surfaces). Use a cape chisel for cutting grooves, slots, keyways, or chipping flat surfaces where a flat chisel is too wide. A roundnose chisel is best for cutting round (concave) grooves and for drawing back drills which have run out. Use a diamond-point chisel for cutting V-shaped grooves.

10-44. As a rule, the cold chisel is used for cutting wire, small round stock, sheet metal, and plate. The cutting edge of the chisel should be placed on the mark where the cut is desired and at whatever angle will cause it to follow the desired finished surface. After each blow of the hammer, set the chisel to the correct position for the next cut. The depth of the cut depends on the angle at which the chisel is held in relation to the work. The sharper the angle, the deeper the cut. It is best to watch the cutting edge, not the head, of the chisel while you are working. Strike sharp, quick blows, taking care that the hammer does not slip off the end of the chisel and injure your hand.

10-45. Here are some precautions that should be taken when cutting wire or round stock. Place the work on the chipping block of an anvil or on any soft metal support. Hold the chisel with the cutting edge on the chalk or pencil mark and have the body of the chisel vertical (depending on the angle of the cut). Strike the chisel a light blow with the hammer and examine the chisel mark to make certain that the cut is at the desired point; then drive the chisel into the work with vigorous blows. The last strokes should be light ones to avoid unnecessary damage to the supporting surface. Thicker material can be cut in much the same way except that the cut is made about halfway through the stock from one side. Then, the work is turned over, and the cut is finished from the opposite side.

10-46. The cutting of sheet or plate metal with a cold chisel should be avoided whenever possible, because stretching the metal invariably results. However, here are some precautions for cutting sheet or plate metal with a cold chisel when no alternative is presented. Grip the work firmly in a vise with the scribed cutting line even with or just below the top of the vise jaws. The waste metal should extend above the jaws, as shown in figure 38. Starting at the edge of the work, cut along the scribed line with a sharp chisel. Use the vise jaws as a base for securing shearing action. Hold the chisel firmly against the work and strike it vigorously, being sure to keep the cutting edge of the chisel flat against the vise jaws, as shown in figure 38.

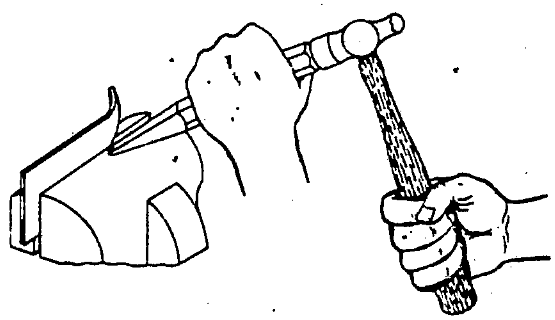

Figure 38. Cutting sheet metal with a cold chisel.

10-47. When you are chipping cast iron, chip from the edges of the work toward the center to avoid breaking off the corners.

10-48. Cold chisels must be kept sharp to give satisfactory service. The cutting angle should be maintained at about 60° and the edge slightly rounded. Sharpening is usually done on an ordinary coarse grinding wheel. The chisel must not be pressed too hard against the wheel, or enough heat will be generated to draw the hardness out of the steel. If the cutting angle is ground too small, the chisel will not be safe to use. If the angle is ground much over 60°, the tool will not cut properly.

10-49. The blows from the hammer will eventually cause the blunt end of the chisel to spread out until it resembles a mushroom. When this happens, the end should be ground to its original shape. It is dangerous to use a chisel with a mushroomed head, because steel pieces can fly off the chisel and cause injury. An example of a mushroomed chisel head and also a properly dressed head are shown in figure 39.

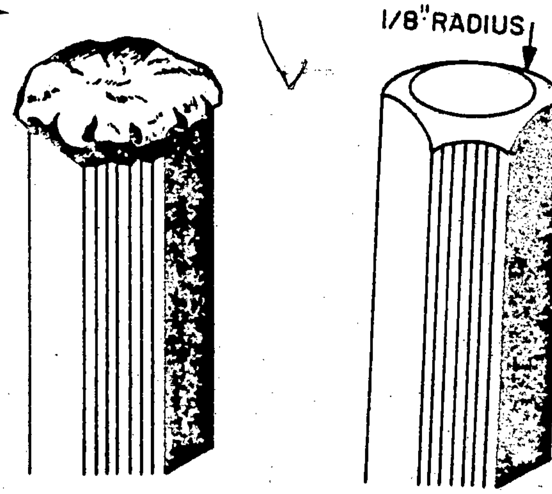

Figure 39. Examples of mushroomed and properly dressed cold chisels.

10-50. When you are using cold chisels, both for your own safety and to prevent damaging the tool or the work, place a chipping guard (a piece of canvas about 2 feet square attached to 2 pedestals) in front of the work to guard against flying metal chips. During chipping always wear face shields. Keep the hammer and the blunt end of the chisel clean and free of grease or oil. This helps to prevent the hammer from slipping and bruising your hand. When the work is held in a vise, the jaws should have guards made of some softer material, such as copper or brass, to protect the finish on the work. It is also advisable to put a block under the work so it cannot slip down and out of the vise. Always chip toward the solid jaw of the vise, not toward the movable jaw. When possible, avoid chipping parallel with the jaws of the vise.

10-51. **Hacksaws.** A hacksaw is used for cutting metal in much the same manner as a carpenter's saw is used to cut wood. Common hand hacksaws have either adjustable frames or solid frames, as shown in figure 40.

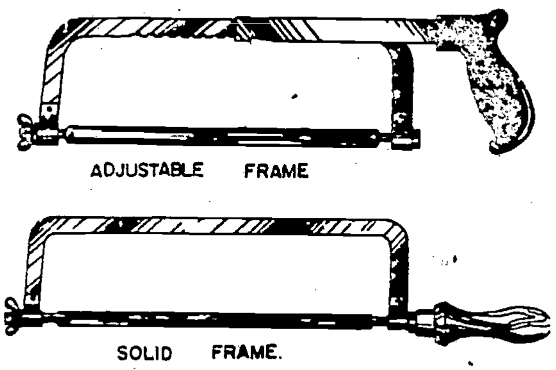

Figure 40. Typical hacksaw frames.

10-52. Hacksaw blades of various types can be inserted in a frame for cutting different kinds of metal. Adjustable frames can be changed to hold blades from 8 to 16 inches long. Solid frames, although more rigid, will take only the length of blade for which they are made. This length is the distance between the two pins which hold the blades in place. All hacksaw frames hold the blades either parallel or at right angles to them and are provided with screws for pulling them taut.

10-53. Hacksaw blades are made of high-grade tool steel, hardened, and tempered. There are two types of blades, all-hard blades and flexible blades. All-hard blades are hardened throughout, while only the teeth of flexible blades are hardened. Hand hacksaw blades range from 7/16 to 9/16 inch in width, have from 14 to 32 teeth per inch, and are from 8 to 16 inches long. Every blade has a hole at each end which hooks on pins in the frame.

10-54. The teeth of hacksaw blades are set to provide clearance for the blade. The three different kinds of set are alternate, raker, and undulated, which are shown in figure 41. Alternate set

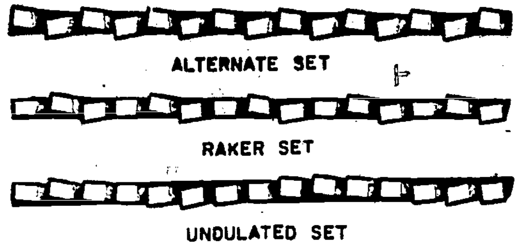

Figure 41. Examples of the set of hacksaw teeth.

means that alternate teeth are bent slightly sidewise in opposite directions. On a raker set blade, every third tooth remains straight, and the other two are set alternately. On an undulated set blade, short sections for teeth are bent in opposite directions. Hacksaw teeth should be set just enough to provide free, smooth, rapid cutting by making the kerf slightly wider than the blade itself and yet removing no more stock than is necessary.

10-55. Selecting the best hacksaw blade for a specific job is a question of using either the all-hard or the flexible blade with the pitch (number of teeth per inch) best suited to the work. Here are the usual practices followed when selecting the proper hacksaw blade for the metal. An all-hard blade is best for sawing brass, tool steel, cast iron, rails, and other stock with heavy cross section. In general, a flexible blade is used for sawing hollow shapes and metals having thin cross section, such as channel iron, tubing tin, copper, aluminum, and babbitt. You should use a blade with 14 teeth per inch for large sections of mild machine steel, cold-rolled steel, or structural steel, as shown in figure 42. This coarse pitch makes the saw free and fast cutting. A blade with 18 teeth per inch is best to use on solid stock, aluminum, babbitt, tool steel, high-speed steel, cast iron, etc. This pitch is recommended for general use. Use a blade with 24 teeth per inch on tubing, tin, brass, copper, channel iron, and sheet metal over 19 gage. If a coarser pitch is used, the thin stock will tend to strip the teeth off the blade. Two or more teeth should always be in contact with work, as figure 42 clearly shows. A blade with 32 teeth per inch should be

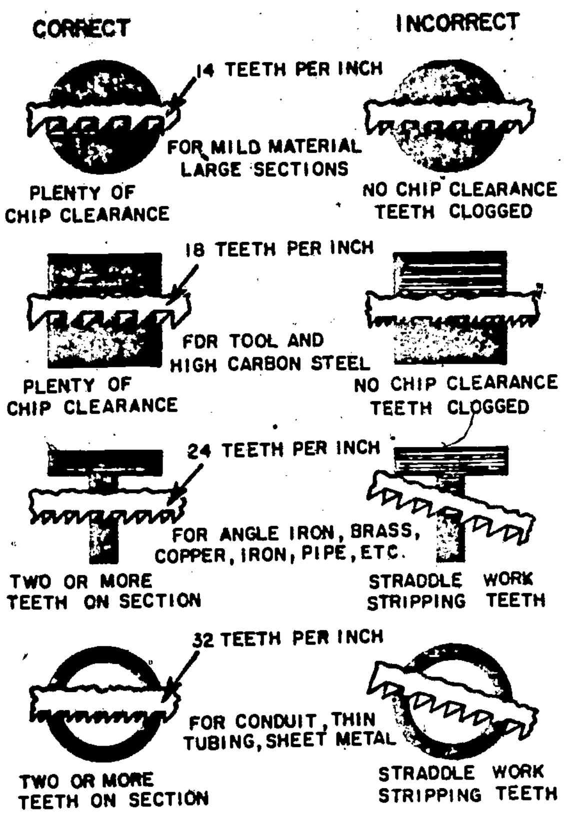

Figure 42. Correct pitch of hacksaw blades.

used on thin-walled tubing conduit and sheet stock thinner than 18 gage.

10-56. After selecting the correct blade and insuring that it is stretched tight in the hacksaw frame, mark the stock with a scriber, soapstone, or a pencil at the point to be cut. If special accuracy is required, nick the work with a file and start the saw in the nick. You must be certain that the work is gripped tightly in the vise, with the cutting line as close to the vise jaws as possible. When cutting angle iron or other odd-shaped material, expose as much surface as possible to the teeth so that a corner can be cut gradually with the maximum number of teeth engaged throughout the cut. It is best to start cutting on the widest surface of the work. The hacksaw should be held vertically and moved forward with a light, steady stroke. At the end of the stroke, the pressure is relieved and the blade drawn straight back. After the first few strokes, each stroke is made as long as possible without striking the saw frame against the work. There should be no bearing down on the saw on the return stroke. The saw should be kept in the same plane through the cut; otherwise the blade can be cramped and broken. To make a cut deeper than the frame, the blade is turned sidewise. The most effective cutting speed is from 50 to 60 strokes per minute. When work is nearly cut through, the pressure on the saw is relieved slightly to prevent the teeth from catching. Caution is needed toward the end of a cut through thin material. When cutting very thin stock, it is advisable to clamp the work between two pieces of wood or some soft metal, then saw through all three pieces. This prevents chattering and possible damage to the saw blade and to the work.

10-57. The chief danger when you are using hacksaws is injuring your hand when a blade breaks. The blade will break if you bear down too hard on the metal or if you do not push the saw in a straight line. When the work is not tight in the vise, it will sometimes slip and twist the blade enough to break it.

10-58. **Soldering Irons.** Soldering irons are divided into two classes—electric and nonelectric. The nonelectric iron is used when there is no electricity or when electrical outlets are not available. This iron is heated by directing such a device as a blowtorch at the tip. This requires the mechanic to check periodically to insure that the temperature of the iron is hot enough to accomplish the soldering job. Most blowtorches have a holder made on the unit for holding soldering irons while heat is being applied to them. This gives the mechanic an opportunity to prepare the fitting without loss of time.

10-59. The electric soldering iron is used when at all possible. This is one of the modern day job handtools which has made the mechanic's job much easier. To properly use this tool to obtain a good soldered joint or fitting, one should have the knowledge of how it operates and how to use it.

10-60. You will see many soldered jobs, but only a few good ones. Soldering is an art, regardless of the people who look upon it as a kind of "paste job." Soldering requires a certain "feel," based on the knowledge of metals, their strength, and their behavior under stress. If you doubt that soldering is an art, then compare the messy soldered joints in a cheap radio with the neat, permanently soldered connections of a well-engineered set.

10-61. A neat soldering job means that the solder must have melted quickly, flowed into or around the fitting, and then frozen into place without including air bubbles, oxides, or other carbon particles. (These impurities are not strong enough mechanically to hold up, or they will not conduct current properly.) To do this, the iron or soldering tip must be designed to give up its heat rapidly and channel the heat only into the working areas.

10-62. Once you have chosen the right size of tip for the job (the one with the largest effective heating surface), there is this fact to recall: the best tool in the shop is worthless in the hands of a man who cannot use it. The tip may have plenty of heating area, but the energy can leak out into space if the iron isn't held properly. So it is necessary to bring as much of the effective area of the tip as possible into play.

10-63. The iron must not be removed before the solder has had time to flow evenly and smoothly throughout the joint. If it doesn't flow, the work is not hot enough, or the work is just plain dirty. Some men try to hold the work with one hand and the iron with the other. As a result, the part isn't steady when the solder passes from a fluid to a solid. Any slight movement can cause a partially fractured joint which will soon break. So the work should be kept on the bench or otherwise supported rigidly.

10-64. Overheating the iron will cause poorly soldered joints. Just because the Government foots the electrical bill, some mechanics are apt to turn on the iron and go away for a short period to clean their nails or perform odd jobs of housekeeping. Meanwhle, the iron goes from one color to another and becomes so hot that the task has to be postponed until the asbestos gloves can be located. The heating should stop when the iron turns blue. Otherwise the solder will sputter and burn neat little holes in the operator's shirt front. Tests prove that the strength of soft-soldered joints is increased when the film of solder between the joints is kept thin.

10-65. Since a dirty tip will not give a neat and efficient job of soldering, it is up to the person using the iron to insure that his tools are kept in good working condition. Here are some helpful hints to follow when cleaning the soldering iron. The tip should be removed and the scaly copper oxide scraped off. If this is not done occasionally, the tip will freeze in the soldering iron. Then, while this is being done, the flat surfaces of the tip are filed until they are bright and smooth. The file must not rock or the tip be otherwise marred by clamping it in the vise jaws. The tip is inserted in the iron, the setscrew tightened, and rosin flux applied to keep the tip clean and free from oxidation. Then, the iron is heated so that solder will just melt, and the tip tinned by applying solder to each face and wiping it with a cloth until it is clean and bright. Obviously, the rags used for cleaning soldering irons should not be held in the hand. Sometimes the iron will overheat and need retinning, but it is not always necessary to remove the tip to do this.

10-66. **Grinders.** Grinders are used to grind off excess metal, to keep tools sharp and dressed, and to make metal surfaces smooth. Always wear a face shield when using the grinder, and keep the wheel guards in place. Only the flat surface of the grinder wheel is used so as not to put any portion of it out of balance. The grinder is allowed to run at least 30 seconds before it is used to insure that it is in balance and not vibrating. When using the grinder, move the metal back and forth across the surface of the stone to insure even wear of the wheel. The bar (toolrest) in front of the wheel provides a true guide. The proper tool must be used to dress grinding wheels.

10-67. **Portable Electric Drills.** Portable electric drills, shown in figure 43, are used to make holes in either wood or metal.

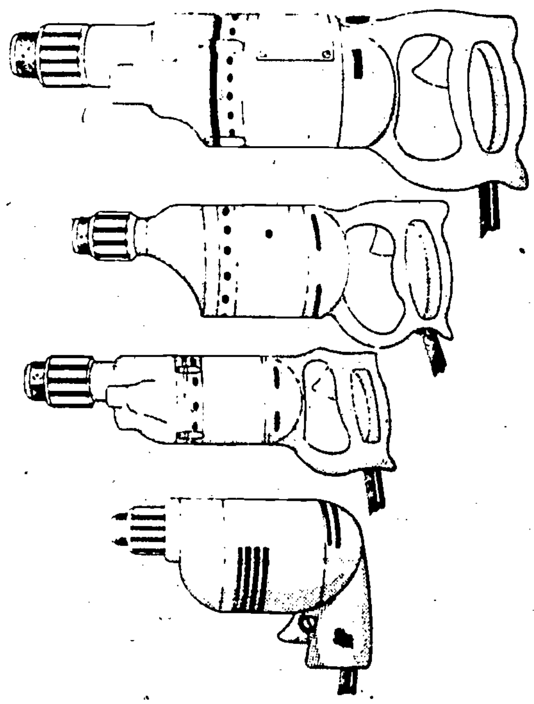

Figure 43. Electric drills.

10-68. A mechanic should be very careful when using an electric drill, especially the heavy-duty drill. All electrical connections *must be* grounded. He should be very sure that he is standing well braced while drilling a hole with an auger bit. Occasionally, a nail is hit while drilling a hole for a piece of pipe and the drill will try to twist out of the driller's hands. If it does, there is a good chance that it will cause injury to him or someone else before it can be shut off. Figure 44 is an illustration showing the auger bits used to make large holes. These bits are used with a heavy-duty drill and can drill holes from 1 to 4 inches in diameter. Extreme caution must be exercised when using auger bits with a power-driven drill.

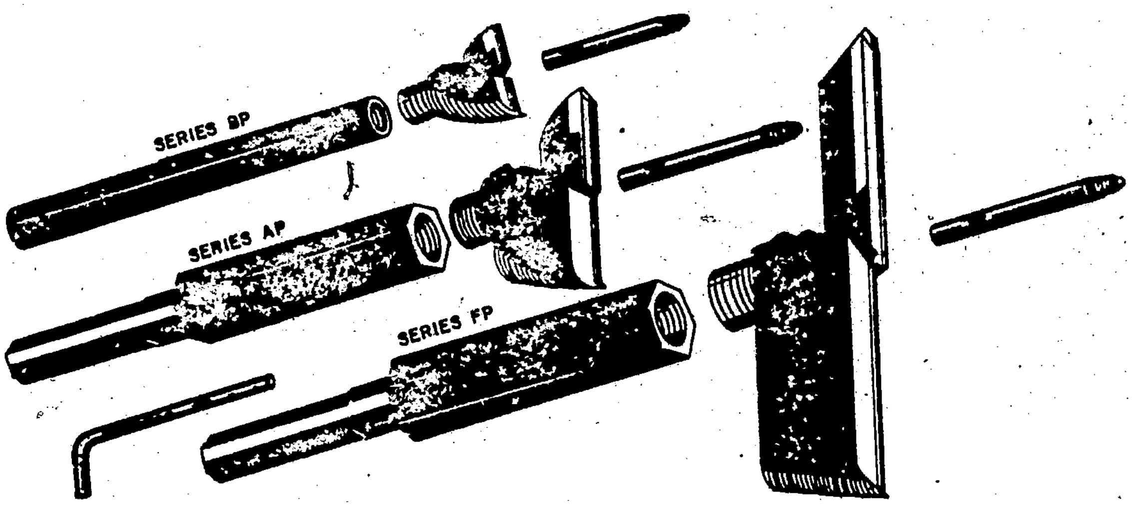

Figure 44. Auger bits.

10-69. **Blowtorches.** A blowtorch is a general shop tool that is used to heat metals which are to be soldered—also the soldering iron. It can be used to effectively apply heat to pipes which are frozen. Figure 45 shows a gas-fired blowtorch.

10-70. Blowtorches can be fired with gasoline, kerosene, or alcohol. If gasoline is used, is must be clean unleaded gasoline. The tank should be filled only about two-thirds full of gasoline. The pump is operated until sufficient pressure is built up in the tank to cause the gasoline to flow when the valve is opened. With the valve open, the gasoline will flow from the jet of the torch and drip into the priming pan. When the pan is partially filled, the valve is closed and the gasoline is ignited with a match. The flame from the burning gasoline heats the perforated nozzle (heat tube). When the nozzle is hot, the valve is opened again, slightly, to allow the gasoline vapor which has been forming to flow from the nozzle. The gas burns with an almost colorless flame, and by working the valve, the flame can be adjusted to the desired intensity.

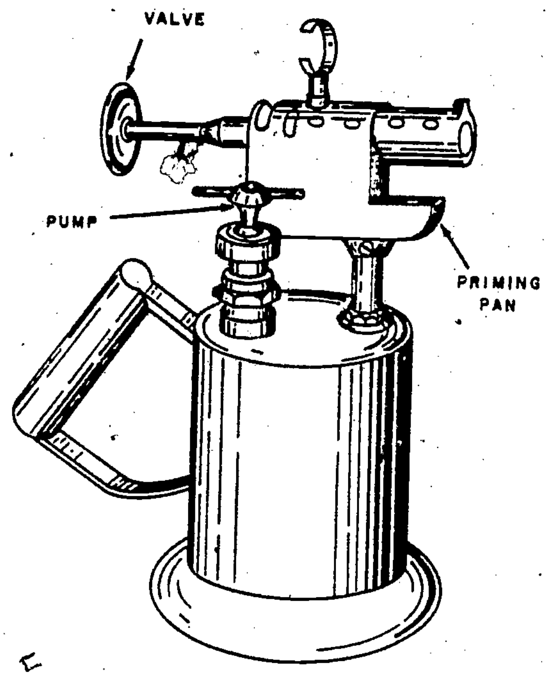

Figure 45. Blowtorch.

10-71. **Pipe Cutters.** Pipe cutters come in different sizes and have from one to three cutting

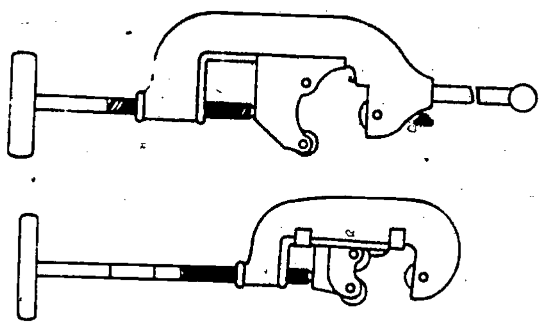

Figure 46. Pipe cutters.

wheels. The two cutters shown in figure 46 are the ones most generally used. They are the one cutting-wheel type.

10-72. When doing maintenance on pipe cutters, it is very important to keep the wheels and handle threads clean and well oiled. These tools are considered to be shop tools and are not included in the toolbox. However, each mechanic who uses them must help keep them in good condition.

10-73. **Pipe Reamers.** Pipe reamers are of two general types, spiral and flute, as shown in figure 47. Either one will accomplish the same operation. They are made for general all-around reaming and will fit various pipe sizes from 1/8 to 2 inches. Your shop might have a larger reamer which reams pipe up to 4 inches in diameter. On pipe larger than 2 inches in diameter, the burr is usually removed with a file. The main part of the reamer to be cleaned is the ratchet in the handle. Reamers are also shop tools and are not included in the box of tools.

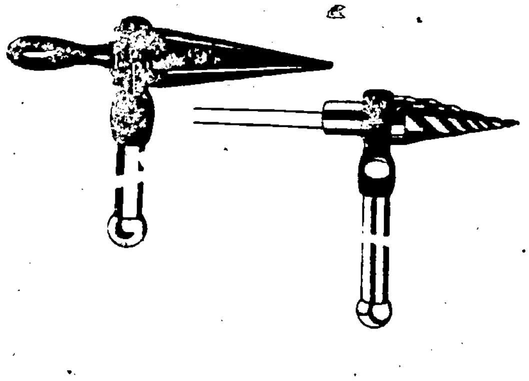

Figure 47. Pipe reamers.

10-74. **Pipe Threaders.** Pipe threaders are shop tools which require maintenance at regular intervals to keep them in good working condition. A set of ratchet threaders is very useful on maintenance work that requires threading the end of a pipe that is in a ditch or close to a wall. One type is the drophead threader, which is illustrated in figure 48. This tool cuts threads on pipe from 1/8 to 1 inch in diameter. The diehead fits into the stock and can be worked backward or forward, depending upon whether a new thread is being cut or it is being backed off. To properly insert new die segments in drophead threaders, it is necessary to remove the four screws, the cover, and the segments. Then, insert the new segments with the tapered ends down and replace the cover and screws. Before tightening the screws, however, a piece of threaded pipe is placed in the diehead to adjust the segments.

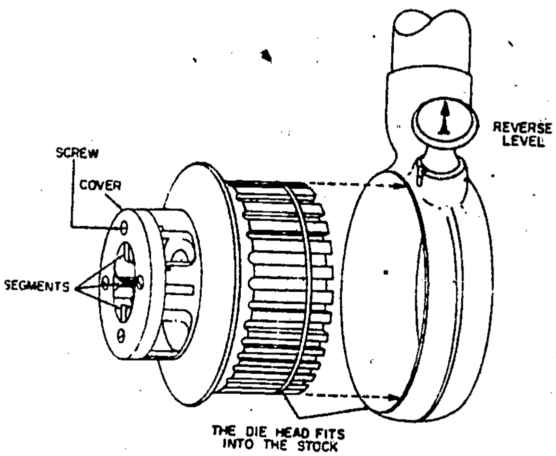

Figure 48. Ratchet pipe threader.

10-75. It is necessary that you use plenty of cuttng oil when cutting threads with ratchet type or other dies. Wet or muddy ratchet dies must be cleaned and oiled before they are stored or used again.

10-76. **Tubing Cutters.** There are several types of tubing cutters being manufactured. One type is illustrated in figure 49. This unit will cut tubing having an outside diameter of 3/16 to 1 1/8 inches. There are larger tubing cutters that will cut tubing from 1 to 2 1/8 inches O.D. When doing maintenance, it is very important to have a sharp cutting wheel and have the roller operate freely. The threads and wheels should be oiled frequently. One or the other of these tubing cutters will be issued nad it will be up to the mechanic to maintain it.

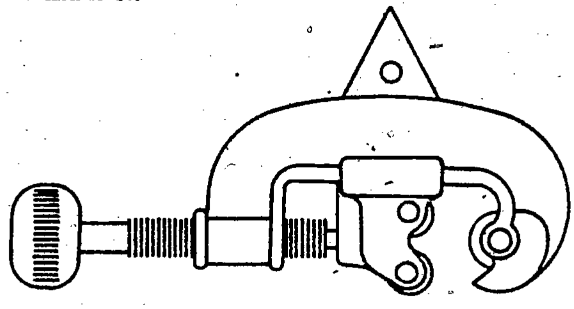

Figure 49. Tubing cutter.

10-77. **Flaring Tools.** There is a variety of flaring tools manufactured, but generally they all accomplish the same purpose. Flaring (or *belling* as it is sometimes called) is the expanding of the end of tubing into a funnel shape that can be held by a fitting. Figure 50 shows improperly flared ends.

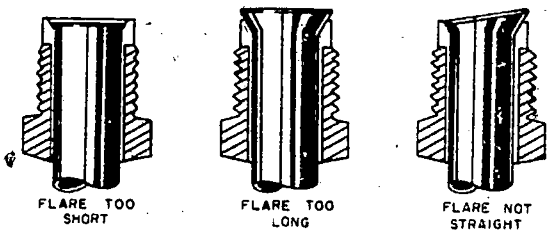

Figure 50. Incorrectly flared tubing.

10-78. When tubing is inserted into the flaring tool, it is projected approximately ⅛ inch above the face of the flaring tool, as illustrated in figure 51. It is imperative that the end be cut square and reamed. A flaring tool like that illustrated in figure 51 is used to make flared joints. Another type of flaring tool is shown in figure 52. Both flaring tools are designed to handle tubing up to ¾ inch in diameter. The latter flaring tool has wingnuts that are used to clamp it together. After the flaring tool has been clamped, the yoke is centered and the T-handle turned clockwise. This forces the tapered head down into the tubing and flares it outward. After the desired flare has been made, the handle is reversed, the head withdrawn, the wingnuts loosened, and the flaring tubing removed.

11. Valves

11-1. The valves used in heating systems are manufactured in various sizes, shapes, and types.

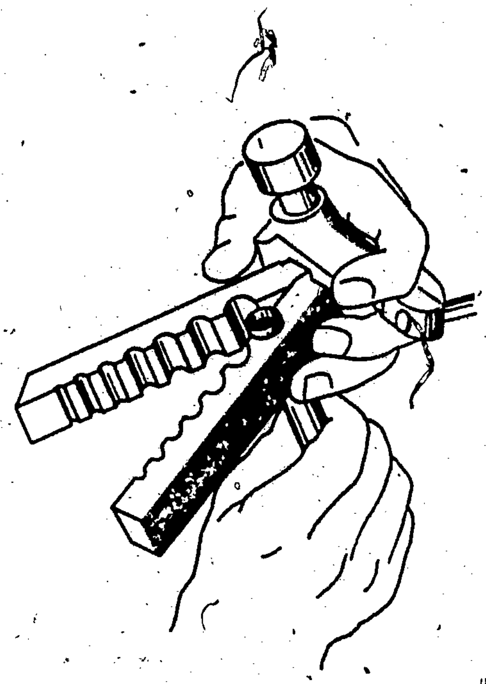

Figure 51. Inserting tubing into a flaring block.

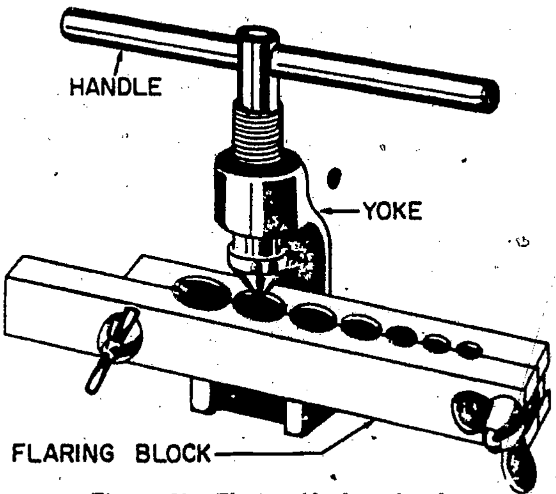

Figure 52. Flaring block and yoke.

Each type of valve has a specific purpose and use. The rated capacity of each valve is stamped on the side of each unit. They are rated in psi of steam, water, or gas.

11-2. **Gate Valve.** There are two general types of gate valves: the rising stem and the nonrising stem. The rising stem valve is commonly used on boiler headers so that the boiler operator can tell at a glance whether the valve is open or not. The nonrising stem type valve is used where space is limited. The stem of the nonrising stem valve goes through the disc instead of rising into the air. Gate valves are never used for throttling, because the steam or water will score the disc and cause the valve to leak. These valves should always be either fully open or fully closed.

11-3. **Globe Valve.** Globe valves are generally used where there is need for controlling a gas or liquid, and the globe valve can be used for throttling. These valves have two types of discs: metal and composition. These valves are used extensively in feed-water systems for boilers. When they are installed in a feed-water system, the flow of water must enter the valve under the disc. This is so that if the disc comes loose from the stem, water can still be fed to the boiler. The water coming in under the disc forces it upward, thus allowing continued flow. When the valve is not properly installed, the water pressure will come in on top of the disc and keep it forced down upon its seat. This will shut off the flow of water and create a low water level, thus endangering the safety of the boiler.

11-4. **Check Valve.** The check valve or non-return valve has many applications. The application that you will commonly come in contact with is the installation of the check valve in the feed-water line near the boiler. The valve is installed to prevent boiler pressure and line steam from forcing the water back down the feed-water line and entering the feed-water pump or cold water line to the building. Another application is the combination stop and check valve installed on the boiler header or main steam line. The purpose of this valve is to prevent the steam pressure of one boiler from flowing into other boilers when there are two or more on a common line. This valve has a stem behind the disc so that it can be used as a stop valve in much the same manner as the gate valve.

11-5. **Quick Opening Valve.** The quick opening valve is installed in a system where there is the need for sudden surges of gas or liquids, or when it is necessary to shut off the flow of gas or liquid more rapidly in an emergency than with another type of valve. These valves have a plug or a gate that can be opened or closed by one quarter of a turn of the knob or by moving a handle 90°.

12. Pipe, Fittings, and Pipefitting

12-1. Different types of pipes and fittings are used in the installation of a heating system. Each type of pipe or fitting is made for a specific use, depending on the installation and its requirements. Some pipes and fittings are made in different weights and strengths for use in gravity or pressure systems. In either case, they are made so that they can be installed to provide watertight, gastight, or airtight joints. Many materials are available currently for use in installing permanent heating and pipefitting systems. Among those commonly used are wrought iron, steel, brass, and copper. Plumbing and heating practices and the physical characteristics of these materials are the basis for establishing specific uses for each type of pipe or fitting.

12-2. Copper pipe and tubing, instead of steel or wrought iron pipes, will be required by specifications on some jobs. Either hard-drawn or annealed types of copper pipe or tubing are used for service lines and underground lines, or when concrete or other hard surfaces will cover the pipe. Some heating mechanics prefer to use the hard-drawn type rather than the annealed copper, because it makes a more rigid and neater job. Either type can be used, however.

12-3. Copper pipe and tubing have become very popular with the mechanics because of the ease with which they can be installed and assembled. Only a relatively small number of tools are required to install copper pipe and tubing as compared to galvanized or black iron pipe. The major tools needed for copper are a tubing cutter, a hacksaw, and an oxyacetylene torch or blowtorch. The oxyacetylene torch is preferred to the blowtorch because of the ease of controlling the flame as well as its heating qualities.

12-4. It is important for the heating mechanic to have a good knowledge of fitting iron, copper, and steel pipe. First, he must study his blueprints and plan his job so that the proper materials and equipment for the job will be procured. The loss of time and materials can be prevented if the correct fittings are procured first. A good mechanic will always prepare a checklist to insure that the proper tools and equipment are on hand, and also that the job is properly planned before it is started. In the following paragraphs we will discuss the fitting of copper, iron, and steel pipe.

12-5. **Copper.** The burrs are removed and the ends are reamed after copper pipe or tubing has been cut to the proper length. Then, the ends of the pipe and the insides of the fittings are cleaned before any flux or soldering paste is applied. It is very important that all the tarnish be removed from the fittings and the ends of the pipe or tubing so that the solder will flow evenly over all of

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the surfaces to produce a leakproof joint. Next in importance is the necessity for the fittings to be at the temperature which allows the solder to flow evenly into the joint by capillary attraction. Cast fittings will require a little more heating than the streamline fittings.

12-6. To insure a well-soldered joint, it is necessary to inspect the end of the pipe or tubing to make sure that it is free from burrs and has not been mashed or otherwise forced out of shape during the cutting. Both the female parts of the fitting and the male end of the copper tubing must be cleaned with emery cloth until they are burnished to a high polish. This helps to insure that they will tin evenly. Then, a liberal amount of soldering paste or flux is applied to both burnished surfaces. After this, the copper tubing is inserted into the fitting and properly aligned in the position where it is to be permanently soldered. Heat is applied to the fitting with either a blowtorch or an oxyacetylene torch for about 45 seconds, but care must be exercised to not overheat the fittings, pipe, or tubing.

12-7. The end of a strip of wire solder (50 percent tin and 50 percent lead) is applied to the edge of the joint while it is being heated, and the melted solder drawn into the joint by capillary attraction. The joint must be held rigidly in place until the solder has hardened and the joint is immobile.

12-8. After the joint has cooled and the solder has hardened, it should look like the one shown in figure 53, provided the joint surfaces were properly cleaned and fluxed and the solder formed the joint by capillary attraction.

12-9. CAUTION: When the soldered joint is being made against a wooden partition or other combustible material, it is best to use a sheet of asbestos or metal back of the fitting during the soldering. The flame from the torch is extremely hot and can quickly start a serious fire in the combustible materials.

12-10. Copper pipes or tubing should be supported with proper supports or hangers, the same as other pipes, except that any kind of metal other than copper or brass should be insulated from the copper pipes to prevent electrolysis. Copper and brass straps and hangers are made for use with copper and brass tubing as well as copper and brass pipe.

12-11. **Iron or Steel.** The iron or steel pipe to be cut is inserted into a properly supported pipe vise attached to a bench or other solid object.

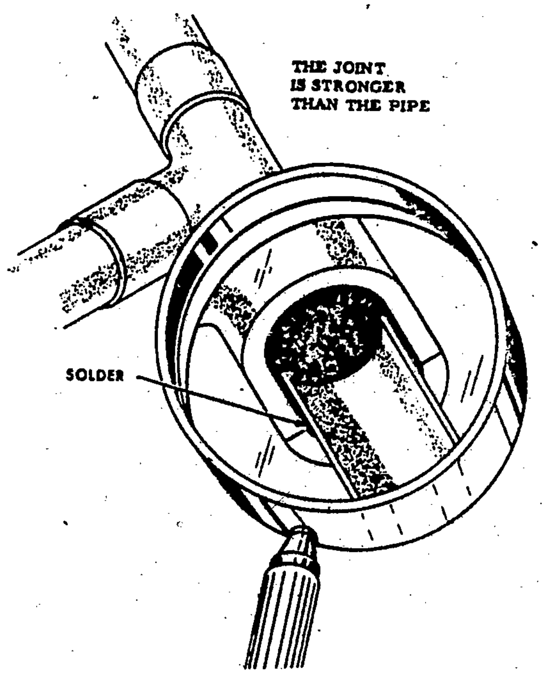

Figure 53. Cutaway of a soldered joint.

Figure 54 shows a pipe that has been inserted into a pipe vise and made ready to be cut with either a hand hacksaw or a pipe cutter.

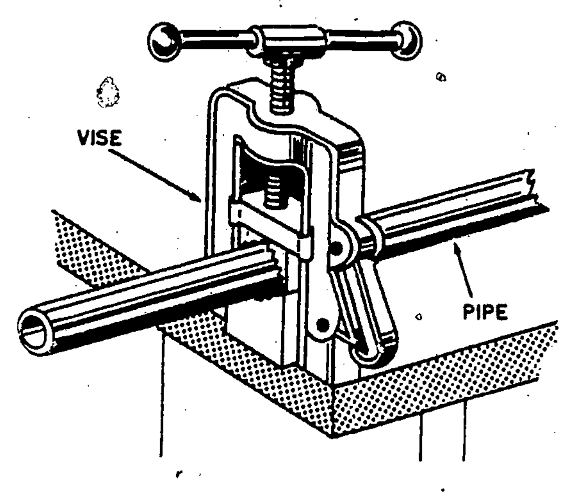

Figure 54. Pipe clamped in a vise.

12-12. The jaws of a pipe cutter are opened by turning the handle counterclockwise. The pipe cutter is placed around the piece of pipe at the mark where the cut is to be made. The cutter must be centered so that the cutting wheel is exactly on the mark. The jaws of the pipe cutter are closed lightly against the pipe by turning the handle clockwise. After the wheels have been brought into contact with the pipe, the handle is rotated one-fourth turn more in the clockwise direction. This puts a "bite" on the pipe that results in a groove being made in the pipe as the cutter is rotated. The pipe cutter is rotated 360° to make a complete cutting mark around the pipe before the handle is turned clockwise again to cut the pipe deeper. If this is not done, the pipe cutter might make spiral marks around the pipe instead of making one complete circle. Figure 55 shows a pipe cutter placed on a pipe and ready to make the first turn.

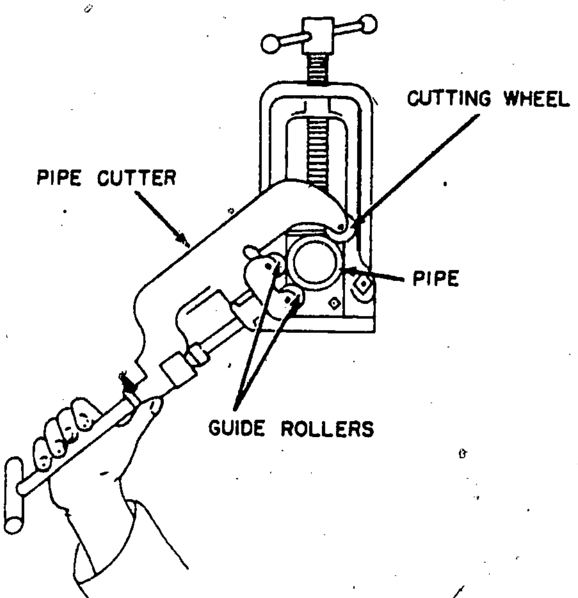

Figure 55. First turn of a pipe cutter.

12-13. When at least one complete turn has been made, the handle on the pipe cutter can be turned to provide another bite on the pipe. Figure 56 shows a cutaway of a piece of pipe, and it

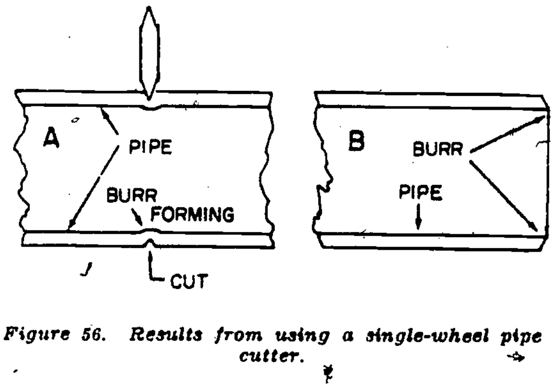

Figure 56. Results from using a single-wheel pipe cutter.

illustrates results obtained by using a single-wheel pipe cutter. Detail A shows how the cutter causes a burr to form inside the pipe, and detail B shows a cross section of the burr after the pipe has been cut completely off.

12-14. Next, the burr is removed from the end of the pipe to prepare it for threading. This is done by inserting the point of a reamer firmly into the pipe, as shown in figure 57, and rotating

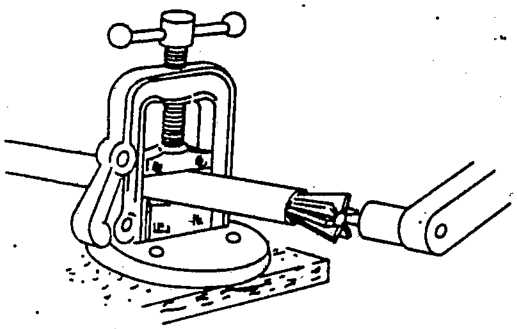

Figure 57. Insertion of pipe reamer.

the handle of the reamer clockwise with short even strokes until the burr has been completely removed. Figure 58 illustrates a cutaway of the pipe after it has been properly reamed.

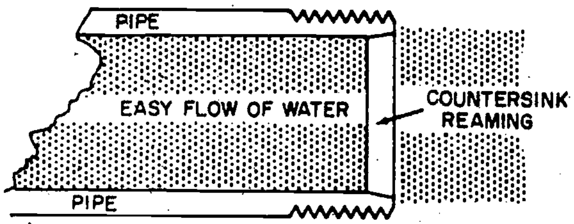

Figure 58. Properly reamed pipe.

12-15. Figure 59 shows the difference between a reamed pipe and a pipe which has not been

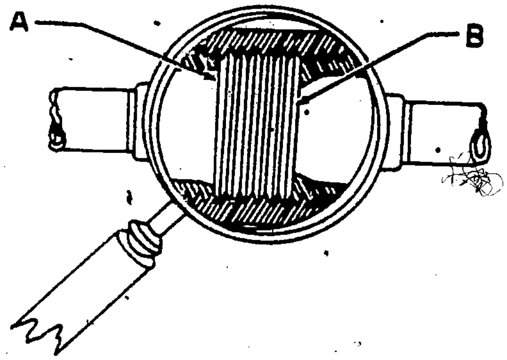

Figure 59. Reamed and unreamed pipe.

reamed. Detail A shows the reamed section; detail B still has the burr. The pipe in detail B will not deliver at full capacity. You can see by this illustration that it is very important to ream the burr out of the pipe. It does not matter whether the pipe is to be used for venting, drainage, or a line which is to carry fluid; just get into the good habit, right now, of reaming all pipe ends.

12-16. **Threading Pipes by Hand.** A ratchet nonadjustable pipe diestock and pipe-threading dies are used to cut threads by hand on a piece of pipe that has been properly cut and reamed. There are other dies, such as the three-way die, that will cut threads on from ½- to 1-inch pipe. Other larger adjustable dies will cut threads on pipe from 1 to 2 inches in diameter by adjusting the dies. The nonadjustable ratchet dies can be used to cut threads on pipe from ⅛ to 1 inch in diameter by changing to the correct size of die. Always inspect the pipe threading dies to see that they are sharp and free from nicks or wear before you use them.

12-17. The round guide end of the pipe diestock is placed on the pipe, as shown in figure 60, and the pipe threading dies pushed against the pipe with the heel of the hand. Considerable pressure must be exerted with the hand against the pipe diestock and three or four short clockwise turning strokes taken to start the pipe threading dies to cutting.

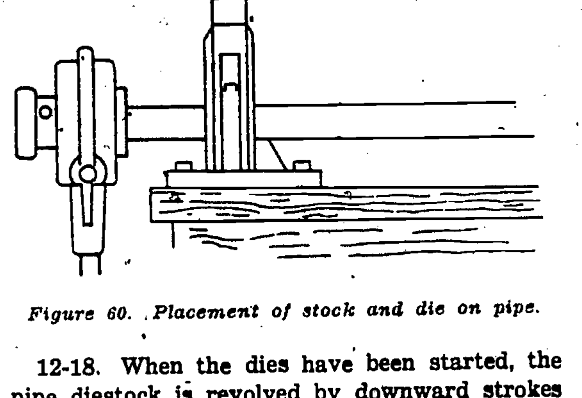

Figure 60. Placement of stock and die on pipe.

12-18. When the dies have been started, the pipe diestock is revolved by downward strokes on the handles, as shown in figure 61, with an even, steady pressure until the ends of the pipe (and with the cut threads on it) project approximately two threads through the pipe diestock. To cut clean threads for watertight and airtight joints, the pipe-threading dies must be oiled with a good grade of lard or sulphur pipe-thread cutting oil after each two or three downward strokes. The oil prevents overheating the pipe-threading dies and marring the threads.

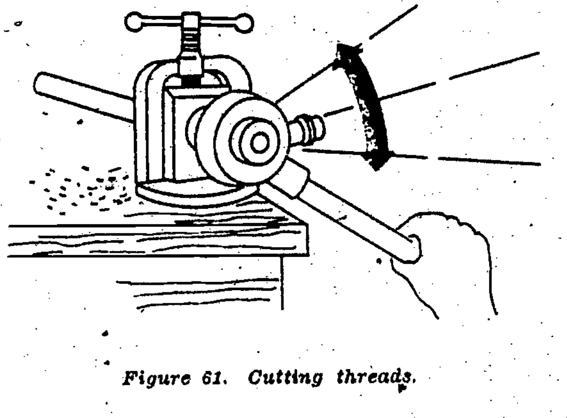

Figure 61. Cutting threads.

12-19. When the threads have been completed, the ratchet on the pipe diestock is reversed for counterclockwise operation, and several short motions made backward and forward with the diestock to loosen the burrs inside the threading dies. The pipe diestock is then revolved counterclockwise until the pipe-threading dies are free of the threads. Many mechanics have the habit of spinning the pipe diestock rapidly to speed up the back-off of the tool. While this is not injurious to the pipe thread, extreme care must be exercised while spinning the diestock to prevent it from striking the legs of the vise or the mechanic. Many mechanics have been hit by the spinning handles.

12-20. Too many threads on a pipe are just as undesirable as not enough threads. Figure 62 shows a pipe with the standard amount of threads. Note that there are three distinct sections of these threads. Section C is area the starting dies have cut, section B shows the threads cut to the proper depth but not finished, and section A shows the threads that have been finished properly from

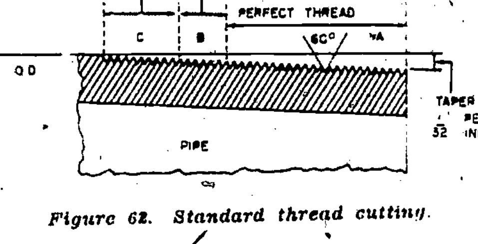

Figure 62. Standard thread cutting.

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top to bottom. It is important that the die segments are in good condition, and that the teeth are not broken or chipped. Die segments that have broken teeth should be replaced; otherwise the threads will be imperfect or burred.

12-21. When cutting large pipe with adjustable threading dies, there will be four segments, and pipe 2½ inches and larger will have as many as five segments. In either case, whether threading large or small pipe, the proper amount of threads will be cut if you will let the pipe extend at least two complete threads beyond the head of the diestock.

12-22. Figure 63 shows the correct length of threads, also threads that are too short and too long. The number of threads cut per inch will be determined by the size of pipe which is to be threaded. Pipe sizes ¼ to ⅜ inch will have 18 threads per inch, ½- to ¾-inch pipe will have 14 threads per inch, 1- to 2-inch pipe will have 11½ threads per inch, and 2½- through 6-inch pipe will have 8 threads per inch.

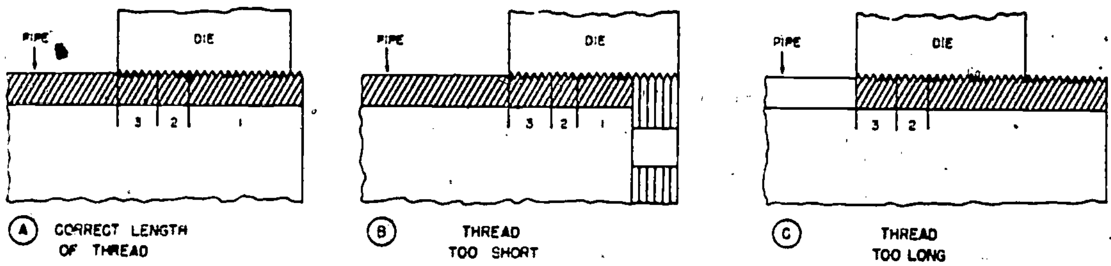

Figure 63. Pipe threads.

12-23. **Cutting and Threading Pipe with Power Tools.** Cutting, threading, and reaming pipe with power tools are a great time saver, but these operations can be very dangerous if not properly done. There are many different types of pipe-threading machines, but each one accomplishes the same purpose. The pipe machine pictured in figure 64 shows the major working parts of a power threading machine. Each machine is equipped with diestocks, which are used to thread pipe from ½ to 2 inches in diameter. For larger or smaller pipe, special dies must be used.

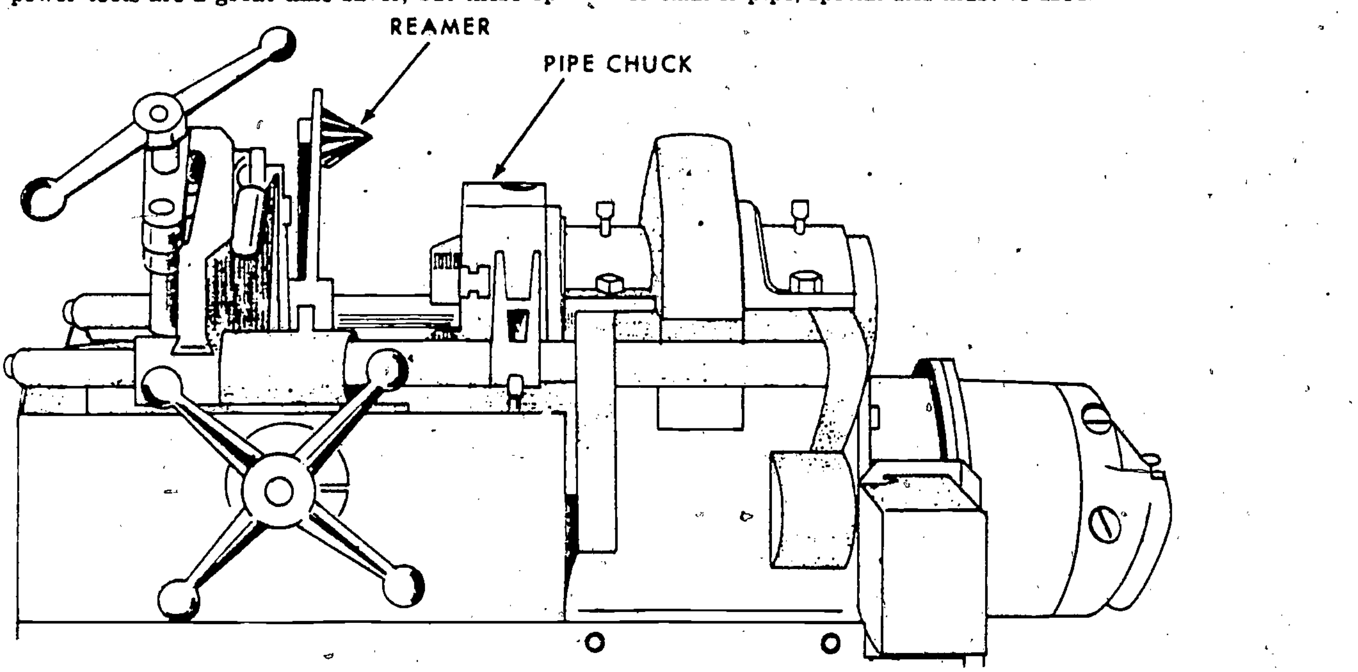

Figure 64. Power threading machine.

12-24. The pipe chuck jaws on a power-driven threading machine should be checked to see that they are clean and free from chips or flakes on the teeth before a piece of pipe is threaded. A stiff wire brush is used to remove any dirt and chips so that the teeth will clamp tightly against the pipe without slipping. After the teeth of the chuck are cleaned and opened to receive the piece of pipe, it is necessary to insure that all of the teeth on the die segment are clean and not chipped. The proper size of diehead must be placed on the machine, and the die-releasing handle moved up and down to see that the segments in the dies open all of the way and come down the proper distance. A short 4-inch nipple that is turned into the die segments by hand will indicate if the segments are properly alined. Sometimes a short pipe is put into the chuck, tightened, and the motor turned on so that the nipple will rotate as the die is brought forward to meet and run onto the nipple to check the setting of the segments. When the segments are run on the pipe the proper distance, they are released by lifting the die-release lever. The die is backed off and the motor shut off to stop the chuck. After the chuck has stopped, it is released and the nipple removed. It is checked with a standard tapped female fitting. The nipple should fit so that it can be turned three to three and one-half turns into the fitting by hand. If the nipple turns more than three and one-half turns, the segments are set too deep. If the nipple will only turn approximately two turns, the segments are worn out or they are improperly set too shallow. After the check, and the dies are properly cleaned and set, the machine is ready to start threading pipe.

12-25. But wait! We have forgotten something very important. While discussing checking the short pipe in the dies, we did not talk about turning on the cutting oil so that it would be directed onto the threads and segments. This is very important, because *you would cut about one full thread without oil and the die segments would be ruined.* Do not forget this! Always check to see that the oil and oil lines are working properly before you start to cut any threads. Now, after all of the working parts have been checked, the machine is ready to use to cut and thread a piece of pipe.

12-26. The pipe to be cut to length is inserted into the chuck so that it protrudes about 8 inches beyond the face of the chuck. The pipe rest is then adjusted so that it will carry the weight of the pipe that is sticking beyond the end of the machine. If the pipe is full length or nearly full length, an additional pipe rest is recommended. Now, the tee wrench is used; or if the machine has a knocker type chuck, it is tightened against the pipe. The tee wrench is removed and inserted in its resting place. If the pipe that is inserted into the machine has manufactured threads, the dies are run over these threads. If there are no threads, the machine is turned on so that the pipe will be rotated in the proper direction. With the pipe rotating, the end of the pipe is ready to be reamed before it is threaded.

12-27. On the side of the machine there should be a bar with a reaming head attached. This reamer is lifted into place. It turns on the bar as it is lifted until it fits directly in front of the dies, as shown in figure 64.

12-28. After the reamer is in place, it is advanced toward the protruding pipe until it enters and touches the pipe. Pressure is applied by turning the large wheel on the side of the machine counterclockwise, and pressure is applied until the pipe is properly reamed. Then, the wheel is turned clockwise so that the reamer will be withdrawn from the pipe and is clear of the end of the pipe. The reamer is removed from in front of the dies by taking hold of the round knob on the reamer.

12-29. When everything is in readiness to start threading pipe, close the release lever on the dies. Then, turn the wheel counterclockwise until the dies touch the end of the pipe. The oil must be running before pressure is applied on the wheel to help start the segments on the pipe. Pressure is applied until at least two threads have been started so that the die will continue to thread itself. The machine must be attended while it is cutting the threads. The operator must stay there to see when the end of the pipe comes beyond the diehead about two full threads, and to release the segments by lifting the release lever. The diestock is then backed by turning the wheel clockwise until the diestock is clear of the pipe. Now, the machine is stopped, and the pipe loosened in the chuck. When the pipe is loose, it is advanced or pulled through the pipe dies and cutter until the next mark is about 8 inches in front of the face of the chuck. Now the chuck is tightened on the pipe and the machine started again. The pipe dies and pipe cutter are advanced by turning the large wheel counterclockwise until the wheel of the cutter is directly in line with the mark on the pipe. Care must be taken to insure that the pipe dies do not strike the face of the chuck before contacting at the cutting mark. When the cutter is alined with this mark, the small wheel is turned clockwise and the pressure applied after the pipe rotates a full turn. Then the pipe is completely cut off. If the pipe section is a long one, the operator must make sure that the proper pipe rest is under the pipe to catch it when it is cut off. This prevents the pipe from dropping to the floor and damaging the threads.

12-30. After the pipe section is cut off, the larger wheel is turned clockwise to withdraw the pipe dies and cutter from the pipe. Now, it is necessary to ream the pipe in the manner described before, and remove the burr caused by the cutter. The cutting and threading are repeated as many times as necessary or until the full length of the pipe has been cut and each piece threaded on one end. Then each piece is reinserted into the machine and threaded or a reamed, balled end can be made.

12-31. When a short piece of pipe is left over, it should not be put back into the pipe storage rack until threads have been cut on both ends. Not threading the leftover pipe on both ends is a very bad habit that many mechanics have.

12-32. **Inspection of Pipes and Fittings.** The periodic inspection and preventive maintenance of fittings and systems associated with heating is necessary to insure continued satisfactory operation. A thorough inspection may reveal unsafe or hazardous conditions that would affect the health and safety of personnel. If so, it is of the utmost importance that immediate steps be taken to correct these conditions.

12-33. When inspecting heating installations, make a visual inspection first, noting all of the minor and major repairs required. The minor repairs should be made immediately, and the major repairs or replacements should be completed as soon as possible.

12-34. Special attention should be given to looking for corrosion, rust, splitting or cracking of pipes and fittings from freezing, excessive strain, etc., during the inspection. All damaged materials should be replaced so as to maintain the efficiency of the heating system. When pipe or fittings are being replaced, the requirement is to use pipe or fittings of equal quality and like material.

12-35. **Making Pipefitting Connections.** It is important that the mechanic have a good knowledge of pipefitting. He must study his blueprints and job plans so that the correct fittings are procured for the job. The loss of time and material is avoided when the correct fittings are procured from the very first. A good mechanic always prepares a checklist to assure that the proper tools and equipment are on hand. He also has the plans available for quick reference.

12-36. Threaded pipe joints are commonly used when wrought iron and steel pipe fittings are installed. This method of joining the pipe involves connecting the threaded male and female ends together.

12-37. To obtain a tightly threaded joint, it is important that the threads be clean and in good condition. The threads must be checked very carefully if the pipe or fittings have been exposed to the weather or "banged" around. It may be necessary to run a tap into or a die over the threads to straighten any that are damaged.

12-38. Cleaning the pipe ends with a wire brush is a good start toward making the joint. After the pipe is secured in a vise, the thread lubricant is smeared on the male threads. Red lead or white lead is used for water pipes, and a mixture of powdered graphite and oil used for steam pipes. This "pipe dope" is not used inside the fitting.

12-39. The fitting is turned on by hand as far as it will go; then it is tightened with a pipe wrench. A "hickey" (an oversized wrench) or too much pull should not be used. Not all of the male threads need to go into the joint. When all the threads are used, the wedging action of the tapered thread can cause the fittings to split.

12-40. Two pipe wrenches should always be used when wrought iron or steel fittings are being installed. This will allow for more pressure to be applied to tighten the joint. It is important that the pipe or fitting to which a new pipe or fitting is being installed does not turn. Figure 65 shows the correct way to apply wrenches. In figure 65, the pipe wrench (A) shows that it is used for holding the pipe to keep it from turning while the fitting is being tightened. Figure 65 shows another pipe being connected to the coupling. Therefore, the coupling (B) must be held to assure that the next pipe is conneoted securely. Two or more fittings should never be connected at the same time.

12-41. Experience is the best teacher when it comes to determining how tight a joint should be. Usually, there will be two or three unused threads on a properly threaded pipe. If the threads have

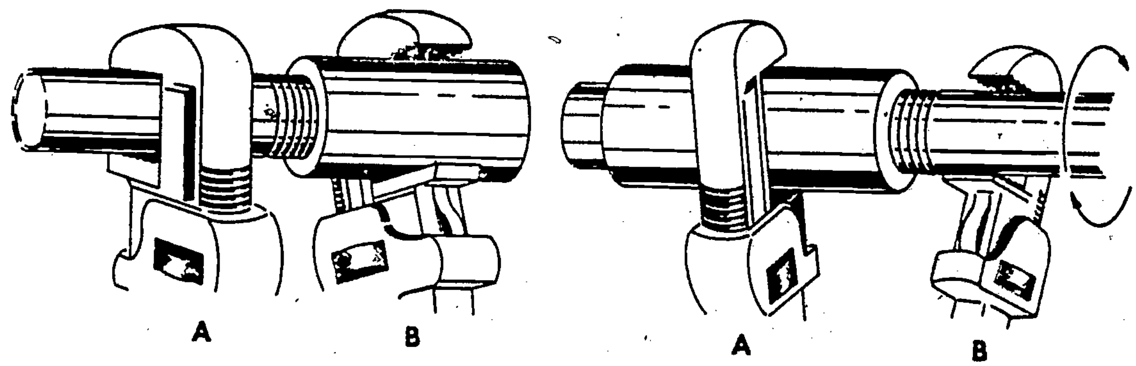

Figure 65. Wrench application.

been made correctly, the joint will be tight enough to withstand the pressure for which the pipe and fittings are made.

12-42. In the previous paragraphs of this section you have been studying about cutting and threading pipe, inspecting pipe and fittings, and connecting pipe and fittings. So, now is a good time for you to do some studying about welding, since welding is sometimes used to connect piping as well as for other purposes.

13. Welding

13-1. At times it will be necessary for you to do some welding. When the first time for you to do welding comes along, you will have to have some knowledge of it, as well as practice, to do a creditable simple job. At first you will probably be called upon to weld pipes, hangers, and perhaps some heating system components. However, do not expect to be allowed to weld on pressure vessels until you have become a certified welder. To weld, you must be familiar with the correct methods of setting up and operating welding equipment. Because of the great area covered by heating systems, you will most likely have to use portable welding equipment. Consequently, we will discuss only the portable welder. The stationary welders used by the civil engineers are very little different from the portable equipment so far as their basic principles of operation are concerned. There are two methods of welding that we will discuss and you will study in the following paragraphs. The first method we will take up is oxyacetylene welding, and the second method we will cover is electric arc welding.

13-2. **Oxyacetylene Welding.** Gas welding is a method of joining metal parts with a gas flame while their edges are in a molten or plastic state. The process of joining the parts by melting is known as nonpressure or fusion welding. This process is contrasted to the pressure process of welding by which heated metals are joined under impact by blows or by pressing them together. These welding processes are thus classified both according to the method of joining and according to the sources of heat. The heat used for welding by the nonpressure method is usually obtained from a gas flame or an electric arc. The edges of the parts are melted together, and any additional metal used for filling in and reinforcing the weld is melted from the ends of welding rods. In some cases, the weld can be made without the use of welding rods. The most common fuel mixtures used for gas welding are oxyacetylene, air acetylene, and oxygen mixed with other fuels. Your work will be done, for the most part, with the oxyacetylene welding torch.

13-3. Oxyacetylene welding is the nonpressure process in which the heat is obtained from an oxyacetylene flame formed by the burning of oxygen and acetylene. These two gases are mixed in correct proportions in the torch, which is controlled by the operator, to give the desired flame adjustment. In oxyacetylene welding, consideration must be given to the proper preparation of the edges of the joint, to correct spacing, and to alinement of the parts so that the finished weld will have the desired appearance and shape. A complete portable oxyacetylene welding outfit consists of a cart carrying a carbon dioxide (CO_2) fire extinguisher, a supply of oxygen and acetylene in gas cylinders, oxygen and acetylene pressure regulators complete with the gages and connections, two lengths of hose with adapter connections for the regulators and torch, an apparatus wrench, a safety flint igniter, and a pair of welding goggles. We will discuss and study the descriptive and operational aspects of this equipment in the text that follows.

13-4. The regulators or reducing valves are mechanical devices used to reduce the high pressure of the gases as they flow from their respective containers.

13-5. The hose lines that are especially manufactured for oxyacetylene welding are used to make the connections between the torch and regulators and convey the gases from their containers to the torch. Hoses for the various gases are the same in construction but different in color. Red or maroon hose is used for acetylene, and black or green hose is used for oxygen. The hoses are equipped with connections at each end so that they can be attached to their respective regulator outlet and torch inlet connections. The nuts for these hoses are the same size, but they have different threads; left-hand threads are standard for acetylene connections, and right-hand threads for oxygen connections. Pneumatic hose must never be used in place of either one of these hoses.

13-6. The welding torch is the unit used to mix the two gas fuels together in correct proportions. The torch also provides the means for directing and controlling the size and type of the flame that is produced.

13-7. Welding tips are manufactured in various styles or types: some have a one-piece hard copper tip; others have a two-piece hard copper tip; others have a two-piece tip and mixing head combination. The tip sizes are designated by numbers, and each manufacturer has his own arrangement for classifying them. The tip sizes differ in the diameter of the orifice so that, in each case, the correct volume of heat for the work to be done can be obtained. Extreme care must be exercised to prevent damage to the orifice of the tip, since the tips are made of copper or brass. Tips should be cleaned with either a soft copper wire or a tip drill made specifically for cleaning the tip.

13-8. Now that you have studied about the construction of gas welding equipment, it is logical that you should learn about setting up and using the equipment. Setting up the apparatus and preparing for welding must be done systematically (in a definite order) to avoid costly mistakes. You should have and follow, in sequence, your list of instructions to assure your own safety and the safety of your equipment. First, you should always secure the cylinders so that they will not be upset; then you may remove the protecting caps. Next, you should crack the cylinder valves by opening each valve slightly for an instant, to clean it out; then, close the valves and wipe off the connections with a clean cloth. Next, you connect the acetylene pressure regulator to the acetylene cylinder and install the oxygen pressure regulator on the oxygen cylinder. You use the special regulator wrench for doing this. Be sure to tighten the connecting nuts enough to prevent leakage. After this, connect the red hose to the acetylene regulator and the green hose to the oxygen regulator, tightening the connecting nuts sufficiently to avoid leaks. As you do this, notice the left-hand thread on the acetylene hose connections.

13-9. Be certain that the oxygen and acetylene regulator adjusting screws are released. In this way you avoid damage to the regulators when the cylinder valve is opened. Now open both cylinder valves slowly while you read the high-pressure gages to check the contents of the cylinders. You next blow out the oxygen hose by turning the regulator screw inward; then turn it back out again.

13-10. If it becomes necessary to blow out the acetylene hose, be sure to do it in a well-ventilated place that is free from sparks, flame, and other sources of ignition. Now, you should be ready to connect the hose to the torch. You fasten the red acetylene hose to the connection gland that has the needle valve marked "AC," and attach the green oxygen hose to the connection gland having the needle valve stamped "OX." Test the hose connections for leaks by turning both regulator adjusting screws inward; then drain the hose by opening the needle valve. Next, adjust the torch tip by screwing it into the mixing head and installing the head in the torch body. Tighten the head by hand and adjust the tip to the proper angle; then secure this adjustment by barely tightening it with the wrench provided with the torch. Now you adjust the torch to the acetylene gas working pressure by opening the acetylene torch needle valve and turning the regulator adjusting screw to the right. Also adjust the regulator to the required working pressure for the tip size. Finally, light and adjust the welding tip by opening the acetylene torch needle valve and lighting the gas with the spark lighter. After the torch is lighted, you open the oxygen needle valve and adjust the pressure for the desired flame cone. You must not allow any oil or grease to be near the oxygen, and be extremely careful not to drop any of the cylinders.

It can be extremely dangerous for either of these conditions to occur.

13-11. Here is more specific information about adjusting the flame. You should hold the torch so as to direct the flame away from you, the gas cylinder, hose, or other inflammable materials. The pure acetylene flame is long and bushy with a yellowish color. Since the oxygen valve is closed at this time, the acetylene is burned by the oxygen contained in the air. This amount, however, is not sufficient to burn the acetylene completely; therefore, the flame is smoky and produces soot composed of fine unburned carbon. The pure acetylene flame is also unsuitable for welding. When the oxygen valve is opened to supply more oxygen, the acetylene flame becomes shorter and the mixed gases burn in contact with the tip face. The flame also changes to a bluish-white color and forms a bright inner cone surrounded by an outer flame envelope or sheath flame. It is the inner cone that develops the high temperature heat required for welding. The outer flame contains varying amounts of incandescent carbon or soot, depending upon the proportion of oxygen to acetylene.

13-12. There are various types of flames used in welding, but you are primarily interested in the neutral flame, because it is the one you will be using. Consequently, the discussions are about only this one type. The neutral flame has two clearly defined zones. The inner portion consists of (1) a luminous bluish-white cone and surrounding this cone is (2) the large flame envelope or sheath that is faintly luminous and has a light bluish tint to it. The neutral or balanced flame is produced when the mixed gases, supplied from the torch, consist of approximately one volume of oxygen, one volume of acetylene, and one and one-half volumes of outside air. When welding steel with this flame, you will find the molten pool of metal to be quiet and clear. You will notice that the metal flows easily without boiling, foaming, or sparking. At the tip of the inner cone the temperature of a neutral flame is approximately 585° F. Your supervisor will orient you on the proper method of holding the welding rod and torch, and he will also show you how to cause the metal to flow properly. You must then practice until you are proficient in the welding operation. After you have completed a welding job, you must shut down the welding equipment and disassemble it properly.

13-13. When shutting down, you first close the acetylene end valve. This prevents black smoke from collecting in the shop, and it stops the flame from backing up in the hose to cause an explosion which can be very destructive. Next you close the oxygen valve for complete shutoff of the torch, and also close the main valve on the tops of both the acetylene and oxygen bottles. Then, go back to the torch and open the cylinder valves to release the acetylene and oxygen in the hoses and cylinder pressure gages. Also, screw out the oxygen regulator gage about two turns to release any tension, and thus avoid damage to the regulator valve seats and diaphragm. You should use the special wrenches made for the acetylene and oxygen bottles when removing the regulators. After this, replace the caps on the bottles and store the gages and hoses in a safe place.

13-14. **Electric Arc Welding.** The ac-dc (rectifier type) arc welding machine (both portable and stationary units) because of its versatility is now being adopted for military use. The welder gives you the choice of ac or straight or reverse polarity dc by throwing a switch to one of three positions. It can be used in areas where only single-phase power is available. It occupies less floor space and removes the necessity of having two independent arc welders of the same rating, thereby reducing maintenance upkeep.

13-15. For you to produce welds of sound quality, it is important that the arc welder which you use be in satisfactory working order. Usually, the equipment that is needed for welding will consist of an ac-dc rectifier type or a dc type of welding machine, a shielding helmet (lenses-shade 10 to 12 for 75 to 400 amps and 12 to 14 for over 400 amps), dry protective clothing and gloves, cables and the electrode holder, welding materials, a chipping hammer, and grinding goggles. It is also recommended that you wear hightop shoes. The welding machine controls provide for adjusting amperage, voltage, and making other adjustments. They must be made to provide the correct current for the following conditions: the electrode used, the thickness of the plate being welded, the position of the weld, and the welder's skill. An experienced welder and trainer should start you out on the same machine you will be using to gain your experience. You will then begin by learning to make these adjustments on your own machine. The experience you gain will also be a good guide for making the necessary adjustments to fulfill the requirements for the job.

13-16. It is important that you avoid hazards that can have a bad effect on you and your equipment or upon other personnel. Certain factors in the direction of hazard prevention should be considered.

13-17. You should observe all protective measures. Avoid standing in water, standing on wet floors, or coming in contact with grounded surfaces.

13-18. Use the safety screens to protect others from *arc glare* during welding operations, and always keep a suitable fire extinguisher available *at all times* during welding.

13-19. **Metallic Arc Welding.** The metallic arc welding process is one of the three major welding processes that do not require pressure to complete the weld. This arc welding consists of local progressive melting and adhering together of the adjacent edges of the metal by applying the temperatures (ranging from 5,000° to 10,000° F), that are developed in the electric arc between a suitable electrode (or electrodes) and the base or parent metal. Metallic arc welding machines are classified as direct and alternating (or a combination of both). Brief discussions of each machine are provided in the text that follows.

13-20. Arc welders are classified according to two principal processes — metallic arc and carbon arc. The metallic arc is the most common method of welding that is used in the shop; so only this type of arc welder will be covered in this chapter.

13-21. The direct current arc welder consists of a heavy-duty dc generator driven by a suitable type of motive power. The current flows or is maintained in the same direction, which results in the work and the electrode being of opposite polarity. When the work is made positive and the electrode is made negative, the arrangement is termed "straight polarity," while the opposite indicates "reversed polarity."

13-22. The polarity of the welding machine reverses with each alternation of the current, and special electrodes must be used to produce satisfactory welds. In welding, an arc is formed between the work and the electrode, resulting in development of a molten pool in the base metal. A crater or depression is made by the force of the arc and serves to indicate penetration. Satisfactory welds cannot be made or produced unless you keep in mind the variables that affect welding.

13-23. It is necessary to check these variables carefully. They are primarily basic to the proper use of the alternate current welder, but they are also factors to consider in other welding operations. The major variables over which you must maintain control are: welding current, arc length, polarity (polarity is a factor to be considered when using direct current), speed of travel, voltage, position of electrode, manipulation techniques, and types of electrodes used.

13-24. **Safety Considerations.** You should wear protective hightop shoes to avoid getting hot slag burns. Wear protective clothing that is not frayed at the cuffs. You must be sure that you have adequate ventilation for welding operations. All welding must be done in accordance with the welding code. In arc welding, just as in gas welding, the best way for you to learn is for your supervisor to demonstrate the proper procedures and for you to practice welding.

Summary

TOOLS ARE VERY essential to you for successfully fitting pipe and completing other work as a heating systems specialist. You surely understand that without the proper tools and the know-how to use them you cannot do your job well.

In the text you studied about the care and use of such handtools as screwdrivers, wrenches, hammers, pliers and nippers, files, calipers, rules and tapes, hacksaws, cold chisels, soldering irons, grinders, portable electric drills, blowtorches, pipe cutters, pipe reamers, pipe threaders, tubing cutters, and flaring tools. Upon reviewing this list of tools you realize that they are common to other fields as well as the heating field.

Tools should be used only to do jobs for which they are designed, and then used correctly. Pointed and cutting tools should be kept sharp, and they must be sharpened correctly to obtain good results. The handles of tools should be kept in good condition. Split or broken handles should be replaced, and rough handles smoothed or replaced. Upset (mushroomed) metal handles should be ground down. Good handles should be used on all tanged tools. Care must be exercised to avoid overtorquing and subjecting tools to excessive strains. (Nuts, studs, screws, etc., should, of course, be torqued to the specified amount but not excessively over this amount, because they too can be broken or otherwise damaged.) Tools should never be dropped, because they will surely be broken, cracked, dulled, sprung, warped, or otherwise damaged. Care must be taken to avoid kinking tapes. Keep all rotating tools such as grinders, sanders, drills, and others in balanced condition. Use flame tools and equipment with extreme care, and always treat the unstored units as if they are hot. Clean and condition tools after using them and before storing them. Inspect them for defects and lubricate them.

As you practice pipefitting, you should remember that the pipe must be cut to the proper length. Then it can be successfully connected by means of threaded, soldered, or welded joints. Connections that are improperly made will leak and cause excessive loss of water, fuel, and labor. You should always keep in mind and obey the safety precautions which are recommended for each work operation. These precautions can prevent injuries to you and others, and damage to the tools, materials and equipment.

Welding is used on the job and in the shop to repair heating components and make pipe connections. Two common methods of welding and the machines are used by the welder in accomplishing his work. These are oxyacetylene welding and electric metallic arc welding. The apprentice learns welding by doing simple jobs first and then progressing to more complex work. The operator who welds pressure vessels must be a certified welder. This is a goal for you to work toward as a welder.

There is considerable danger in welding for the *careless operator,* and much less for the *careful welder*. In either case there is danger involved, and the operator of welding equipment must follow the correct sequence in setting up the equipment, observe the instructions for using it, and wear the correct protective clothing.

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Electricity

THE PRACTICAL use of electricity has been a development of mankind for a little over one hundred years. During this time, he has learned more about the rules governing the behavior of electricity and has made more varied applications of electricity than he has about any other known force. Designs of electrical units can be developed by engineers and their performance predicted in advance. Yet, with all this knowledge and know-how, no one knows exactly what electricity or magnetism is. We do know, however, that electricity is a very strange and interesting force that can be transformed into many forms of energy to produce heat, light, and motion.

Years ago man learned how to put electricity to work. But the early inventors could not possibly foresee the almost limitless applications of electricity to labor-saving, comfort-giving, and safety devices and equipment. Even as late as immediately prior to World War II most of the developments in the heating field were centered around hand-fired furnaces and boilers. With the later developments of modern electric and electronic controls and instruments, however, it became necessary that the heating specialist also become familiar with these controls and the electricity that operates them.

You can clearly realize the effect that electricity has had when you see a burner or stoker motor start and operate. However, the forces at work and the action taking place in the wire conductors are not easy to realize. Since it is impossible for the human eye to actually see the flow of electrical current through a conductor, it becomes necessary for you to be sufficiently acquainted with the nature and behavior of electricity to visualize the action. Your ability to form accurate mental pictures of the events occurring within electrical circuits does not depend on a high degree of intelligence. Instead, this seemingly difficult ability hinges primarily on understanding a small number of electrical principles which, surprisingly enough, are logical in nature and not difficult to understand. Once you do understand the principles, you can build on them to learn and understand the rules that govern the practical applications of electricity in all of its existing relationships. When equipped with this basic knowledge, you will be in the best possible position to mentally "see" what takes place inside the electrical circuit.

All activity which takes place in any type of electrical circuit depends on the behavior of tiny electrical charges called *electrons*. To understand the behavior of electrons, you must first understand the nature of matter. Hence, your first step in the study of electricity involves learning how electrons fit into the world of physical things that surround us.

14. Nature of Matter

14-1. The word "matter" is one generally used to describe all things in existence. This single word includes everything that has weight, volume, and occupies space. Thus, this word can be applied to any one thing or everything which is known to exist in our everyday world. It is common knowledge that all solid matter — metal, stone, wood, etc. — is actually made up of large numbers of very tiny particles, rather than existing as solid bulk. Matter in the form of gases and liquids is also made up of tiny particles. Therefore, all matter, including metals, air, and water, must be thought of as being composed of a tremendous number of tiny particles massed together to form that particular substance.

14-2. At one time or another most of us have heard about the hundred or so pure *elements* which individually or in combinations make up the entire world of matter. Each element can be properly regarded as matter, since each has weight and occupies space. So, here again, we find that elements are composed of tiny particles, a condition typical of the structure of all matter.

Some common examples of elements are hydrogen, oxygen, gold, copper, iron, mercury, and radium. Although some of the many elements can be isolated and made to appear in their pure state, it is far more common to find single elements combined with other elements to make up matter in all of its existing forms. Matter that is made up of a combination of two or more elements is technically called a *compound.*

14-3. The smallest particle into which any one element can be divided and still be identified as that element is known as the *atom.* When elements are combined to form a specific compound, it is the atoms of the separate elements which join to produce that compound. The smallest particle into which any compound can be divided and still be identified as that compound is known as the *molecule.* These molecules of the compound are all identical, of course, and are made up of the atoms of those elements that have combined to form the compound. The interesting thing about this combining process is the fact that after two or more elements are joined, the physical and chemical properties of the newly formed compound differ entirely from those of the pure elements that went into its makeup.

14-4. One common example of a compound is ordinary table salt; another example is water. Table salt is the result of the combination of two separate and distinct elements — sodium (a metal) and chlorine (a gas). The structure of a single molecule of salt is shown in figure 66.

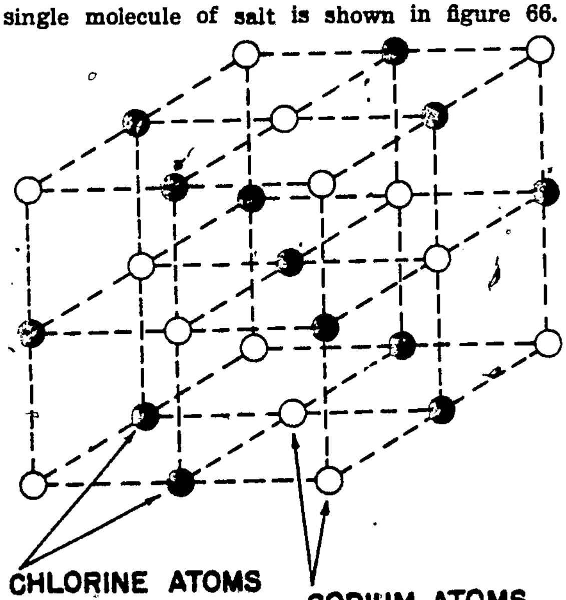

Figure 66. Salt crystal.

Water represents another combination of two other separate elements — hydrogen and oxygen. In this last example, it should be obvious that either one of the two distinctively different gases has nothing in common with water. These examples are only intended to show the manner in which all compounds are fashioned.

14-5. To show the relationship between compounds and elements, we need to closely compare the nature of their basic principles, molecules and atoms respectively. To do this, let us scientifically discuss water.

14-6. If a single drop of water were to be divided again and again until there remained the smallest possible particle that still could be identified as water, that particle would be a molecule of water. In a similar manner, all compounds can be reduced to molecules, with each of these molecules having all the characteristics of the substance of which they are only a minute part. Thus, one molecule of water would still have the same appearance and the same characteristics of a drop of water.

14-7. If this molecule of water is now further divided, what remains is no longer water, because we have now separated the molecule into the atoms of the two elements — hydrogen and oxygen — which were chemically combined to form the molecule of water. These hydrogen and oxygen atoms represent the smallest division into which these elements can be divided and still keep their identity.

14-8. Previously, it was mentioned that atoms combine to make up all compounds. Since this is true, we should not be too startled to find within a molecule of water the atoms of those elements which are the ingredients of water.

14-9. To carry the thought through, remember that water is just one of an infinite number of compounds. Any compound, then, can be divided until the molecules of that compound are reached. Then, any further division resolves that molecule into atoms, and this sample of the compound no longer exists as that compound. Furthermore, since compounds and pure elements constitute the entire realm of all matter, then the atom is looked upon as the basic construction unit upon which our world — indeed, our universe — is built.

14-10. At this time a question concerning the elements may be raised. If atoms constitute the primary makeup of all the hundred or so elements, what accounts for the physical differences between the elements? Why should there be any difference between any two elements — hydrogen and copper for example? The answer lies in the fact that each of the atoms contained in any one specific element is *structurally different* from the atoms contained in all other elements. Since the structure of each atom is different, the elements themselves, as they appear to us, also differ in appearance and other physical qualities.

15. Structure of the Atom

15-1. By examining different atoms, we find that all atoms are constructed of *protons, neutrons,* and *electrons.* Within the atom, each proton is known to contain a *positive* electrical charge; whereas each electron within the same atom is a *negative* electrical charge, and each neutron contains no charge. All of the protons and neutrons are grouped together to form the nucleus, or core, of the atom. The electrons (planetary electrons) revolve about the nucleus in definite orbits, or paths, in much the same manner as the planets revolve about the sun. In the study of electricity, we are primarily interested in the outer orbits of electrons.

15-2. The atom of one element differs from an atom of another element only in the number and arrangement of electrons, neutrons, and protons. Figure 67 shows some examples of this difference in atomic structure. The hydrogen atom is the simplest of all; it consists of a nucleus with only one proton and has but one planetary electron. The single proton makes up the entire nucleus of the atom, and the one electron constitutes the entire planetary system. The atoms of all other elements have some neutrons within the nucleus. The simplicity of the hydrogen atom can be appreciated when it is compared to a uranium atom. The latter has a nucleus made up of 146 neutrons and 92 protons, around which revolve 92 electrons arranged in seven concentric orbits.

15-3. Under normal conditions, each atom contains an equal number of protons and electrons. The planetary electrons (negative) are held in their orbits by the attraction of a like number of protons (positive) concentrated within the nucleus of the atom. The atom itself will always react to maintain this relationship between its protons and electrons. Should some external force displace an electron from the outer orbit of an atom, the atom will immediately attempt to attract another electron to restore its normal electrical balance.

15-4. Under normal conditions, each individual atom is electrically neutral, because the equal number of positive and negative charges within the atom cancel each other.

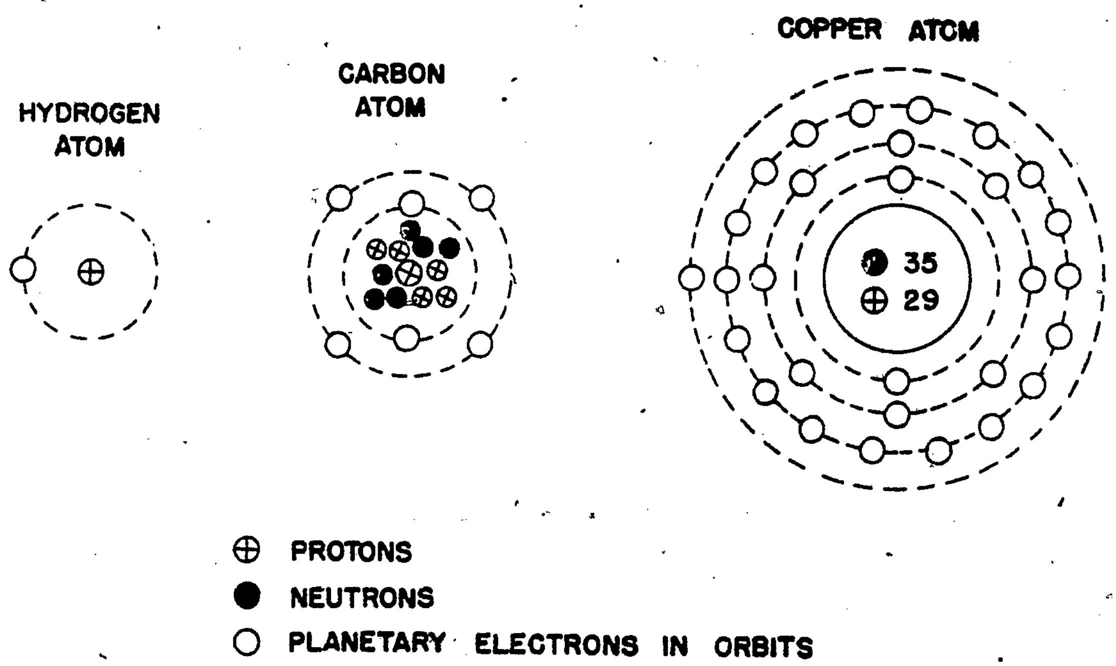

Figure 67. Example of atomic structure.

15-5. From the foregoing information, you should now realize that all matter is basically electrical in nature. Furthermore, all solid-appearing compounds are not really solid but are actually more porous than we imagine. This is due to the relatively large empty spaces which exist between the nucleus and planetary electrons of an atom, as well as the emptiness existing between the atoms themselves.

15-6. To illustrate this point, let us consider an ordinary one-cent piece. If this penny could be enlarged to a great copper disk 189,000,000 miles in diameter (the same size as the diameter of the earth's orbit around the sun), the individual atoms would then be spaced about 3 miles apart. In this enlarged picture the electrons would now appear to be the size of baseballs.

15-7. The tremendously large numbers of whole atoms contained in any substance move constantly. In this restless state there are frequent collisions between atoms which cause some electrons to be jarred loose from their orbits to quickly interchange positions with other electrons within the same substance. That the collisions occur is not so strange when we consider the 700,000,000,000,000,000,000,000 electrons in motion and contained within an ordinary copper penny. Strange as it seems, this is the true nature of all things in the world today.

16. Electrical Charges

16-1. Up to this point our discussion has been centered on the structure of the atom, which, because of its balanced proton-electron structure, is electrically neutral. The same is true of the entire compound when it is made up entirely of these balanced atoms. However, by introducing one of several external forces, electrons within a substance can be released from the outer orbits of their atoms. Electrons detached from atoms in this manner are called *free electrons,* since they are now free to attach themselves to neighboring atoms of the same substance or to the atoms of some other substance. The ability of relatively small forces, which exist or can be made, to detach electrons makes it possible for normally neutral substances to acquire either a positive or negative electrical charge.

16-2. If, by any method, a substance gains electrons from an outside source, the substance automatically becomes *negatively* charged. Hence, to have a negative electrical charge, a substance must simply have more electrons than protons — more electrons than it has in its normally neutral state.

16-3. On the other hand, when a neutral substance loses some of its electrons to some other substance, it immediately acquires a *positive* electrical charge. Hence, any substance having a positive charge is simply one which has fewer electrons than protons.

16-4. In simple experiments with static electricity (electricity at rest), the most common method of charging substances is by the use of friction. The act of rubbing two suitable substances together brings the planetary electrons of each substance in such close contact that one substance will readily lose some of its electrons to the other. Such is the case when a glass rod is rubbed briskly with a silk cloth. By this process the glass rod loses some of its electrons to the silk cloth. This results in the glass rod being left with a positive charge and the silk cloth acquiring a negative charge. Since the number of electrons gained by the silk cloth is exactly equal to the number lost by the glass rod, the two substances are said to be *equally and oppositely* charged. It must be remembered, however, that each of the charged substances still has large numbers of normal atoms which were not altered by the charging process.

16-5. To separate the silk cloth from the glass rod requires overcoming the force of attraction that exists between unlike charged bodies. If the two substances are allowed to touch each other again, the surplus electrons on the silk cloth will return to the glass rod, resulting in each substance returning to its former neutral state. Any spark that might occur from the two unlike charged bodies being placed close together is caused by the surplus electrons jumping the airgap to restore the electron balance of the two substances.

16-6. This, and other similar experiments, can be used to predict the behavior of all charged bodies. From these experiments the two following conclusions have been established. First, *like charged bodies repel* each other. Second, *unlike charged bodies attract* each other. Hence, electrons will repel other electrons but will be attracted to protons.

16-7. In regard to two bodies having unlike charges, it is important to note that each charge can be neutralized in a manner other than by allowing the two substances to touch each other. Instead, when a length of copper wire is placed between and touching the two bodies, an immediate redistribution of the electrons between the two substances takes place. For example, if the copper wire were placed between the glass rod and silk cloth, the *electrons within the copper wire* would be attracted by and move toward the glass rod (positive) and repelled by the silk cloth (negative). Hence, a shifting, or movement, of electrons would occur from the cloth through the copper wire to the rod. However, this electron movement lasts for only that split instant of time necessary to bring the two substances to their normal uncharged condition. Once a balanced electron condition of the two substances is reached, all further coordinated electron movement between the two substances stops.

17. Electromotive Force

17-1. From the above information it should be clear to you that no electron movement will occur unless an *electrical pressure* exists between two points of a conductor. The pressure is created simply by causing an imbalance in the number of electrons between two points of a conductor. When this condition occurs, a *difference in potential* is said to exist between those two points. Since this electrical pressure, or difference in potential, is the force which causes electron movement through the conductor, it is called an *electromotive force* (emf). Still another word used to describe this pressure or force is *voltage.* It is very important to remember that voltage, electromotive force, and potential difference are three different ways of saying the same thing. They all mean the same thing — electrical pressure.

17-2. Two common sources of emf, or voltage, that are probably most familiar to us are the lead-acid battery and the generator. The lead-acid (wet cell) battery used in our automobiles creates a difference in potential between the battery terminals by *chemical action.* The ordinary automobile generator similarly creates a difference in potential, or voltage, by *electromagnetic action.* In each case, the result is the same — a force capable of moving electrons.

17-3. At this point in our discussion, it is necessary to fix firmly in our minds the fact that pressure in itself does not move. When charging a cylinder or other suitable container with air, we think of the air pressure exerting its force equally at all points within the container, but certainly not as being in motion within the container. This is also true of voltage. It can exist in varying amounts within a conductor, but it does not move along the conductor. Actually, it is the electrons within the conductor that move, and their movement is caused by electrical pressure.

17-4. Since it is possible to have greater or lesser electrical pressure exerted on a conductor, it becomes necessary to have some way of expressing this difference. For this purpose, a unit of measurement of electrical pressure is required. This unit of measurement is the *volt.*

18. Electric Current

18-1. Figure 68 shows a battery with a copper wire connecting the two terminals. The surplus electrons at the negative terminal repel electrons from the atoms of the copper wire near the negative terminal. The positive battery terminal attracts electrons from neighboring atoms in the copper wire. This condition causes movement of electrons from atom to atom along the entire length of the copper wire. However, this movement involves only a small percentage of the total number of electrons contained within the copper wire. By far the largest number of electrons remain fixed within the neutral atoms of the copper wire. Notice that the electrons flow from negative to positive through the copper wire. This concept of electron movement is known as the *electron theory of* electricity.

18-2. Many years ago, Benjamin Franklin's experiments with electricity revealed to him that electricity involved the movement of "something" through the air or through a wire. He was not sure of what moved nor in what direction it moved. He considered it a "flow" of something similar to water; hence his theory became known as *current flow.* He assumed that this current, like water, would flow from a high level to a lower level, and he was right. However, he got his levels mixed up, and thus he assumed the motion to be from positive to negative. This theory was accepted, built upon, and used for many years. The theory became the basis for textbooks and rules governing electrical circuit operation.

18-3. Years of further study and further experiments have proved Franklin's guess to be wrong. The electron theory is now accepted as being correct. Even though today negative indicates the presence of electrons and positive the lack of electrons, we use the words to refer to

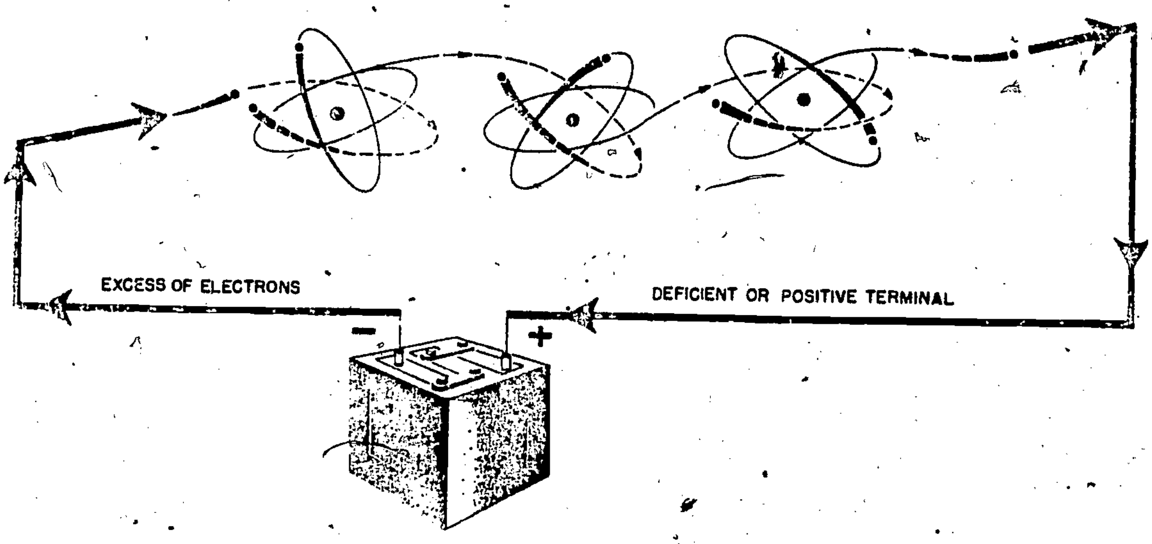

Figure 68. Electron movement through a conductor.

the same terminals of a source of electrical power as did Mr. Franklin.

18-4. The two theories now exist side by side because of the difficulty involved in trying to change or get rid of all material written in the past. In many recent texts, including military technical manuals, you will find that the current flow theory is used in discussion involving *direct current* (dc) circuits and that the electron theory is used in discussion concerning *vacuum tube* operation and some *alternating current* (ac) principles. This course will use the electron theory, and during the ensuing discussions we will again note this difference at points of possible confusion. As far as the *effects* produced by electrical current are concerned, it seldom matters which theory is used.

18-5. Electric current, then, is the movement of electrons through a conductor. If a steady difference of potential exists between two points of a conductor, a continuous current will flow through that conductor.

18-6. To produce any noticeable effect, extremely large numbers of electrons must be moved through a conductor. The word "coulomb" is used to express such a quantity of electrons. In the study of instruments, the coulomb will seldom be encountered, except in the study of electrical fundamentals. The coulomb represents a quantity of 6,280,000,000,000,000,000 free electrons. When 1 coulomb of electrons passes a given point on a conductor in 1 second, there is said to be *1 ampere* of current flowing through the conductor. Remember, a coulomb is a quantity of electrons, and an ampere is the unit of expression for the *rate* of electron flow.

19. Electrical Resistance

19-1. Previously, we mentioned that perfect conductors or perfect insulators do not exist. This statement can then be interpreted to mean that all good conductors offer at least some opposition to current flow. The opposition which either a conductor or an insulator offers to the flow of electrons is called *resistance.*

19-2. From our brief study of the nature of matter, we learned that all substances have a different electron arrangement. It follows, then, that different materials will vary in their ability to transfer electrons. Said another way, different substances offer different amounts of resistance to current flow. For this reason, the type of material used is one of the four factors that determine the amount of resistance present in any conductor. Now, compare the current in a conductor to water flowing through a pipe. The greater the diameter of the pipe, the less opposition it offers to the flow of water. So, diameter of the material becomes another factor. On the other hand, the longer the pipe, the more wall area the water has to pass, and so the greater the opposition is to flow. Consequently, the length of the material becomes a third factor. You should remember that the resistance in a conductor is directly proportional to length and

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inversely proportional to cross-sectional area or thickness of the conductor.

19-3. The fourth factor determining the amount of resistance in a conductor is very important in its effect on instruments. This factor is *temperature coefficient of resistivity* or simply temperature coefficient. This means simply that while the resistance of one material can double, because of a 50° temperature increase, the resistance of another may increase so little as to be negligible, or even decrease. Most conductors are said to have a *positive temperature coefficient;* that is, as the temperature increases, the resistance increases. However, some materials, such as carbon, will decrease in resistance with an increase in temperature. These materials are said to have a *negative temperature coefficient.*

19-4. A length of copper wire offers less opposition to current flow than an iron wire of the same dimensions. As a result, copper is said to have less resistance than iron. Here we can see the need for some unit of measurement which will allow numerical values to be fixed to the amount of resistance present. This unit of measurement of resistance is the *ohm.*

20. Ohm's Law

20-1. In our brief discussion of electrical current, you probably have noticed that there are two factors which determine the rate of electron movement. First, we pointed out that a difference in potential, created by a difference in the number of electrons at two points along a conductor, caused electrons to move. Then, we pointed out that all conductors offer some opposition to this electron movement. From these two observations, we can conclude that the amount of current flow is determined not only by the amount of electrical pressure but by the amount of resistance present as well. Since a relationship exists between voltage and current on the one hand and between current and resistance on the other, it seems logical that there should be one basic relationship between the three factors: voltage, current, and resistance. Such a relationship does exist and is simply expressed as Ohm's law.

20-2. Due to constructional features, all types of electrically operated equipment have a certain amount of inherent (built-in) resistance. This internal resistance is far greater than the amount of resistance present in wire conductors. Since conductor resistance is so small (when compared to equipment resistance), it is ignored in the consideration of total resistance in basic circuit operation. Therefore, for our purposes, circuit resistance will be considered to appear only in the electrically operated devices themselves. For example, if a single light bulb is connected to a voltage source, only the resistance of the light bulb is taken into account. In this instance, the resistance of the wire conductors is considered to be zero.

20-3. Since light bulbs, motors, relays, and all units common to electrical circuits have resistance, we can properly substitute the electrical symbol for resistance for any one or all of these electrical devices.

20-4. In every practical electrical circuit, there must be a complete or continuous path for flow of current. This path consists of a conductor which forms a closed loop between the voltage source and the electrical unit to be operated. This arrangement of closed connections between the voltage source and operating unit is called a *circuit.* In every circuit where there is a movement of electrons, voltage and resistance are also present. Thus, current, voltage, and resistance must be considered in order to clearly understand circuit operation. The relationship between these three factors is expressed by Ohm's law. Although this law applies primarily to direct-current (dc) circuits, it is also used, in modified form, to determine alternating-current (ac) factors.

20-5. Since Ohm's law contains two separate thoughts, it may be expressed by the following two statements: (1) current in any electrical circuit is *directly proportional* to voltage, and (2) current in any electrical circuit is *inversely proportional* to resistance. The combination of the above two statements is commonly expressed mathematically. In any circuit or part of a circuit, the current is always equal to the voltage divided by the resistance. Shown as an equation or formula, it is:

$$\text{current} = \frac{\text{voltage}}{\text{resistance}}$$

This same relationship expressed in the proper units of measurement for each of the above factors is:

$$\text{amperes} = \frac{\text{volts}}{\text{ohms}}$$

or, using symbols,

$$I = \frac{E}{R}$$

20-6. A good way to remember the symbols is to know the word or phrase from which each symbol is derived. Current has the symbol *I*, which is the first letter of the word "intensity" (or current flow). *E* is derived from the term "electromotive force," or voltage; and, of course, *R* denotes "resistance."

20-7. Before going on to a more detailed explanation, it is important that you remember that Ohm's law applies to any part of a circuit as well as the entire circuit.

20-8. A resistor is an electrical unit which is placed in a circuit to limit current flow. Since all dc electrical devices offer resistance, the electrical symbol for a resistor can be used to represent the resistance of any piece of equipment operated on dc electricity. When a light bulb or other unit having the same resistance value is substituted for a resistor, circuit values and circuit operation remain the same.

20-9. Let us assume that the battery voltage is 6 volts and the resistance is 3 ohms. By Ohm's law, then, the current flow in the circuit is determined by dividing the voltage by resistance.

$$I = \frac{E}{R} = \frac{6}{3} = 2 \text{ amperes}$$

20-10. Keeping this formula in mind, assume that the 6-volt battery is replaced with a 12-volt battery. Using the same method, you now find the circuit current flow to be 4 amperes.

$$I = \frac{E}{R} = \frac{12}{3} = 4 \text{ amperes}$$

Once again, if the 12-volt battery is replaced with a 24-volt battery, we can logically expect the circuit current flow to increase further, and it does.

$$I = \frac{E}{R} = \frac{24}{3} = 8 \text{ amperes}$$

20-11. These three simple problems in the application of Ohm's law should help you to understand the first statement of Ohm's law: *current is directly proportional to voltage.* In our three problems it should be noted that every increase in voltage (electrical pressure) brought about a proportional increase in current flow. In each case, the doubling of the voltage applied to the circuit resulted in doubling the amount of circuit current flow. Needless to say, if the voltage applied to a circuit were *reduced*, a proportional *decrease* in current would result.

20-12. If we assume that the battery voltage is 12 volts and the resistance is 6 ohms, then the circuit current of 2 amperes can be determined as follows:

$$I = \frac{E}{R} = \frac{12}{6} = 2 \text{ amperes}$$

Now, if only the resistor is replaced by a 12-ohm resistor, the current would be reduced to 1 ampere.

$$I = \frac{E}{R} = \frac{12}{12} = 1 \text{ ampere}$$

By replacing the 12-ohm resistor with a 24-ohm resistor, the current flow would be further reduced to ½ ampere.

$$I = \frac{E}{R} = \frac{12}{24} = 0.5 \text{ ampere}$$

It is important to note that, in each instance, doubling the resistance reduces the current to one-half of its previous value. These last three examples serve to show what is meant by current being inversely proportional to resistance.

20-13. For review purposes, table 1 shows the results of all the Ohm's law problems solved thus far in the order of their appearance. The first set of three problems is represented by block A. Notice that the circuit resistance remained unchanged. With this condition, an increase in voltage brings about a proportional increase in current flow.

20-14. In block B the voltage remained constant. Here it can be seen that an *increase* in resistance results in a *decrease* in current flow. This condition is known as an inverse relationship.

20-15. Using the values appearing in both blocks A and B, note that in each single problem *I* multiplied by *R* equals *E*, and *E* divided by *I* equals *R*.

21. Conductors and Insulators

21-1. In many nonmetallic substances, such as wood, rubber, and glass, the planetary electrons of each atom within the substance are held rather rigidly to the nucleus. The atoms of these substances refuse to free their planetary electrons easily. These kinds of substances are known as *insulators*. Additional substances commonly used as insulators are mica, bakelite, shellac, and paraffin. Dry air is also a good insulator.

21-2. On the other hand, most metals, such as copper, silver, and iron, have electrons in their outer orbits which are loosely bound to the nucleus. Upon the application of a suitable force, these electrons can be easily freed and made to move. Substances of this kind are called *conductors*. Platinum, gold, silver, copper, and aluminum are all good conductors. Copper is most commonly used as an electrical conductor, because it

TABLE 1

CIRCUIT CHARACTERISTICS

E ÷ R = I			E ÷ R = I		
Volts	*Ohms*	*Amperes*	*Volts*	*Ohms*	*Amperes*
6	3	2	12	6	2
12	3	4	12	12	1
24	3	8	12	24	0.5
BLOCK A			BLOCK B		

is relatively inexpensive, as well as strong and flexible.

21-3. When a conductor is connected between a substance having a surplus number of electrons (negative) and another substance having a shortage of electrons (positive), the immediate result will be a movement of electrons. The electrons within the conductor, being negative charges, will be attracted to the positive substance. At the same instant, this movement of electrons will be aided by the repelling force of the negative substance.

21-4. This electron movement is caused by an electrical pressure which always exists whenever there are more electrons at one point than at the other. This pressure exists whenever an unequal distribution of electrons occurs in one substance, or exists between two separate substances.

21-5. The greater the difference in the number of electrons between the two points, the greater the electrical pressure. In turn, the greater the pressure, the greater is the number of electrons that will be made to move. Likewise, the less the difference in the unequal number of electrons, the less is the pressure and the less is the amount of electron flow.

21-6. In addition to the electrical pressure exerted, the amount of electron flow also depends on how good a conductor is used. A good conductor offers little opposition to electron flow, whereas a good insulator offers a great deal of opposition to electron flow. Actually, there is no such thing as a perfect conductor or a perfect insulator. A substance is either a good conductor or a poor conductor, a good insulator or a poor insulator.

22. Electrical Circuits and Symbols

22-1. You will be concerned mainly with three aspects of electricity which are electrical shock, heat, and magnetic fields. Shock is one thing which an experienced man tries to avoid. A careless person can electrocute himself. The action of electromagnetic fields will be discussed later in this chapter. Heat is produced when current passes through a resistance. The greater the current, the greater is the heat. The heating effect of electricity is used in many ways. The filament in an incandescent lamp is heated so hot that it gives out light. The three types of circuits that you will be working with are series, parallel, and series-parallel.

22-2. **Series Circuit.** A series circuit is defined as one in which the current has only one path to follow. Knowing that electricity flows through copper conductors and that there is a pressure (voltage) pushing it through these conductors, the electricity will seek to find new paths through which it can travel. Figure 69 shows a series circuit. The series circuit derived its name from the fact that the electricity flows through a series of lamps that are connected one following the other, with each lamp consuming an equal amount of current.

22-3. In a series circuit, as shown in figure 69, when any one of the lights in the circuit fails to burn, all other lights in the circuit will also fail to light because the circuit is broken. Series-connected circuits are used where electrical heating system controls are used. All safety devices and controls must be hooked in series.

22-4. **Parallel Circuit.** A parallel circuit can be defined as one in which there is more than one path for the current to flow. In a parallel circuit, two or more electrical devices provide independent paths through which the current can flow. The voltage across each device in parallel is the same. The total current in the crcuit is equal to the sum of the currents flowing through all devices. Thus, the total amount of current is greater than the current in any individual part, and the total resistance (the resistance of the circuit as a whole) is less than the smallest resistance in it. (By Ohm's law—the current is greater: therefore the resistance must be less.) The more electrical devices or resistors connected in parallel, the greater will be the total current;

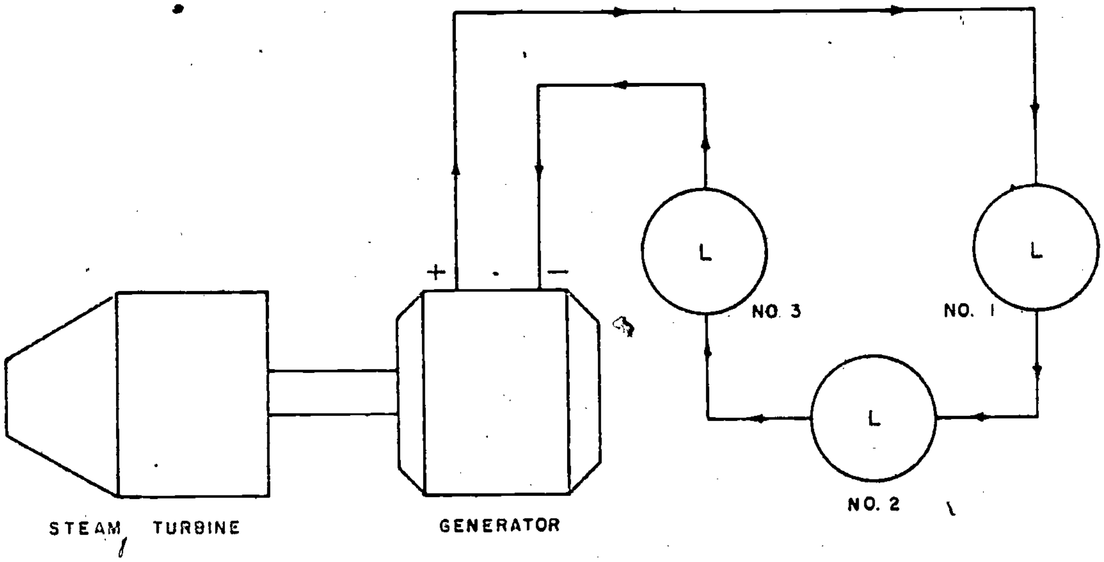

Figure 69. Series circuit.

hence the smaller is the resistance of the complete circuit.

22-5. Electrical devices are connected in parallel to decrease the total resistance and to allow them to be operated independently. If one device in a parallel circuit burns out, the others can still be operated. (One path is broken, but the others are still complete.) Figure 70 shows a parallel circuit.

22-6. **Series-Parallel Circuit.** The series-parallel circuit is a combination of the above two circuits and is not used as extensively as the other two.

22-7. **Electrical Symbols.** Electrical symbols are used in much the same way as are the mechanical symbols that you studied in Chapter 2. Figure 71 shows some typical electrical symbols.

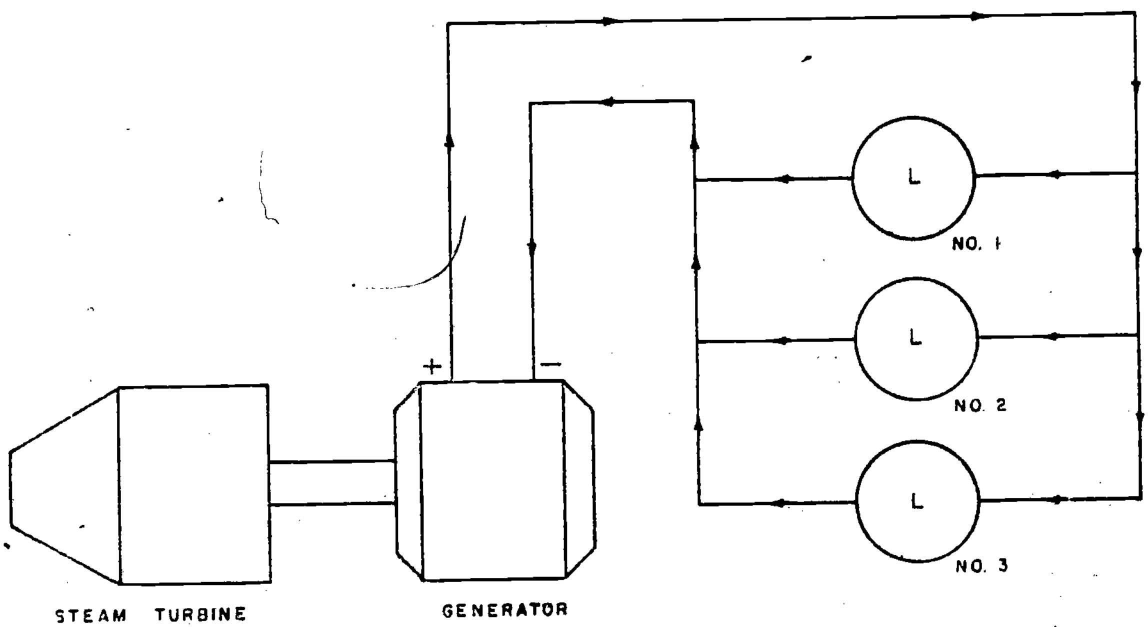

Figure 70. Parallel circuit.

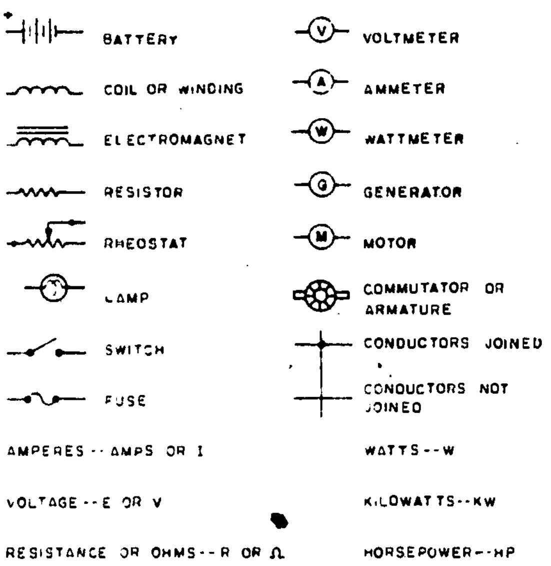

Figure 71. Electrical symbols.

23. Circuit Protective Devices

23-1. As determined from Ohm's law, if the resistance is extremely small, the current will be extremely great. For this reason, a great deal of trouble is caused by a short circuit such as results, for example, when the wires to a motor become bare and touch each other. Not only does the motor fail to run (because practically all the current is going through the short), but if a protective device—such as a fuse, circuit breaker, or a circuit protector—is not in use, there is danger of fire.

23-2. Fuses. A fuse is a strip of metal having a very low melting point, which is so connected that all of the current in the circuit flows through it. An alloy of tin and bismuth is used in most fuses. A fuse will melt and break the circuit whenever the current becomes excessive. Two types of fuses most used in the military are the screw-in type and the cartridge type. Since a fuse is a protective device, it is very important to use one that fits the need of the circuit in which it is to be used. When a fuse is replaced, it is necessary to check to see if the fuse is the correct type and capacity. All fuses are hooked in series; consequently, a fuse must not be installed in the ground side of a circuit.

23-3. **Circuit Breakers.** A circuit breaker is a device that breaks the circuit when the current reaches a predetermined value. It is often used in place of a fuse and sometimes eliminates the need for a switch. The feature which distinguishes a circuit breaker from a fuse is the fact that a circuit breaker can be reset, while a fuse must be replaced. Several types of circuit breakers are used by the military. One is a magnetic type which operates by the pull of an electromagnet on a small armature which trips the breaker. Another type is the thermal-overload breaker or switch, a bimetallic strip which, when it becomes heated, bends away from a catch on the switch liner and permits the switch to trip open.

23-4. Some circuit breakers have to be reset by hand, while others are automatic. When a manual-reset type circuit breaker trips to the OFF position, it is necessary to move it back to the ON position to put the circuit back in operation. An automatic type circuit breaker resets itself. If the overload is still present, the circuit breaker will again trip without damage to the circuit.

23-5. **Circuit Protectors.** The circuit protector is a device which automatically opens the circuit whenever the temperature of the associated unit becomes excessively high. It has two positions, automatic OFF and automatic ON, and it is most often used with motors. If an inoperative part causes the temperature of the motor to become excessively high, the circuit protector breaks the circuit. The operation of the circuit protector depends upon a bimetal disc or strip which bends and breaks the circuit when heated. Upon cooling, the bimetal disc or strip assumes its original position and closes the circuit.

23-6. Most electrical devices are rated according to the voltage that should be applied to them, also according to the power they require. For example, one lamp might be rated as a 115-volt, 40-watt lamp, while another is rated as a 115-volt, 20-watt lamp. This means that both lamps are to be operated on a 115-volt circuit, but twice as much power is required to operate the first lamp as the second.

23-7. You can find the wattage of an electrical unit—that is, the power it requires—by multiplying the current flowing through it by the voltage applied to it. Thus, a starter motor using 70 amperes with a pressure of 24 volts uses 1,680 watts of electrical power. To convert wattage to horsepower, divide by 746. Thus, by dividing the 1,680 watts by 746 (the electrical equivalent of 1 horsepower), you will find that the starter motor mentioned before will develop approximately 2 horsepower.

24. Measuring Devices

24-1. The measurement of electrical quantities plays a very important part in helping the heating specialist do his work. Electrical-indicating instruments have been devised for measuring the various electrical quantities. Such instruments are meters, and you need to master their use. Before using any instrument, read and follow all instructions for operation and safety.

24-2. *Ammeter.* The electrical instrument used to measure the amount of current in an electrical circuit is called an ammeter. It is connected in such a manner that it will measure all the current passing by a given point. When a meter is connected so all of the current flows through it, it is said to be in series.

24-3. *Voltmeter.* The electrical instrument used to measure the difference of potential or voltage is called a voltmeter.

24-4. *Ohmmeter.* The ohmmeter is an electrical instrument which is used to measure the amount of resistance in a circuit. The resistance of a circuit is one of the factors which determine its proper operation. Faults in circuits often can be located by checking the values of their resistance. Never connect an ohmmeter into an energized circuit. These meters are hooked in parallel with the circuit being checked, which must be isolated from other circuits to obtain a correct reading.

25. Magnetism

25-1. *Magnetic substances.* Long ago it was discovered that certain iron ore possessed the peculiar property of attracting small pieces of iron and certain other metals. Also, it was found that if a piece of the ore was suspended so it could turn freely, it would line up in nearly a north-south position, because it possessed natural magnetism. Consequently, pieces of this ore came to be used as compasses and were called *lodestones,* or *leading stones.* Pieces of iron or steel can be magnetized by rubbing them with a magnet, or by inserting them in a coil of wire and then passing dc current through the coil. Such magnets are called *artificial magnets.* If the bar is made of hardened steel, it will retain a large percentage of its magnetic strength. If the bar is made of soft iron, it usually loses most of its magnetic properties in a short period of time. If a material is attracted by a magnet, or if a magnet can be made of it, the material is called a *magnetic substance.* Iron and steel are the most common, although nickel and cobalt are also magnetic substances. Materials such as wood, glass, copper, aluminum, and rubber are not attracted by a magnet and cannot be magnetized and are called *nonmagnetic substances.*

25-2. *Magnetic fields.* The space around the magnet where the magnetic forces exist is called the *magnetic field.* If a sheet of plastic is placed over a bar magnet and iron filings are sprinkled over the plastic, the filings will arrange themselves as shown in figure 72. The lines described

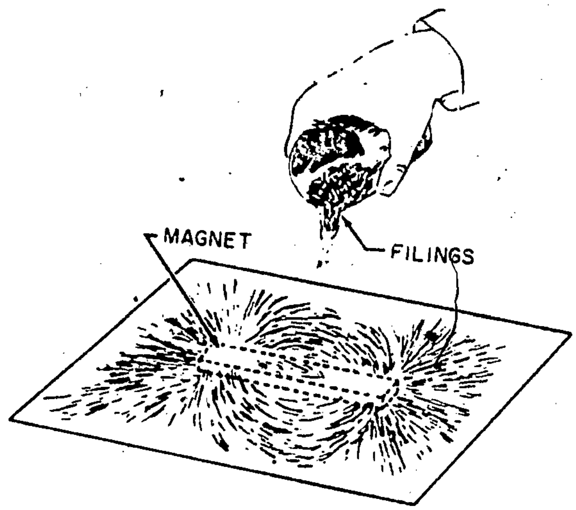

Figure 72. Pattern of lines of force.

by the filings are called *lines of force.* The field is strongest at each end of the bar and each end is called a pole. These poles are distinguished by the position they take when the magnet is freely suspended. The end that points toward the north pole is called the *north-seeking pole,* or simply the north pole; the other end is called the *south-seeking pole,* or the south pole. Scientists do not yet know why substances cannot be magnetized, nor do they know how to insulate against magnetic fields. Stray magnetic fields affect meters, watches, and other instruments. Such instruments can be shielded by placing them in a soft iron case so that the lines of force take the path through the soft iron case and do not affect the instruments.

25-3. *Behavior of magnets.* If the north pole of a magnet is placed near the south pole of another magnet, there is an attraction between the poles. The attraction is illustrated in figure 73.

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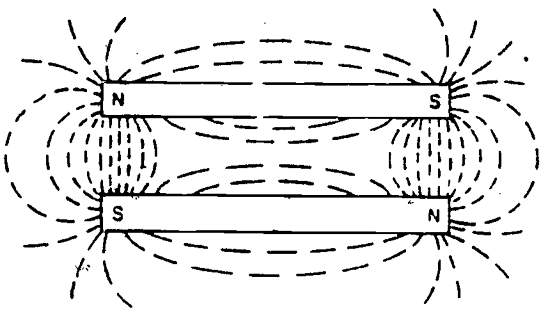


Figure 73. Attraction of unlike poles.

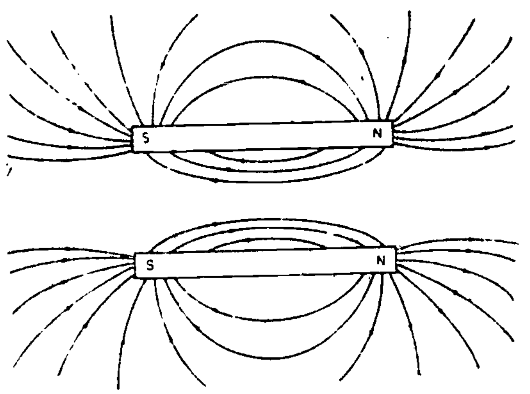


Figure 74. Repulsion of like poles.

The magnetic lines leave the north pole and enter the south pole. In figure 74, it can be seen that there is a force causing the like fields to push against each other. Thus, unlike magnetic poles attract each other; like magnetic poles repel each other, as shown in figure 75.

25-4. *Theory of magnetism.* When a magnetized needle is broken into two parts, then four, then eight, and so on, as far as you can go, each part will become a complete magnet with a north and a south pole. How far can this process go? Can a north pole ever be separated in this way from a south pole? Scientists say the process ends with the molecules themselves. On this basis the molecule is the smallest possible magnet and has north and south poles like any larger magnet.

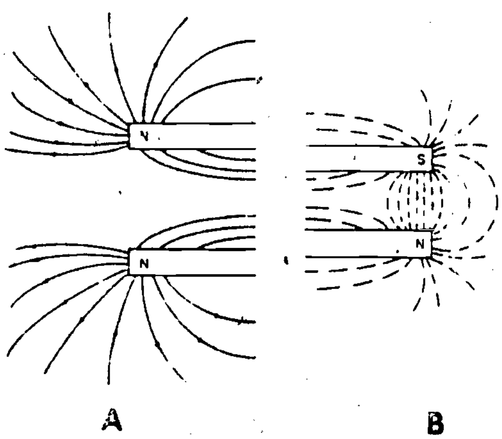


Figure 75. Comparison of magnetic fields.

25-5. It appears, then, that each molecule of a magnetized substance is a magnet. For example, in an unmagnetized piece of iron the molecules point in all directions. When the piece of iron becomes magnetized, the molecules are alined in a north-south manner. As a result, the magnetic effect of the molecules is cumulative, producing a magnetic field about the piece of iron.

25-6. *Electromagnetic fields.* Magnetic fields are also produced by electrical current. Such fields are called *electromagnetic fields*, and they are composed of lines of force like all other magnetic fields. In the field around a straight current-carrying conductor, for example, the lines of force are concentric circles. The force of the field is strongest close to the wire and decreases rapidly with increased distance from the wire. The direction of the lines of force in the magnetic field is determined by the direction of current flow in the wire. This is shown in figure 76.

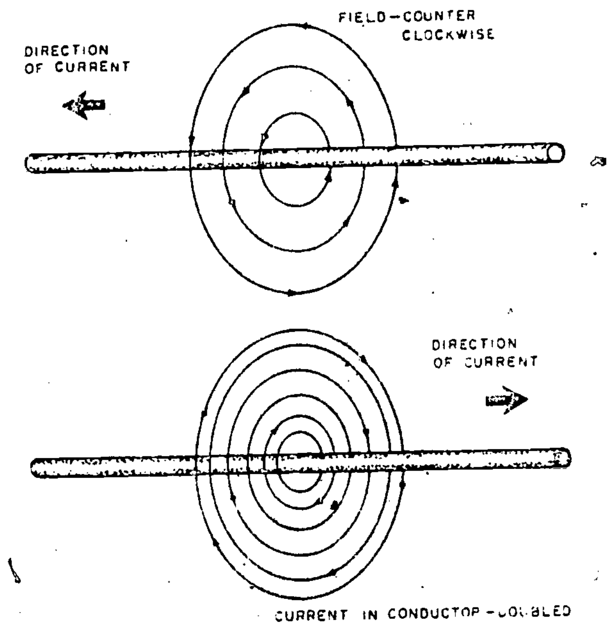


Figure 76. Magnetic fields around current-carrying wire.

25-7. We can test for the presence and direction of the field by the use of a simple circuit, a piece of cardboard, a compass, and iron filings, as shown in figure 77. When the compass is placed in different positions on the cardboard, the needle alines itself with the lines of force. The compass shows both the presence of a magnetic field and the direction of the field, since the north end of the compass needle points in the direction of the lines of force. When iron filings are sprinkled on the cardboard, they show the pattern of the magnetic field.

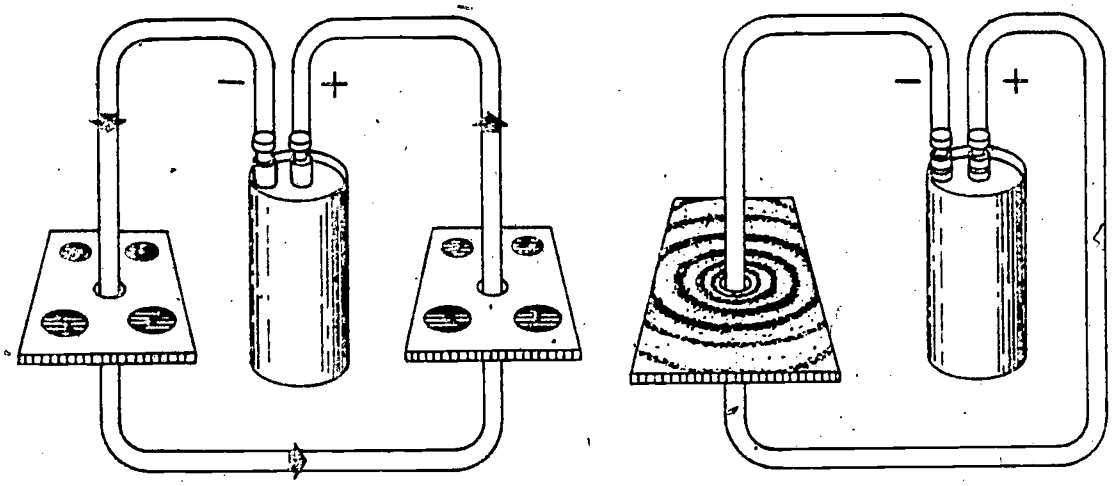


Figure 77. Compass and iron filings indicate field pattern.

25-8. The direction of the magnetic field about a current-carrying conductor can be determined by the left-hand thumb rule, illustrated in figure 78. The rule is: *With the thumb pointing in the direction of current flow, and fingers wrapped around the wires, the fingers point in the direction of the magnetic field.*

25-9. When a current-carrying wire is formed into a coil, as in figure 79, the coil takes on the characteristics of a bar magnet. The coil sets up a magnetic field that consists of lines of force passing through the center of the coil and returning outside the coil. Since each individual turn

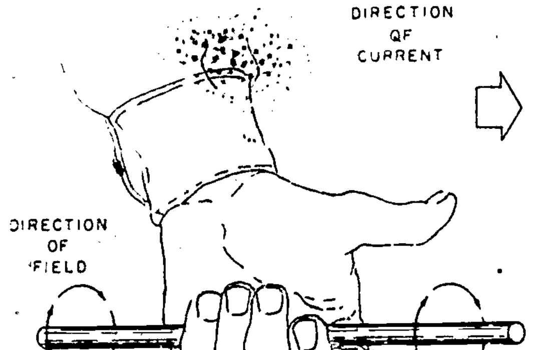


Figure 78. Left-hand thumb rule.

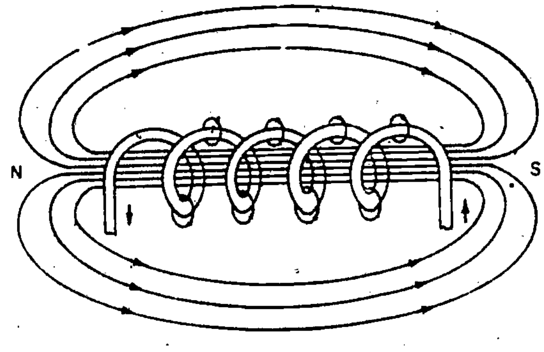


Figure 79. Magnetic field about a coil.

of wire has its own magnetic field, the total magnetic strength (magnetomotive force) of the coil depends upon the number of turns and the amount of current passing through the wire. Hence, the field strength of a coil is expressed in ampere-turns. For example, a coil having two turns and a current flow of 1 ampere should have a field strength of 2 ampere-turns. The field strength can be increased to 10 ampere-turns by increasing the current to 5 amperes (2 turns and 5 amperes), or increasing the turns to 10 and keeping the current at 1 ampere.

25-10. Again like the bar magnet, the coil has a polarity as well as a magnetic field, and the left-hand rule can be applied to determine this polarity. Figure 80 shows how this is done. With the fingers pointing in the direction of the current

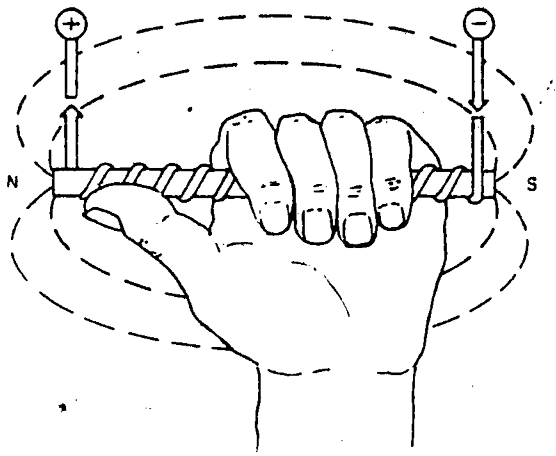


Figure 80. Left-hand thumb rule applied to a coil.

flow through the coil, the thumb points in the direction of the north pole. Thus, if the direction of current flow is reversed, the polarity is reversed.

25-11. *Electromagnets.* An electromagnet, shown in figure 81, can be defined as a fixed iron core in a coil of wire. The iron core is used to produce a stronger magnetic field than is possible without a core. A movable iron bar, referred to as the armature with contacts, is attracted to the iron core when the coil is energized, thus making or breaking the circuit. This is a type of relay.

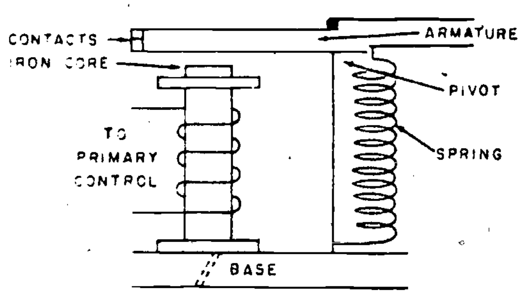


Figure 81. Simple relay.

25-12. *Electromagnetic devices.* Although the greatest concentration of flux in a current-carrying coil is through the center of the coil, the magnetic strength of the coil is comparatively weak. If a soft iron core is placed in the coil, however, the magnetic strength is enormously increased. The soft iron core has less reluctance than air, and as a result the concentration of lines of force is increased through the iron. Such a device is called an electromagnet. Large electromagnets are used for loading and unloading steel, pig iron, etc. Small electromagnets are used in electrical measuring devices, door bells, buzzers, and the like.

25-13. One of the most common types of electromagnetic devices used in controls is a relay. A relay is nothing more than a switching device. It can be controlled manually by electricity from distant locations, or controlled automatically by the circuit.

25-14. Almost all of the more common relays contain a length of insulated wire wrapped around an iron core, as you see in figure 82. When current is passed through the relay coil, a magnetic field builds up around the coil to make the iron

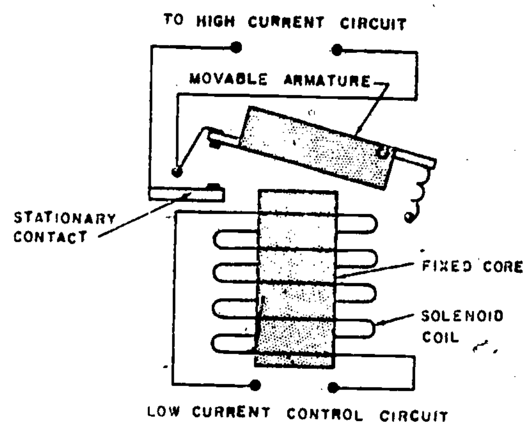


Figure 82. Armature type relay.

core an electromagnet. The switch end of the relay is made up of a piece of soft iron attached to some nonconducting material. This is hinged at one end of the relay frame and extends over the top of the relay coil. The instant current flows through the relay coil, the iron core pulls down on the free end of this armature, while the other end swivels on its hinge. At the free end of the armature we find one or more contact points which are made of copper, silver, or platinum.

25-15. The idea behind the relay is to create a switch by connecting one part of a circuit (or circuits) to these swinging contact points. Then, continue the circuit (or circuits) from one or more stationary contact points located somewhere in the downward path of the moving (armature) points. When these two sets of points come in contact with each other, the once open circuit becomes a closed circuit. The relay remains energized until someone or something shuts off the current flowing to the coil.

25-16. As you remember from an earlier discussion, a relay is nothing more than an electromagnetic switch. One relay can be made to control many other relays. In electronic controls, we can use a master relay to make other relays automatically open or close their respective circuits when a particular event in the firing sequence should take place.

25-17. *Solenoids.* For all practical purposes, solenoids are nothing more than heavier duty relays. The one main construction difference is that the solenoid moves an internal iron core instead of attracting an armature to close a set of contact points. Figure 83 shows the two parts of the high current circuit attached to two fixed contact points mounted in line with each other, but separated by an airspace.

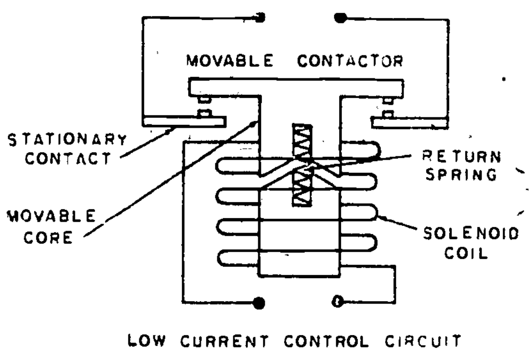
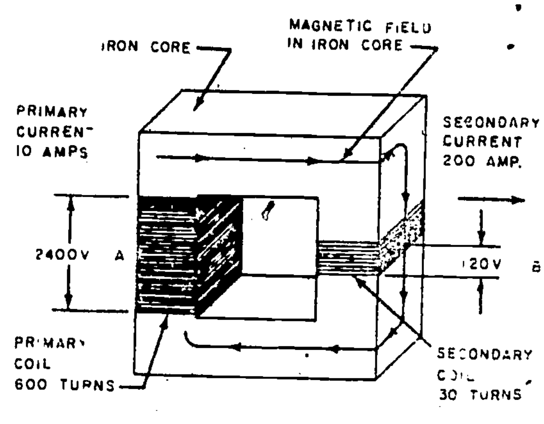


Figure 83. Typical solenoid.

25-18. When current is passed through the coil, the magnetic field developed around the coil pulls the movable iron core down into the coil. When it comes to rest on the fixed contact points, the core's metal T-head forms a bridge to complete the main circuit. Because of its heavy-duty construction, the solenoid can handle much higher main-circuit currents than a relay. Instead of simply closing the points, a solenoid can be used to operate a mechanism such as a valve, brake, change gear ratio, etc.

25-19. **Transformers.** In the discussion of solenoids, you found that by wrapping a coil of wire around an iron core and passing electricity through it a magnetic field could be produced in the core. Similarly, if a magnetic field can be passed through a coil, electricity can be produced in the coil. This is the principle of a transformer. (See fig. 84.)



$$\text{RATIO} = \frac{\text{TURNS IN PRIMARY}}{\text{TURNS IN SECONDARY}} = \frac{600}{30} = \frac{20}{1}$$

Figure 84. Closed-core transformer.

25-20. Alternating current flows through coil A causing a magnetic field in the core. Each time the current changes direction the magnetic field collapses and builds up again.

25-21. As the field collapses and builds up, the magnetic lines of force cut through coil B. An alternating current is thus produced in coil B.

25-22. The coil connected to the source of electricity is the primary coil. The coil in which the electricity is induced or to which it is transferred is the secondary coil.

25-23. Thus, when voltage is induced in the secondary coil in a closed circuit, current flow results. Transformers are primarily installed in electrical circuits used in the heating field to step up or step down the voltage. Step-up transformers are used in circuits of oil burners, and step-down transformers are used in connection with low-voltage controls.

26. Circuit Troubles and Troubleshooting

26-1. Before current can flow, there must be a path for it to follow from the source to the device it operates. Three types of troubles can interrupt this flow of current. They are open circuits, shorts, and grounds.

26-2. An open circuit is a break in the line. Breaks can be repaired by reconnecting the broken ends and insulating the splice with insulating tape. A continuity light, like the one shown in figure 85, is a valuable testing device to use when you are finding a broken line. This tester consists of a flashlight socket, bulb, battery, and two test

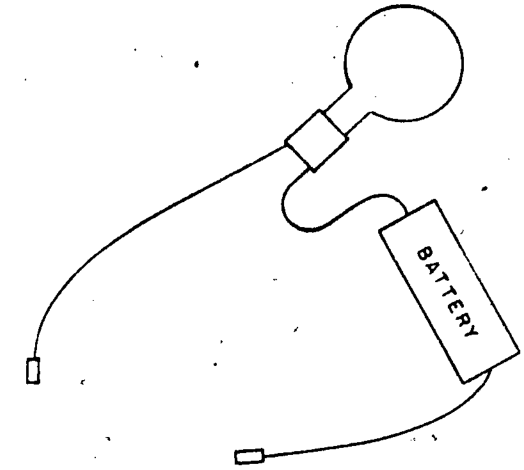


Figure 85. Continuity test lamp.

leads. It is useful for checking a dead circuit (electric power off).

26-3. The flashlight bulb will light when the test leads are connected across the circuit if there is a closed or continuous circuit. If the circuit is open or has a high resistance because of a loose or corroded connection, the flashlight bulb will not light.

26-4. The use of the test lamps, in figures 86 and 87, can greatly assist the heating specialist in locating open circuits, shorts, and grounded circuits.

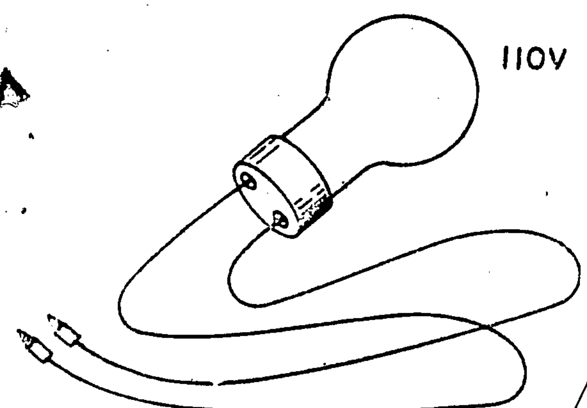


Figure 86. 110-volt test lamp.

26-5. A short is an accidental direct connection between two wires. This is caused by broken insulation allowing metal-to-metal contact between the wires.

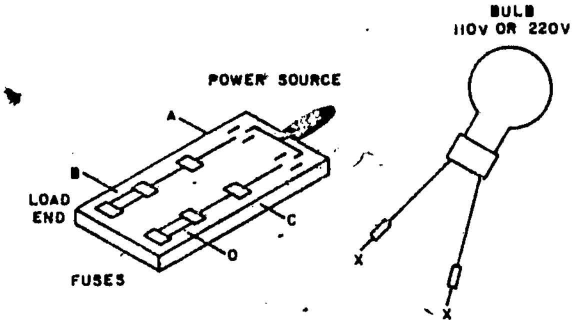


Figure 87. Testing with power (electricity) on.

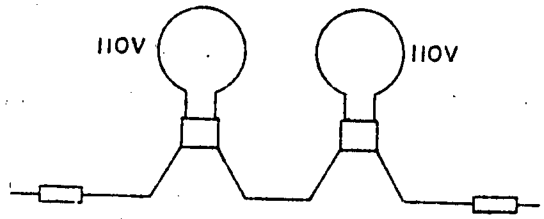


Figure 88. Test lamp for 220-volt circuit using two 110-volt lamps.

26-6. A ground is caused by a bare wire prematurely completing a circuit to the ground. This trouble is found most often when the wire is run through metal conduit. The lamps are easy to use and simple to construct. When the test lamp is being used (fig. 86), the voltage of the lamp must be equal to or greater than the voltage in the circuit being tested. Otherwise the lamp will burn out. A 110-volt lamp cannot be used to test a 220-volt circuit; so it will be necessary to use two 110-volt lamps in series. Figure 88 shows the connecting of two 110-volt bulbs for testing a 220-volt circuit.

26-7. Power must be provided to the switch controlling the circuit before the circuit can be tested. This condition can be tested by connecting the two test prods (XX in fig. 87) to A and C. When this procedure is completed, the test bulb should light. This indicates that there is power through the switch to the fuses. The fuses are checked by placing the test prods on B and D. If the test bulb lights, the fuses are serviceable; if the test bulb fails to light, one or both fuses are defective. To locate the blown fuse, use a method of cross checking. The fuse CD is checked by placing the test prods on A and D. To test the fuse AB, the same method is used by placing the test prods on C and B.

26-8. The test for a ground is made with the power off. To test for a ground, the continuity test lamp is connected to the ground wire and the circuit. If the circuit is grounded, the light will burn. Again the bare wire must be located and insulated.

26-9. Troubles that are both of a mechanical and electrical nature often occur in heating control systems, Knowledge of the circuit, control unit construction, and its operation is essential to quickly locate the trouble. When checking for a defective piece of equipment, a definite procedure is essential. Checking in a haphazard manner only results in a loss of time. When the inoperative unit is located, an effort is made to determine if the failure was due to improper installation, faulty operation, or defective construction. Simply replacing a unit which has failed does not always solve the problem permanently.

26-10. As each unit is checked, carefully inspect and clean the contacts, and check the wiring for clean and tight connections. Dirty and corroded connections provide high resistance, which reduces the effective voltage. This causes a unit to operate intermittently or not at all. Inspect each unit for safety and freedom from defects. An ohmmeter or a continuity device is used to test the coils and wiring for open circuits, shorts, or grounded circuits. The inspection of each unit should be as thorough as possible and nothing taken for granted.

26-11. Sometimes a unit will give advance warning of impending failure. Units such as motors, transformers, relays and solenoids often give off a burnt odor, smoke, and get hot. At other times they operate intermittently. If the operator is alert, he is sometimes able to prevent complete failure of the unit by shutting off the power and investigating the cause. It could be friction caused by lack of lubrication or by shorted or grounded wirings.

26-12. Generally, a good way to go about locating electrical trouble is to start with the power source. First, the voltage, switch, and fuses should be checked with a voltmeter or test lamp. If this portion of the circuitry is satisfactory, the electricity is shut off and an ohmmeter or a continuity light is used to check each unit in the order in which they are located from the power source. In a gas heating system these units could be the thermostat and limit control. Next, check the wire connections, switches, elements, and adjustment. Then, check the relay and plot light, as a sudden downdraft while the main burner was off might have blown out the pilot light. Also, check the solenoid gas valve for a sticking plunger and an open or shorted coil; check the blower motor and the overheat cutout switch. For coal and oil heating electrical troubles, start with the power source and continue through the circuits until all of the units have been checked. The fuel supply must not be overlooked when you are making these checks.

26-13. If you have found nothing wrong during the above checks, leave the control covers off, turn on the electricity and watch the operation of each unit carefully. If the plant still fails to operate, a test lamp is used to check each circuit to find out where the break in the electrical operations occurs. Troubleshooting is not always easy, and sometimes it is a drawn-out process of elimination. The ability to read and interpret electrical diagrams and symbols, a thorough knowledge of the construction and operation of the units, and plenty of patience and determination are the primary requirements of a good troubleshooter. The covers are replaced on the controls after the troubles have been found and corrected.

Summary

MASSES OF TINY atoms collectively make up the molecules which, in turn, make up elements. It is these elements which combine to make up all substances and materials. Each atom is made up of positive particles called *protons*, negative particles called *electrons*, and neutral particles called *neutrons*.

In this study of electricity, you are primarily interested in the planetary electrons which are in motion around the nucleus of the atom. These planetary electrons are held in their orbits by the attraction that exists between unlike charges. The ability of some substances to hold their planetary electrons makes it possible for substances to acquire either a positive or a negative charge. Free electrons also make it possible to create an electrical pressure or difference of potential. In either case, the substance or portion of the conductor having a surplus of electrons acquires a negative charge. Also, that substance or portion of the conductor that loses electrons acquires a positive charge.

All materials can be classified as conductors or insulators, depending upon their ability to hold their electrons. Substances, mostly metals, which allow their electrons to be readily freed are called conductors; those substances which do not allow this are called insulators.

Voltage is the pressure of an electrical circuit, and being a force it does not move or flow. Voltage is measured and expressed in units called *volts*. Current flow (sometimes called *amperage)* consists of a stream of free electrons flowing through a conductor. The term "electron flow" correctly describes the direction of electron movement from negative to positive. The unit of measurement of electrical current is called the *ampere*.

All conductors offer some degree of opposition to current flow. Insulators also vary in their ability to block the flow of current. This opposition to current flow is called ***resistance***. Resistance is expressed in units of measurement called *ohms*.

There are three types of circuits that are normally used in the heating field. These are series, parallel, and series-parallel circuits. There are a number of protective devices that can be used in each type of circuit to protect against damage to the circuit.

Electrical meters are the eyes that "look" inside the electric circuit. With them you can measure the effect of current flow despite the fact that you cannot see or hear the actual movement.

CHAPTER 5

Insulation and Refractory

INSULATION is any type of material which has high resistance to heat flow. It is used to help prevent heat loss. Insulating brick is the form of insulation placed in the firebox of a furnace to minimize the escape of heat through firebox walls. Sheet insulation is used to cover the outsides of boilers, furnaces, and air ducts to reduce heat loss. Tube insulation is installed on distribution lines so that an excessive amount of heat is not lost from the heating media while going to the radiators. Insulation is also placed on return lines so that the condensate will not freeze before it returns to the boiler. By preventing heat loss, less fuel is needed to supply the demands for heat. Insulation for heating systems should be fireproof, be verminproof, have lasting quality, be mechanically strong, be compact, and be light in weight.

It is necessary from an economical standpoint for mechanics and operators to know something about what refractories actually do for boilers and furnaces. Knowledge of the properties and limitations of refractory materials will make it possible as well as encourage them to avoid abusing the materials while working on or operating the units. In the light of these knowledge requirements, we are giving you an insight into the properties and limitations of insulation and refractory.

27. Types of Insulation

27-1. The insulation used by the military on heating units can be procured in a variety of forms, such as powdered, sheet, block, blanket, tube, and roll. Powdered insulation is usually mixed with water and used to cover odd shapes, such as pipe unions, elbows, valves, etc. Sheet insulation is used to cover warm-air and cold-air ducts, as well as the walls and ceilings of furnace rooms. Block and brick insulation materials are most often used to insulate the outside surfaces of boilers. Blanket insulation is used to cover the warm-air and cold-air ducts in a warm-air heating system. It is also used to cover the cold- and hot-water pipes in a steam or a hot-water heating system. Tube insulation (fabricated in tubular shapes) is used to insulate steam and hot-water pipes. Roll insulation, such as asbestos paper, is used to cover cold- and warm-air ducts for furnace casings in hot-air heating systems.

27-2. Magnesium asbestos insulation is the most common type used to cover heating equipment. Other insulating materials, such as rock wool, hair felt, glass wool, fire felt, etc., are also used to a limited degree in military heating installations.

27-3. *Powdered insulation.* Powdered insulation is procured in 25-, 50-, and 100-pound bags. It is mixed with water to prepare it for application. Usually four parts of insulation to one part of water, by volume, will give a mixture of sticky consistency. The prepared insulation is applied to odd-shaped areas and compressed by hand until the excess moisture is removed from it. The insulation is then covered with cheesecloth or canvas, which has been saturated with plastic asbestos cement. This covering should then be allowed to dry thoroughly before the area is heated.

27-4. *Sheet insulation.* Sheet insulation can be procured in various sizes and thicknesses. Sheet insulation is usually applied to flat areas, since it will not bend. Insulation of this type can be wired, screwed, nailed, or pasted in place.

27-5. *Block insulation.* Block insulation held with plastic asbestos cement is normally used to cover the outside surfaces of boilers. When boilers are being insulated, the insulating value can be increased by first covering the boiler with ribbed metal. This procedure provides a dead-air space next to the boiler and gives higher insulating results than the use of the insulation alone. The application of ribbed metal to a boiler is illustrated in figure 89. After the boiler has been

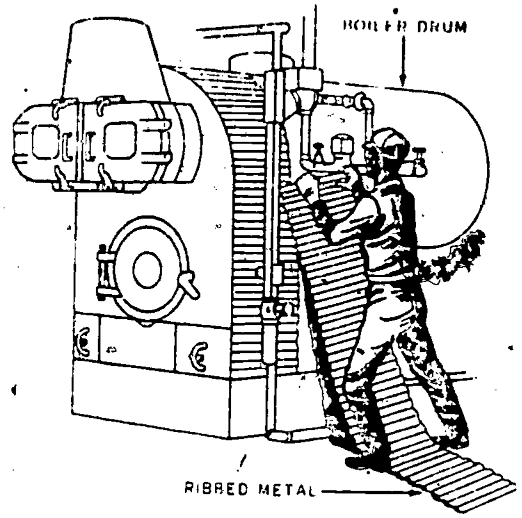


Figure 89. Applying ribbed metal to a boiler.

covered with ribbed metal, the block asbestos is applied.

27-6. Several wires are passed loosely and vertically around the boiler shell (about 30 inches apart); then the insulating blocks are slipped under the wire and positioned with their edges closely butted together. Application of the blocks is started at the bottom and laid up on the sides. If the blocks do not come out evenly at the top, the spaces are filled in with small fitted pieces of block. After this the wires are drawn tight, and other wires are then installed at about 6-inch intervals until the blocks are wired securely in place. Three or four more wires are passed horizontally around the bottom of the firebox so that they are below the rivet heads or other projections which will prevent them from slipping up. The wires are twisted into a cable and thus drawn tightly around the firebox. Several lacing wires can then be run over parts of the boiler shell above the firebox and wired to the cable around the firebox, as shown in figure 90. Sufficient lacing wires should be added to insure that the blocks will be held firmly in place, crossing and tying the wires as necessary.

27-7. When the asbestos blocks are wired in place, the boiler is covered with 1½-inch hexagonal galvanized wire netting (poultry netting). Openings are cut in the netting wherever necessary. When the openings in the wire netting tend to spread, wire is laced through the meshes of the netting around the opening to draw the meshes together. This makes the wire netting

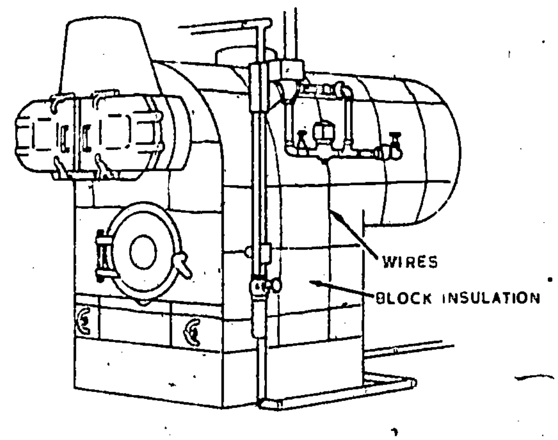


Figure 90. Wire installed on a boiler.

conform to the shape of the opening in the boiler.

27-8. The asbestos cement should be mixed in a tub or a large container, only enough water being used to make the cement workable. Best results can be obtained by thoroughly mixing the cement and applying it to the boiler when the boiler is hot.

27-9. The asbestos cement may be applied in one coat or two coats. If one coat is applied, the coating should be about ½-inch thick. If two coats are applied, each coat should be about ¼-inch thick. Usually, when the cement is applied in one thick coating, it has a tendency to fall off before it dries. Actually, for the inexperienced boiler operator, it is better to apply the cement in two coats. When applying two coats, take care to roughen the first coat with a trowel and allow it to dry thoroughly before the second coat is applied.

27-10. A canvas jacket is not always used to cover heating units. It will be found, however, that the protection afforded by it will prevent the insulation from crumbling. A heavyweight canvas (preferably 8 ounce) is recommended for this purpose. Large pieces should be used to avoid making joints and laps. However, when joints are made, the canvas should overlap about 2 inches.

27-11. The canvas should first be applied on the ends, turning the edges back over the sides. If it is installed in this manner, the canvas that is applied to the sides will lap over the first canvas applied to form a neat edge. The canvas is first dipped in cold water paste and wrung out by hand. Then it is spread neatly and smoothly over the surface of the insulated boiler. The canvas should not be applied closer to heated metal surfaces than ¼ inch.

27-12. When canvas is to be fitted around openings, it should be cut after it has been dipped in the paste. Care is taken not to cut the openings too large. The edges can be trimmed neatly when the canvas is being pasted and smoothed into place. Short slits are cut in the edge of the canvas around the openings to permit the canvas to lie smoothly when it is turned back on beveled edges. When the canvas is thoroughly dry, two coats of good oil paint or sealer should be applied if the covering needs waterproofing.

27-13. Another type of block insulation is the high-temperature type used to form the lining in the firebox of a boiler. High-temperature block insulation is composed of uncalcined diatomaceous earth mixed with asbestos fiber. These blocks should not be used where they will come in direct contact with the flame. They are usually protected by regular refractory firebrick and are laid in the same manner.

27-14. *Blanket insulation.* Blanket insulation is another form of insulation used to cover warm-air heating ducts and steam and hot-water pipes. This insulation is usually composed of minute glass fibers. It resists fire, corrosion, vibration settling, and the effects of humidity. The glass fibers are inorganic; they provide no sustenance for fungus or bacteria, and no food for rodents or insects. Its lightness, flexibility, and resilience make it easy to handle in large sections and easy to place properly. It is simple to cut wtih a knife or shears, and it can be bent around curved surfaces and easily fitted in irregular areas. To install blanket insulation, you glue it with asbestos cement, cover it with cloth, or clamp it with metal bands.

27-15. *Tube insulation.* Tube insulation is made in the form of a tube, as illustrated in figure 91, to fit around the various sizes of piping. The insulation for piping systems is made slightly different from that used on boilers. Tube insulation can be procured in various lengths. If the insulation can be cut conveniently on the job, only long lengths should be procured. However, if the composition of the tubing insulation does not permit easy cutting, then various lengths should be obtained. Usually, tube insulation is split in half and covered with a layer of cloth which can be opened somewhat like a hinge, as shown in figure 91.

27-16. After the tube of insulation is placed on the pipe, asbestos cement is applied to the

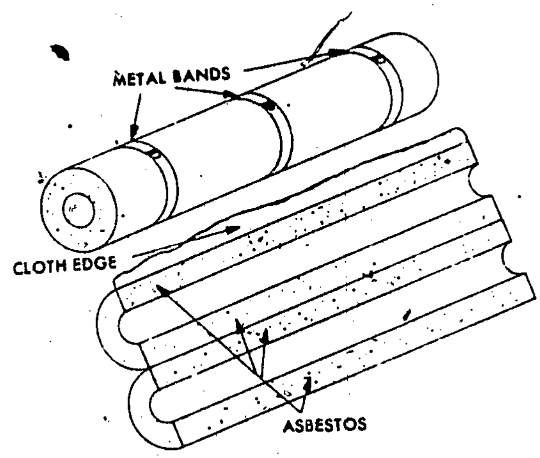


Figure 91. Tube insulation.

loose edge of the cloth. The cloth is then pulled tightly around the insulation. After drying, the paste holds the cloth and insulation in place. Metal bands are placed at frequent intervals around the insulation for added strength.

27-17. When insulated pipe is outside where it will be exposed to the weather, the insulation should be covered with tar paper. Then, the tar paper should be given a coating of melted tar to provide additional waterproofing quality and hold the paper in place.

27-18. *Roll insulation.* Roll insulation, commonly referred to as asbestos paper, is procured in rolls of various widths. Roll insulation should be applied to reasonably flat areas, such as square or round air ducts and casings of furnaces. The insulation is applied by pasting it to the surfaces with asbestos cement or other appropriate cements.

27-19. Insulation that is installed must be properly maintained to provide effectively its insulating qualities. Therefore, the next discussion is centered around maintaining insulation.

28. Maintaining Insulation

28-1. It is necessary to repair all breaks and cracks in the insulation. Corners or exposed edges of insulation should be protected by installing iron guards. All insulation must be protected from moving parts which can mar, puncture, or damage it. Insulation must be protected from excessive pressures. Ladders, plants, piping, iron bars, etc., should never be allowed to rest on the insulation installed on a boiler or piping. One should never step or walk on insulation. The insulation around the pipes in dining halls can be protected with a sheet metal sleeve.

28-2. The refractory is very important to efficient combustion; therefore it is necessary that you develop your knowledge concerning it. The purpose, types, bonds, and maintenance of refractories are some of the things to be discussed in the next section.

29. The Refractory

29-1. The refractory is a lining or wall made of fire clay which surrounds the combustion chamber and plays a part in effecting efficient combustion. To provide good combustion, the fuel and air must be brought together in the right proportions at the right temperatures. The gases resulting from ignition must keep on mixing with the air until it is completely burned. Also, the combustion products must be directed over the boiler or furnace heating surfaces to squeeze the most heat out of them. In the following discussion, you will study about the refractory, its purpose, composition, and construction. Figure 92 shows a refractory lining in a horizontal type boiler.

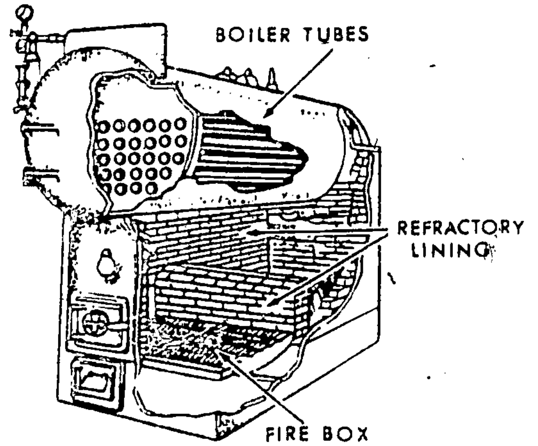


Figure 92. Refractory lining in a horizontal type boiler.

29-2. *Purpose of the refractory.* The purposes of refractory linings are to protect the furnace or boiler lining and assist in maintaining high combustion chamber temperatures. It prevents the escape of heat through the walls of the combustion chamber and helps to accelerate the rate of combustion. The lining protects boiler drums, headers, water walls, and other parts from direct contact with the flame and from radiant heat. It resists the cutting and abrasive action of the unburned particles of fuel and the flame. It also possesses uniform expansion and contraction characteristics within operating limits, and it resists mechanical shock and fusion at the high temperatures to which it is exposed. The refractory withstands heavy pressures from other brickwork and boiler parts at high temperatures, and resists spalling, slagging, and the vibration caused from panting and ignition explosions. Spalling is the flaking and chipping of brick surfaces. Slagging is the fusion of mineral residue such as ash with brick surfaces.

29-3. *Factors affecting the refractory.* The life of a furnace or boiler lining is influenced by many factors. Three common factors are: (1) high furnace temperatures, (2) rapid changes in temperature, and (3) vibration or panting of the boiler. The first factor can be offset by using the best grade of refractory material.

29-4. The second factor can be reduced to a minimum by intelligent boiler operation. A boiler should never be heated as fast as possible. It should be fired at low fire to allow the brickwork to warm up slowly. The same procedure applies to cooling a boiler. In case of an emergency, however, it may be necessary to ignore these precautions, but continuation of this practice should not be allowed because brickwork troubles will soon develop.

29-5. The third factor is sometimes difficult to correct. The vibration and panting of any boiler can be caused by method of operation, design of the combustion chamber, type of fuel used, and other factors. Such malfunctions can be determined only by the careful analysis of operating methods and a complete inspection of the boiler unit.

29-6. **Refractory Materials.** There are many different types of refractory materials on the market. Each manufacturer recommends his products and lists various reasons why his products are superior to others. However, the ordinary heating specialist should know the use of firebrick, insulating brick, ordinary building brick, and mortar.

29-7. *Standard firebrick.* Standard firebrick is made chiefly of refractory clay. It can be either hard and dense or comparatively soft, depending on the treatment given during its manufacture. This firebrick is used in direct contact with the flame, and it withstands a temperature of about 3000° F. before it melts or fuses.

29-8. Standard firebrick is manufactured in various shapes and sizes. The dimensions of a standard firebrick are 9 inches long, 4½ inches wide, and 2½ inches thick. All other shapes of firebrick are usually 9 inches long also, but they have various widths and thicknesses to fit special spaces during refractory construction. Figure 93 shows some of the various sizes and shapes of firebrick you will use.

29-9. *Plastic firebrick.* Standard firebrick is generally used for normal refractory work, but plastic firebrick is recommended for emergency patching and for building furnace openings. Plastic firebrick is unburned brick in a stiff plastic condition. Because of its plastic nature, it can be pounded into a cavity or space where a prefabricated firebrick will not fit unless the cavity is chiseled to the proper dimensions. Plastic refractory must be rammed into place with a wooden mallet to insure that there are no voids in it. The fusion point of plastic firebrick is practically equal to that of the standard firebrick,

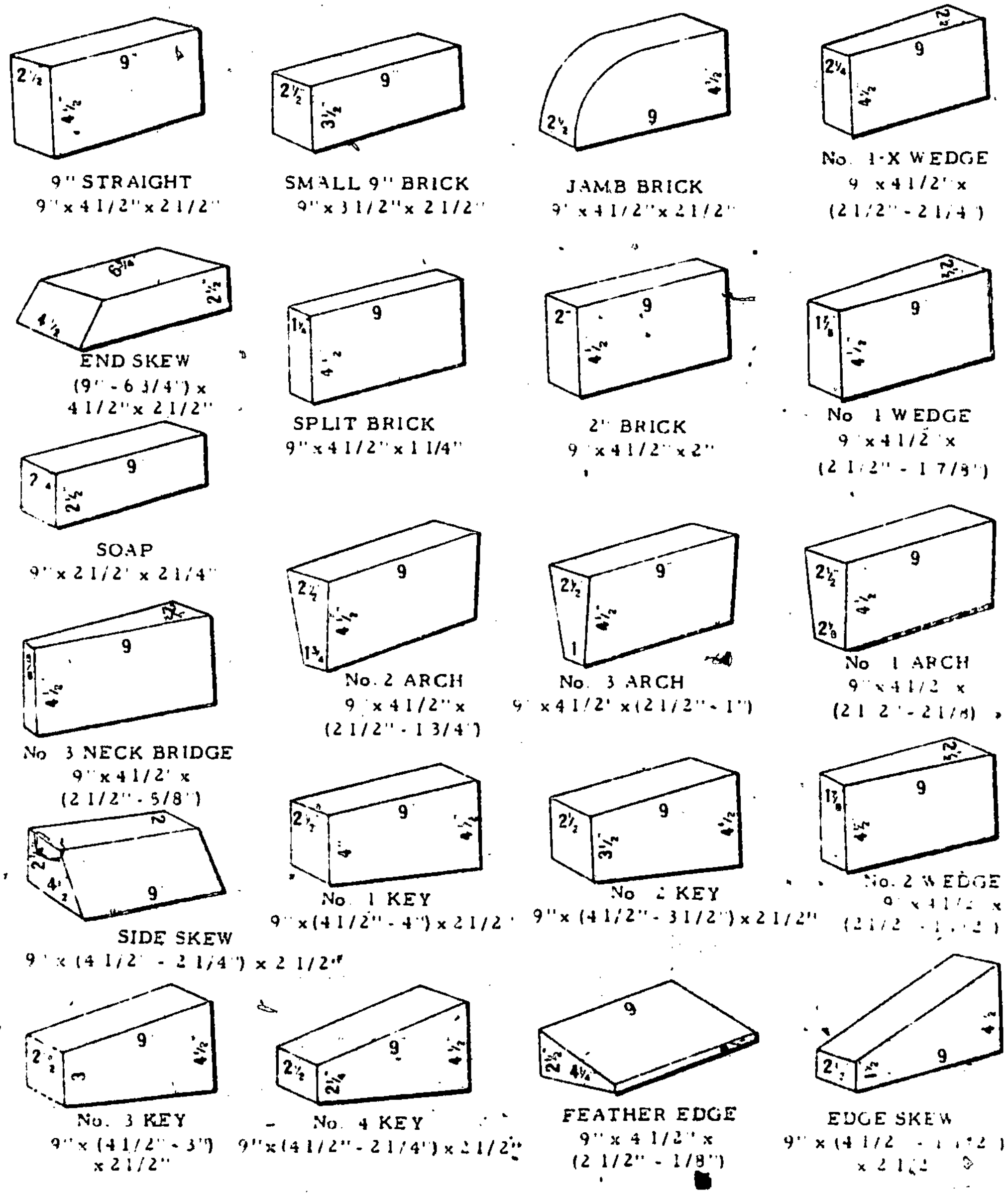


Figure 93. Types and sizes of firebrick.

but because of the additional moisture in the plastic firebrick, greater shrinkage will result.

29-10. In general, plastic firebrick is used during the construction and repair of sidewalls, backwalls, burner openings, and other irregular constructions in the combustion chamber that are not exposed to temperatures in excess of 3000° F.

29-11. Plastic firebrick is shipped in lightweight metal drums, with the total weights varying between 75 and 200 pounds. Wooden heads are provided to give the drums strength. It frequently happens that the drums or heads are cracked or broken by rough handling and the weight of the material. When this occurs, particularly if the drums have been in storage for some time, the plastic becomes partially dried. However, it can be treated, as explained in the following paragraphs, to restore it to a workable condition.

29-12. The plastic is removed from the broken drums and cut into small chunks. These chunks are spread on the boiler floor and sprinkled lightly with water. Then they are immediately covered with damp burlap for about 12 hours. After this, the plastic is pounded to a workable consistency with a mallet. It is then ready for use.

29-13. If it is not desirable to remove the plastic from the drums until it is workable, a number of 1-inch holes about 12 inches deep are drilled into the plastic and filled with water. You may find it necessary to refill the holes with water, but never add more than 10 percent of the weight of the plastic material, exclusive of the drum.

29-14. Care should be exercised in preparing plastic firebrick material to a stiff workable consistency. Too much water added to the plastic causes excessive shrinkage when the firebrick is heated. Too little water will not permit the plastic to bond properly. Plastic firebrick should never be thinned with water to such a consistency that it can be used for a thin layer of patching.

29-15. *Insulating firebrick and block.* Insulating firebrick is made of calcined diatomaceous earth with high insulating value. It withstands direct flame to 2500° F. The insulating brick is porous and lightweight; its heat conductivity is less than one-third that of heavy firebrick. It is used between the inner firewall and the outer wall of a boiler to reduce heat loss from the combustion chamber. Insulating brick is soft and must be handled carefully. It is available in all of the standard 9-inch series shapes.

29-16. Insulating block is made from uncalcined diatomaceous earth and a bonding material to make it hold its shape. It will not stand exposure to direct flame, but it withstands temperatures up to 1500° F. It is used as the first insulating layers against the metal casing. Various methods are used to tie the block to the casing. It is lightweight and porous and must be handled carefully. Standard sizes of insulating block are 1" x 6" x 18" and 1" x 6" x 36".

29-17. *Building brick.* Standard building brick is made by molding a mixture of sand and clay, then baking the mixture in a kiln. Building brick is normally used to form the outside portion of the boiler combustion chamber wall. The brick affords protection to the insulating brick and adds strength to the construction of the boiler assembly.

29-18. The ordinary building brick is 8 inches long, 4 inches wide, and 2 inches thick. Brick of this type is less resistant to high temperatures and should not be substituted for firebrick or insulating brick.

29-19. *Mortar.* Mortar is a mixture of fire clay, water, and sand. It is used for setting firebrick, insulating brick, and building brick when you are constructing boiler combustion chambers, walls, supports etc.

29-20. Mortar should be uniformly fine when it is mixed. Any lumps in the mixture should be broken during the mixing procedure. Sufficient water should be added to the mixture so that when a sample of it is placed between two bricks and the top brick is raised by hand, the stickiness of the mortar will almost hold the bottom brick to the top brick. This consistency should be maintained during the process of bricklaying by stirring the batch of mortar at frequent intervals. The mortar is air-setting and must be allowed to dry for at least 48 hours before the boiler or furnace is fired.

29-21. Types of Bonds. Brickwork must be mechanically strong, airtight as possible, and flexible enough to permit component parts of the furnace to expand and contract with rising and falling temperatures. Without weakening the wall, the brick should be laid so that it can be repaired and relined as easily as possible. All joints should be staggered to cut down air leakage into the furnace or gas leakage out of it.

29-22. When constructing a wall for a furnace, the bricks must be laid in a pattern that has good "bond." There are a number of different bonds;

however, only a few representative types will be discussed in this publication. Figure 94 illustrates the arrangement of bricks for a 9-inch wall.

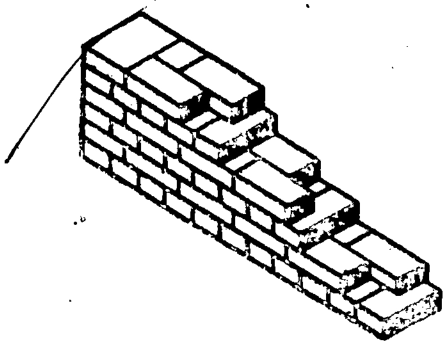


Figure 94. A bond for a 9-inch wall.

29-23. If a wider wall is needed, the bricks can be arranged like those in figure 95. This bond makes a 13½-inch wall with no joints extending through it. The arrangement of bricks for an 18-inch composite insulating firebrick wall is shown in figure 96. In this diagram, the insulating bricks are those that are shaded.

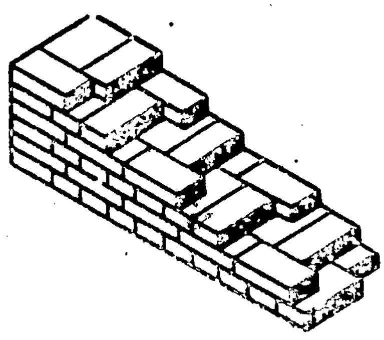


Figure 95. A bond for a 13½-inch wall.

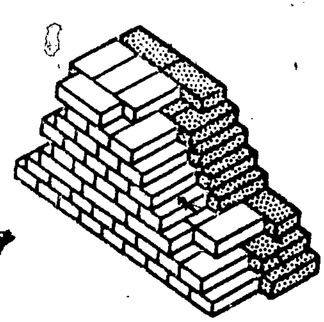


Figure 96. A bond for an 18-inch wall.

29-24. When an even wider wall is needed, bricks can be arranged as illustrated in figure 97.

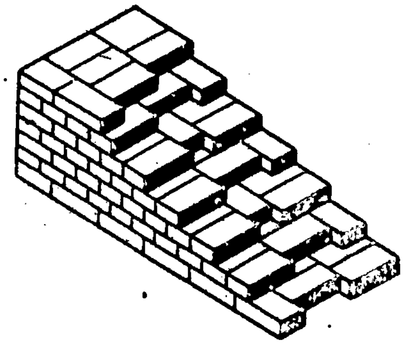


Figure 97. A bond for a 22½-inch wall.

Construction of this type is recommended for comparatively high furnace walls where extra thickness is needed. Figure 97 shows a bond for a 22½-inch wall.

29-25. **Expansion Joints.** Many combustion chambers are constructed of bricks that fail because no provision has been made for normal expansion. This condition results in cracks in the brick joints and allows air to leak into the combustion chamber, thus making it difficult to regulate combustion. Eventually, too many cracks develop in the walls and the efficiency of the furnace becomes very low.

29-26. It is necessary to install expansion joints in the combustion chamber brickwork to prevent a combustion chamber from cracking because of expansion. Figure 98 illustrates staggered expansion joints in the corner construction of a typical furnace wall. These expansion joints usually extend the height of the wall.

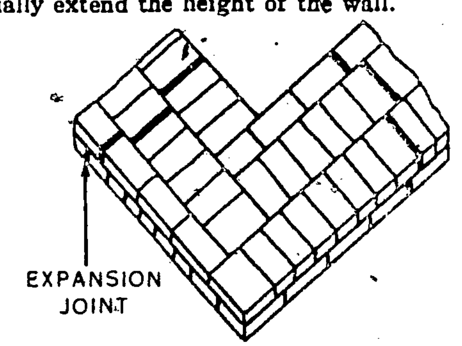


Figure 98. Expansion joints in the wall of a combustion chamber.

29-27. When installing a refractory, strips of ¼-inch plywood are used to make uniform expansion joints. At the time the furnace is fired, the wood burns out and leaves room for expansion. The joints are then packed with asbestos rope or other suitable material that allows some movement of the brick and still maintain an air seal at the joints.

29-28. **Tying Brick Courses.** Sometimes it is desirable to tie standard firebrick to the outer brick wall. For this purpose, it is necessary to procure notched firebrick and tying irons. The wall is constructed in a manner like that shown in figure 99.

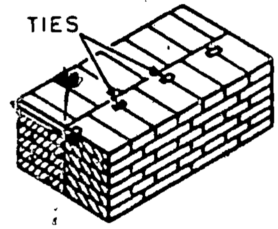


Figure 99. Tying firebrick to an outer wall.

29-29. **Making Openings.** A support, called a *lintel,* must be placed at the top of the openings when it is necessary to install peepholes and fire access doors in a firebrick wall. A square tile or an iron plate can be used. Figure 100 shows the construction of a peephole with a square-edged tile used as the lintel.

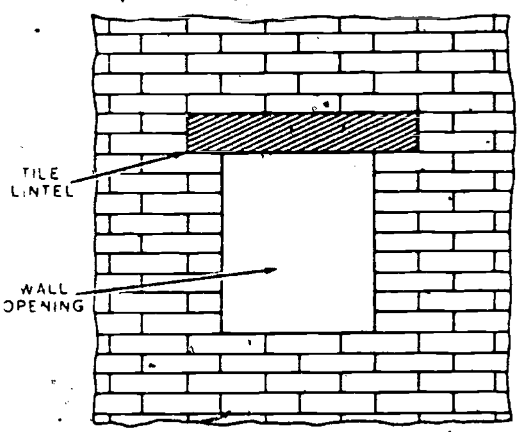


Figure 100. An opening in a furnace wall supported by a tile lintel.

29-30. **Heater and Furnace Linings.** The simplest of refractory linings is used in small coal, gas, and oil heaters and furnaces. The linings in these units are composed of refractory firebricks placed on end, either in a round or square arrangement, to conform with the type of firebox. The arrangement of a round-shaped furnace lining is illustrated in figure 101. The refractory bricks can be held in place by a sheet metal brick retainer, which is made of two pieces that are

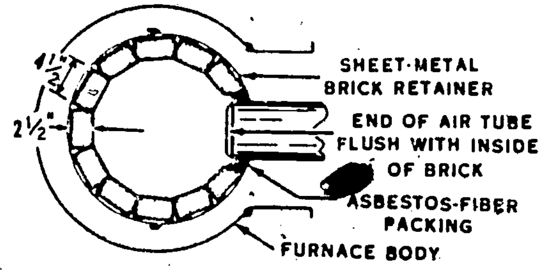


Figure 101. Refractory lining for a round firebox.

hooked together after they are placed inside the furnace. The space between the bricks is then filled with refractory mortar. In some cases, refractory firebricks are molded in special sizes and shapes to fit specific fireboxes. Firebricks of this type usually do not require mortar to seal the joints, because they fit closely together. This method is by no means the only one. Some brick courses in a wall can be held together by anchor bolts which extend through the complete wall. They are of different lengths and are staggered to prevent cleavage planes.

29-31. **Boiler Refractory.** Boilers which are designed with the firebox as an integral part require only a refractory lining for the floor and walls. The refractory lining is laid in courses of firebricks and insulating bricks. Much care should be taken when laying the bricks so that the inside of the fire wall is comparatively smooth.

29-32. Laying the bricks can be started when the mortar and bricks are in readiness. Each brick should be inspected for flaws and uniformity of dimensions. The best edge of the brick should be selected for the inside surface exposed to the flame. The brick is dipped in water and the excess water allowed to drip off. Then one end and side of the brick is dipped into the mortar. In dipping the brick into the mortar, an edgewise motion is used to prevent the formation of air bubbles on the surface. The excess mortar is allowed to drip off the brick; then it is laid in position in the wall and tapped into place to squeeze as much mortar as possible out of the joints. These joints should be made as narrow as possible, not over 1/16 inch thick. The sides of the bricks exposed to the flame should not have any projecting edges. Quick deterioration of these edges will result if they are exposed. The joint between the bricks should be beaded over, as shown in figure 102, with a trowel.

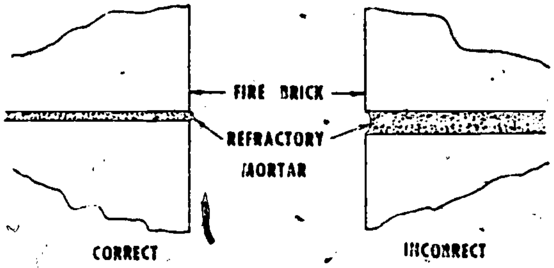


Figure 102. Beaded joint between firebrick.

29-33. Some manufacturers recommend that the entire inner wall of a newly constructed combustion chamber be sprayed with a thin layer of cement mortar.

29-34. It is generally recommended that the firebox of the furnace be allowed to dry for 12 hours before firing. At this time, the boiler should be started and slowly brought to operating temperature. Some mortars require more time to set before firing, while others of the heat-setting type require less time. It is recommended that the manufacturer's instructions pertaining to the application of the mortar be followed when laying brickwork.

29-35. Plastic firebrick can also be used as a refractory material for linings. However, its length of service is much less than that of standard firebrick. Chunks of plastic firebricks can be laid just as they are taken from the can. The chunks should be rammed tightly into place, preferably in horizontal layers. In general, the more solidly the section of plastic is rammed together, the better it will be. The plastic section then should be vented with 3/16-inch holes extending through the plastic and not more than $1\frac{1}{2}$ inches apart. This allows deeper heat penetration during the vitrification process and it permits the escape of steam formed from the moisture in the plastic. Vitrification is the process of changing to a glasslike structure. It is not recommended to trowel the surface of a new plastic section, since this tends to prevent the escape of steam during the vitrification process.

29-36. Generally, the plastic section should be air-dried from 48 to 72 hours, depending on the humidity in the atmosphere. As soon as practicable after air-drying, the furnace should be fired with a low fire and gradually brought up to operating temperature. This action permits vitrification to take place. Plastic requires a temperature of about 2900° to 3000° F. for vitrification. Should any shrinkage cracks open up during this process, they should, if small, be filled with fire clay; if large, with plastic. If the plastic section is not vented, it is necessary to bake it from 24 to 36 hours at a low temperature prior to vitrification. However, some manufacturers recommend that certain types of plastic be baked within 24 hours to complete the vitrification process. The heating specialist should always check the manufacturer's recommendations before installing any type of refractory.

29-37. **Boiler Settings.** In large installations, the entire combustion chamber must be built under the boiler. The brickwork surrounding the combustion area is usually composed of two or more rows of bricks, as shown in figure 103. The

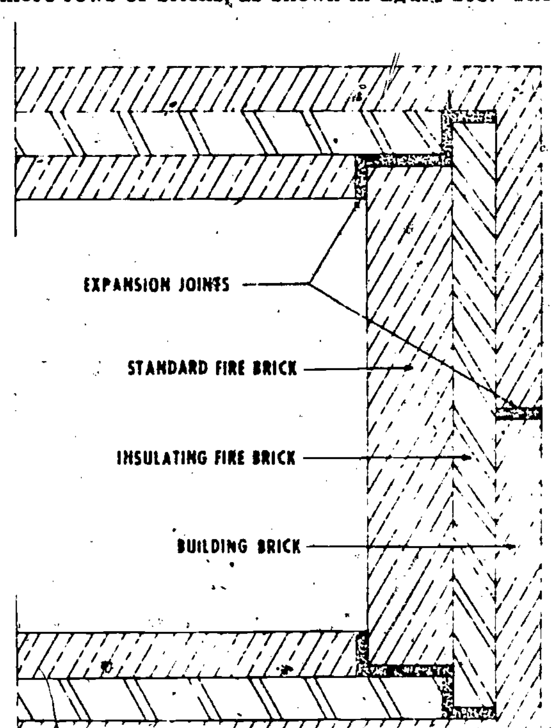


Figure 103. Types of brick in a furnace wall.

inner row next to the fire is built up of firebrick, using a high-temperature mortar to bond the brick together. This brick must be able to withstand the heat of the flame. Surrounding the wall of firebrick is a wall of insulating firebrick. The purpose of this brick is to prevent the loss of heat from the combustion chamber to the outside of the furnace. A third row of brick is laid next to the insulating brick. This is common building brick. It affords protection to the insulating brick and added strength to the construction of the furnace.

29-38. Usually, the brickwork around a boiler is held together by bolt-holding buckstays, as shown in figure 104. Whenever brickwork encloses a boiler, or where parts of the boiler project through the walls, provision must be made to permit relative movement between the boiler and brickwork because of the difference in expansion. The joints which permit expansion must be constructed in such a manner that air will not leak into the setting or gases leak out of it. The seal normally consists of asbestos rope or fibers which are packed into the joint and kept in place by a plastic compound.

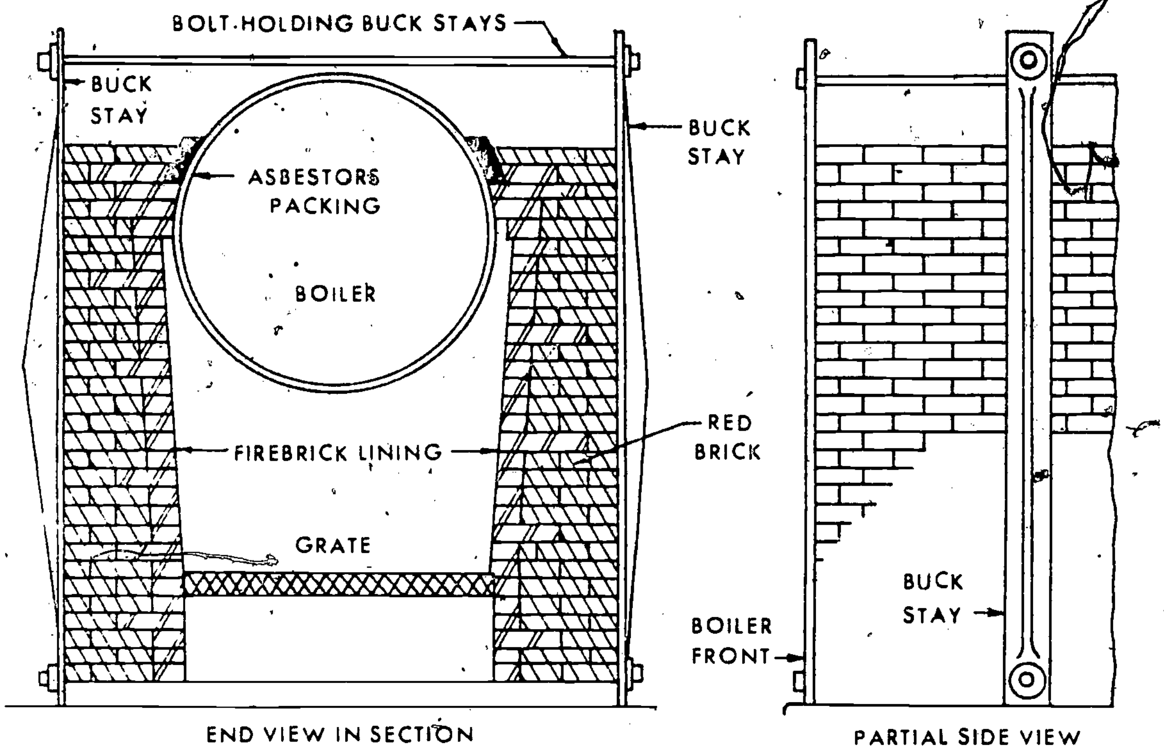


Figure 104. Solid wall for a boiler.

29-39. The method of laying brick for boiler settings is the same as that used when the refractory linings in a firebox boiler are laid. Plastic firebrick can be used in the construction of a boiler setting. This type of brick is best adapted for use in constructing a wall pierced by peepholes, inspection holes, and places where irregular-shaped bricks are needed.

29-40. **Repairing the Refractory.** Standard firebrick is generally used for refractory brickwork. However, plastic firebrick is recommended for emergency patches and for building furnace openings. Where a damaged section of brickwork is found, the old brick and mortar should be removed and the new installed. The fresh mortar must completely fill the space between the old brick and the new brick. When plastic firebrick is used for patches, as in case of a brick falling out, clean out the hole at least 4 inches deep and cut it wider at the inner side (away from the fire) so that the plastic will wedge and not fall out. With a mallet, pound the plastic into the hole until it is completely filled. A crack can be repaired by chipping a channel down through the crack and filling it with plastic firebrick or fire clay. A good practice is to wet the sides of the hole thoroughly with water before filling it with the new fire clay or plastic firebrick. This reduces the absorption of moisture by the old brick from the new and improves the bonding action. It is very important that the mortar be properly mixed for best results. The mortar, whether fire clay or fire cement, should be free of lumps and mixed only with fresh water. Sufficient water should be added to make a rather thin mortar or grout. This will make the required thin joints.

29-41. **Maintaining Boiler Refractory and Settings.** The boiler is the principal and most costly unit in a boiler plant. Preventive maintenance of it represents the difference between a normal useful life extending up to 50 years or a short life with much time lost for repairs and a ruined boiler in a few years. All boilers have common characteristics and require similar care. In general, the outside as well as the inside surfaces of a boiler should be kept clean. All outside surface water leaks should be stopped. Small water leaks, if allowed to continue, become larger and require major repairs. Water leaks frequently provide moisture on metal surfaces. These damp spots are the basis for corrosion and more leaks. They should be stopped at once.

29-42. Air that leaks into the setting of a boiler will cause cooling and dilution of the combustion gases. This must be held to a minimum to insure adequate steam-generating capacity and efficient operation. Cracks and leaks usually start around drums or other places where a strain is placed on the setting. This is shown by the arrows in figure 105. These cracks should be filled immediately with filler material. If a setting is completely covered with many small cracks, it should be overspread with a boiler-seal coat. This coat is applied with a trowel to the depth of about 1/4 inch in thickness. The material is manufactured with an asphalt base which causes the surface to get moderately hard; underneath, however, it remains quite soft.

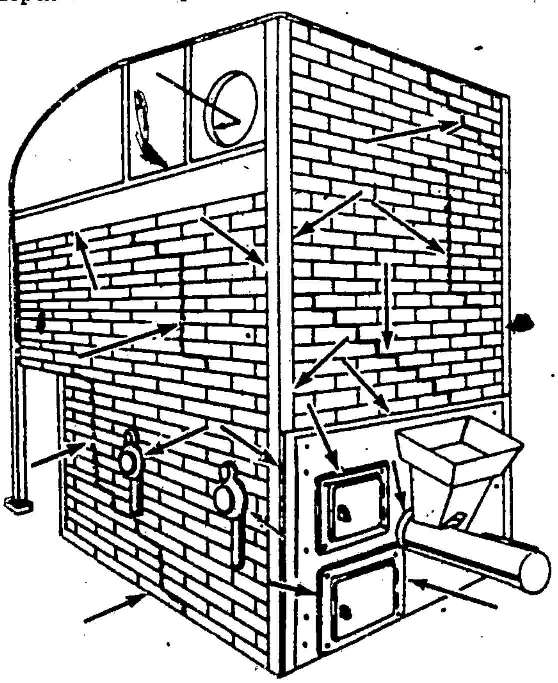


Figure 105. Cracks and leaks in a boiler setting.

29-43. The area between the drum and the brick setting usually develops air leaks that are caused by expansion. This area must be filled with refractory material that will not hinder the movement of the drum or its setting under heating and cooling conditions. If there is any question about the hardness of the material already installed, it should be removed and replaced with a soft material that will not cause binding between the drum and setting. Such an area will usually open in one place when the boiler is cold and in another place when the boiler is hot. After a boiler has been on the line a short time, the drum should be inspected and any openings plugged with an expansion joint filler, asbestos packing, etc.

29-44. The interior of the combustion chamber should be inspected for spalling, slagging, cracked or broken bricks, and damaged arches and baffles. Occasionally it is necessary to chip away slag and clinkers formed on the linings. This can be done with a chisel and hammer.

Summary

INSULATION IS USED to direct heat, reduce heat losses, and protect material and personnel from burns. Insulation can be procured in several forms, including powdered, sheet, block, blanket, tube, and roll.

As a rule, the application of insulation is a fairly easy job. Block insulation is wired in place, plastered with powdered insulation, and covered with canvas. Pipe is covered with tubular insulation and, if necessary, is protected from the weather by a coating of tar paper and melted tar. Insulation needs little maintenance if properly protected from breakage and water damage.

The lining for the firebox of a heater, furnace, or boiler is one of the most important components of the heating units. The lining should be properly installed and the proper refractory materials used. The firebox lining protects the furnace casing and assists in maintaining a high furnace temperature because it retains heat for relatively long periods of time. This characteristic of a lining accelerates the rate of combustion and produces efficient combustion.

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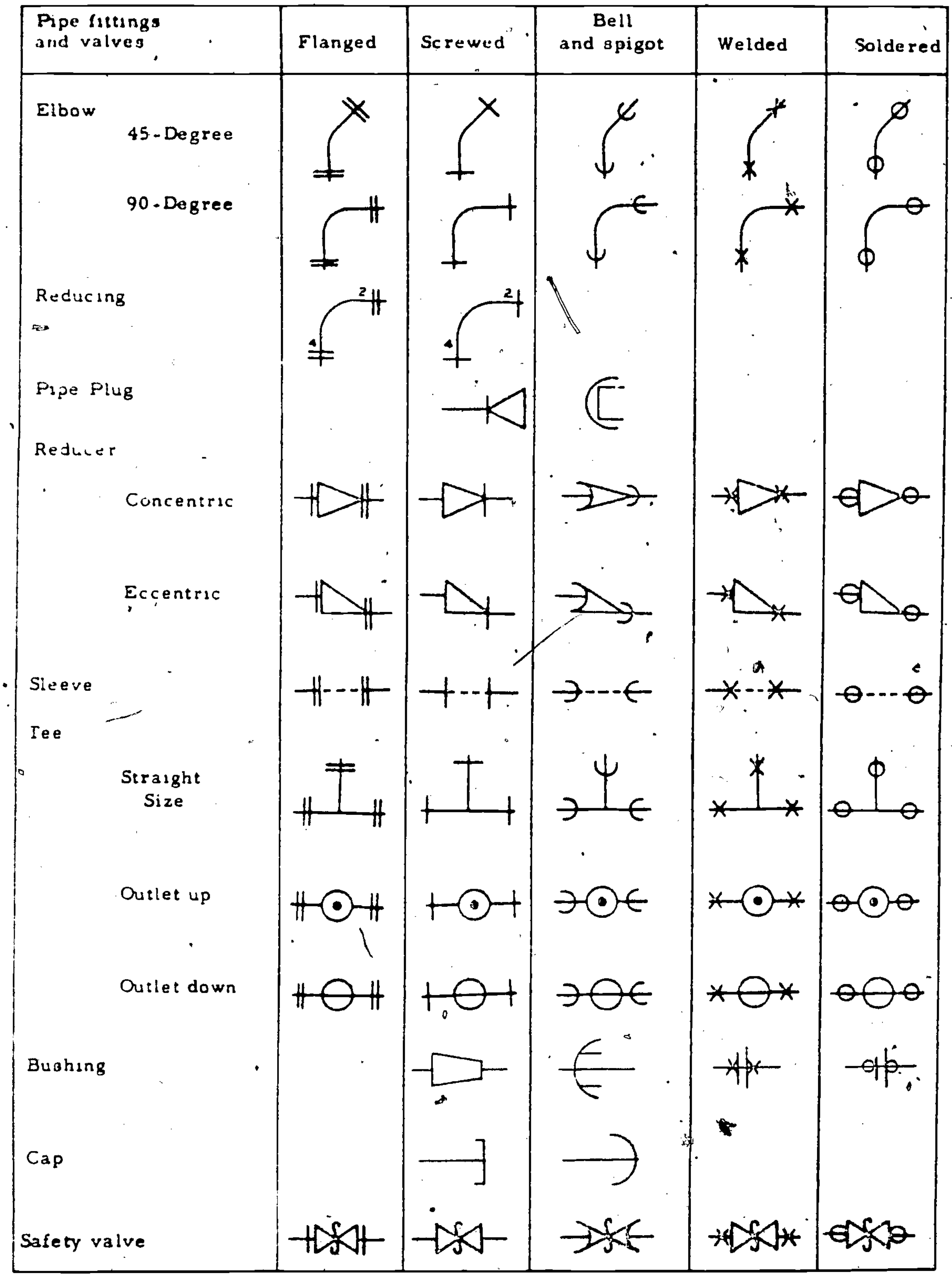
Appendix A. Pipefittings, Valves, and Piping Symbols



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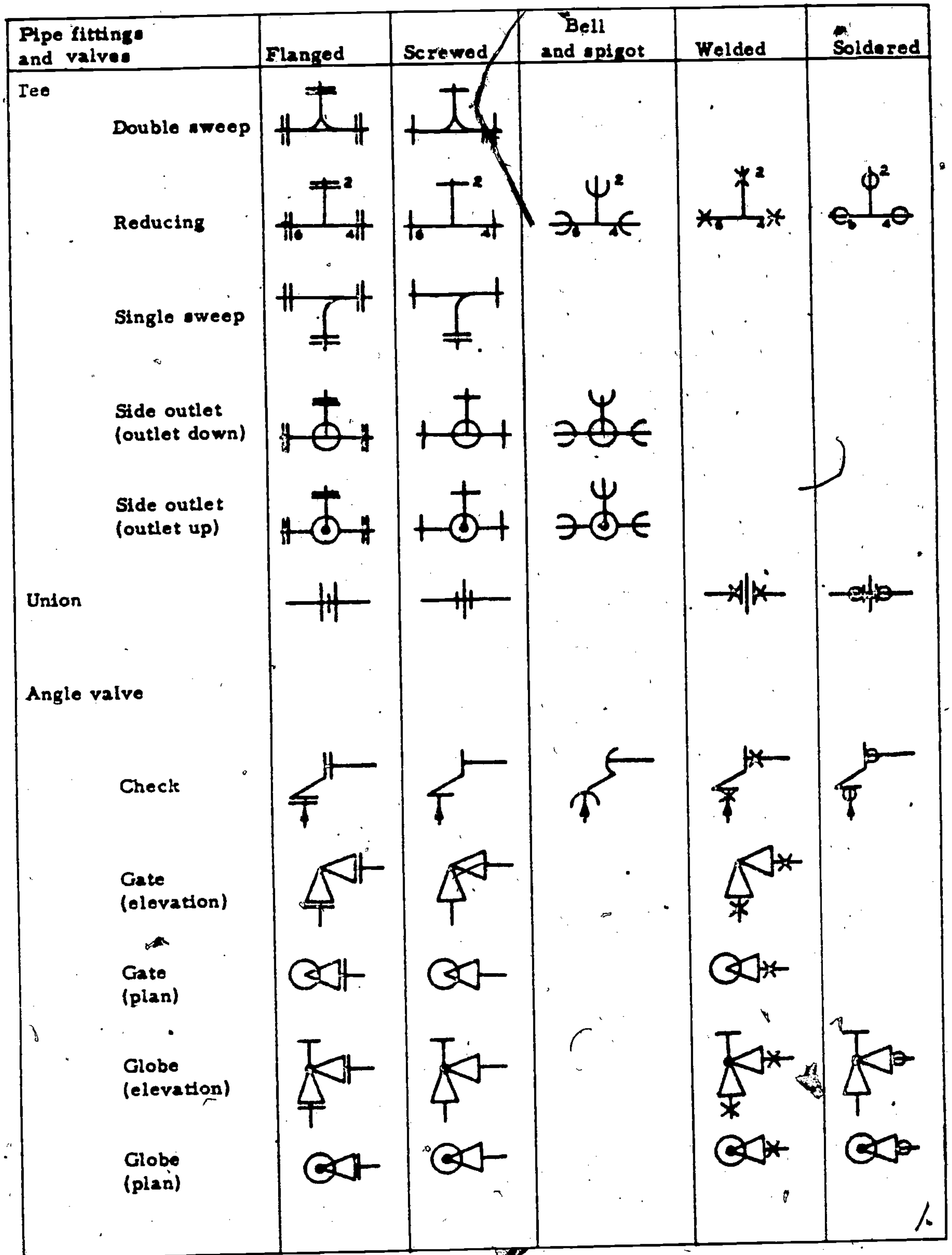
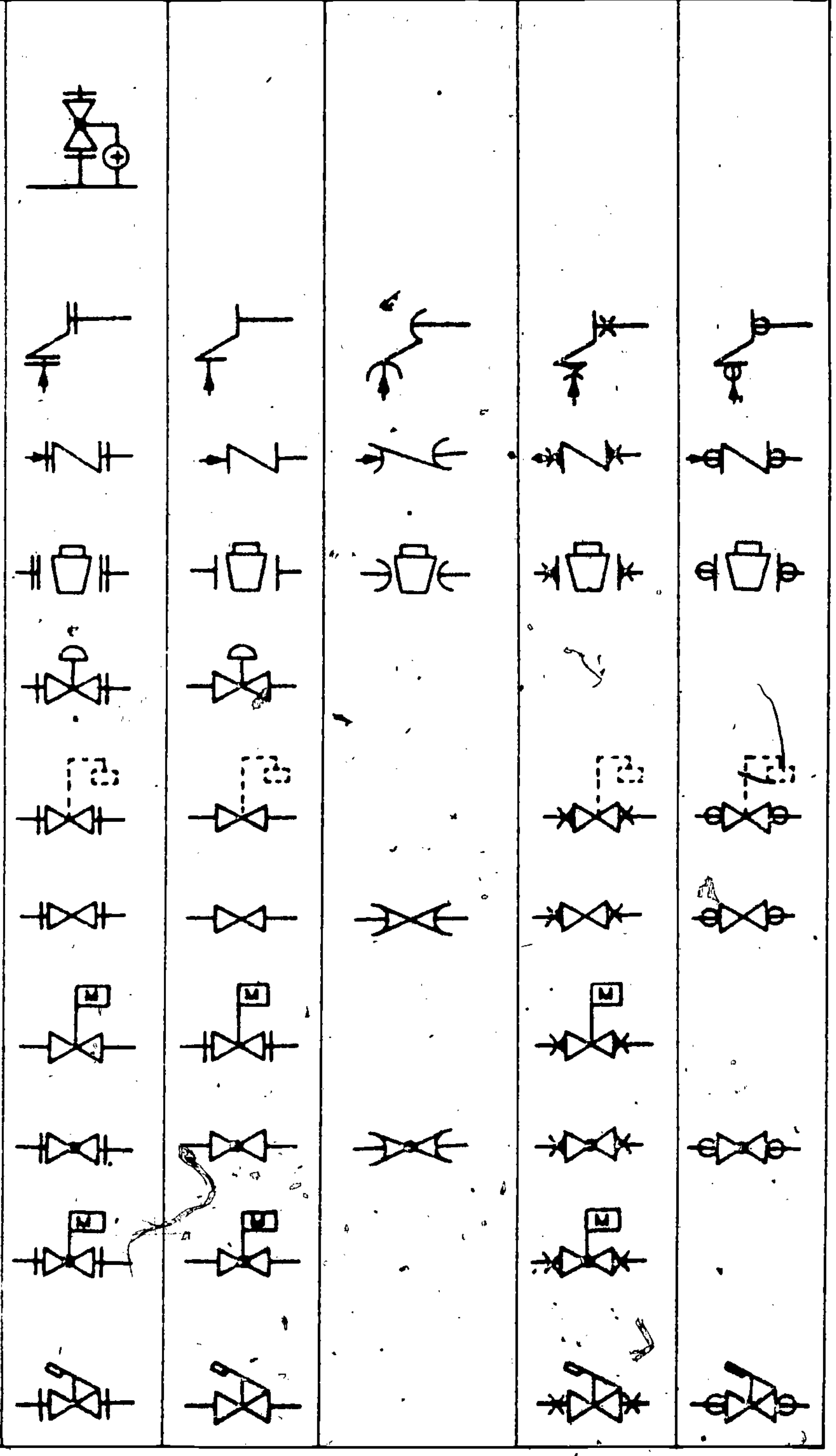
APPENDIX A (Cont'd)



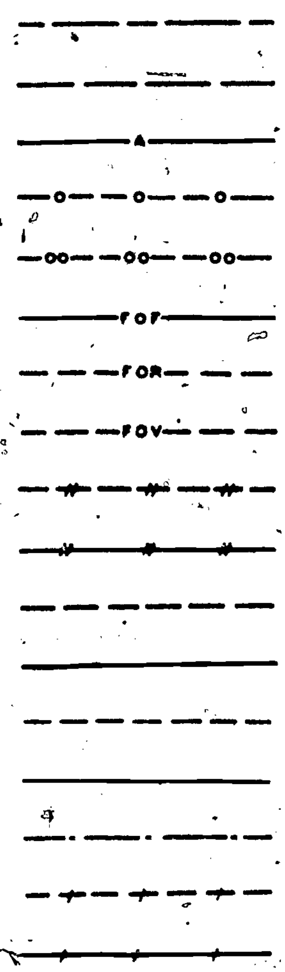
Pipe fittings and valves	Flanged	Screwed	Bell and spigot	Welded	Soldered
Automatic valve — By-pass					
Check valve — Angle Check					
Check valve — Straight way					
Cock					
Diaphragm valve					
Float valve					
Gate valve					
Gate valve — Motor-operated					
Globe valve					
Globe valve — Motor-operated					
Quick opening valve					



APPENDIX A (Cont'd)

Piping

- Air-relief line
- Boiler blow off
- Compressed air
- Condensate or vacuum pump discharge
- Feedwater pump discharge
- Fuel-oil flow
- Fuel-oil return
- Fuel-oil tank vent
- High-pressure return
- High-pressure steam
- Hot-water heating return
- Hot-water heating supply
- Low-pressure return
- Low-pressure steam
- Make-up water
- Medium pressure return
- Medium pressure steam



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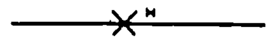
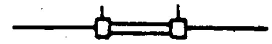
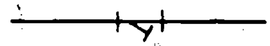
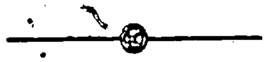
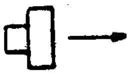
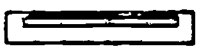
APPENDIX A (Cont'd)

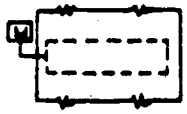
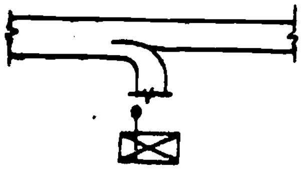
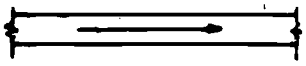
Piping

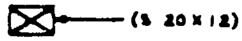
Air-relief line	—— ———— —— ———— ——
Boiler blow off	——— ——— ——— ———
Compressed air	————A————
Condensate or vacuum pump discharge	—o— —o— —o—
Feedwater pump discharge	—oo— —oo— —oo—
Fuel-oil flow	————FOF————
Fuel-oil return	— — —FOR— — —
Fuel-oil tank vent	— — —FOV— — —
High-pressure return	—#— —#— —#—
High-pressure steam	——#——#——#——
Hot-water heating return	—— —— —— —— ——
Hot-water heating supply	————————
Low-pressure return	— — — — — — —
Low-pressure steam	————————
Make-up water	——·———·———·——
Medium pressure return	—+— —+— —+—
Medium pressure steam	——+——+——+——

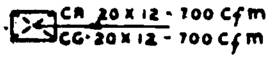
Appendix B. Heating Symbols

Expansion joint	
Hanger or support	
Heat exchanger	
Heat transfer surface, plan (indicate type such as convector)	
Pump (indicate type such as vacuum)	
Strainer	
Tank	
Thermometer	
Thermostat	
Traps	
Boiler return	
Blast thermostatic	
Float	
Float and thermostatic	
Thermostatic	
Unit heater (centrifugal fan), plan	
Unit heater (propeller), plan	
Unit ventilator, plan	

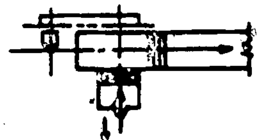
APPENDIX B (Cont'd)

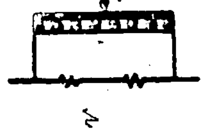
Valves	
Check	
Diaphragm	
Gate	
Globe	
Lock and shield	
Motor operated	
Reducing pressure	
Relief (either pressure or vacuum)	
Vent point	
Automatic dampers	
Deflecting damper	
Direction of flow	
Duct (1st figure, side shown; 2nd side not shown)	
Duct section (exhaust or return)	

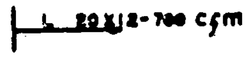
Duct section (supply)


Exhaust inlet ceiling (indicate type)


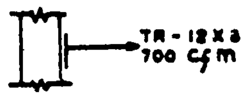
Exhaust inlet wall (indicate type)

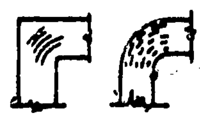

Fan and motor with belt guard


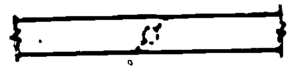
Intake louvers on screen


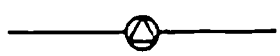
Louver opening


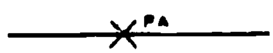
Supply outlet ceiling (indicate type)


Supply outlet wall (indicate type)


Vanes


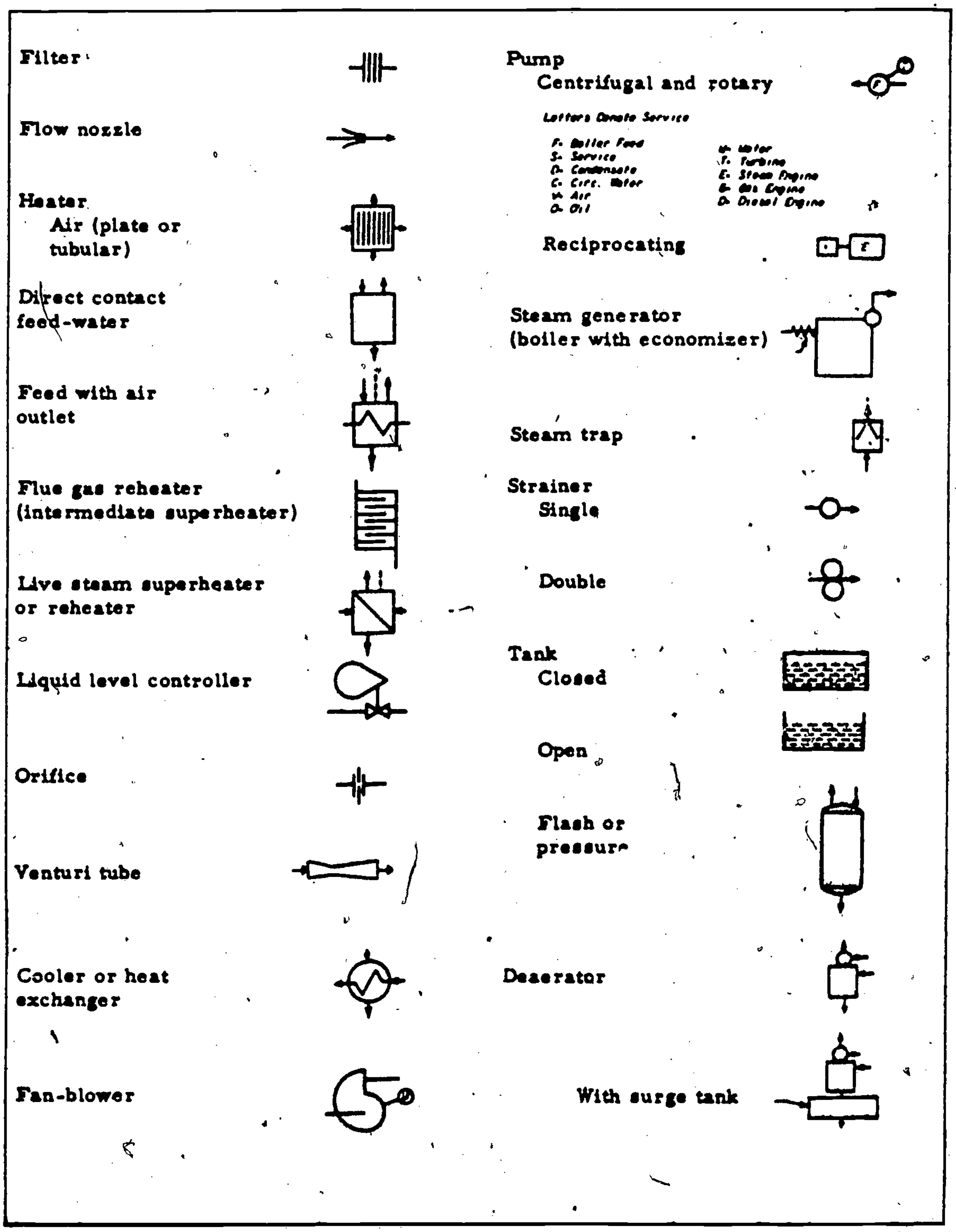
Volume damper


Air eliminator


Anchor


Gauge


Appendix C. Heating Power Symbols



ENGINEER

SUBCOURSE 564-1

HEATING AND VENTILATING I

(INTRODUCTION TO HEATING)

CORRESPONDENCE COURSE PROGRAM

U. S. ARMY ENGINEER SCHOOL

FORT BELVOIR, VIRGINIA

MOS: 51J20

EDITION 1 (NRI 110)

INTRODUCTION

This is the first of four subcourses on the subject of heating and ventilating, the MOS 51-J career field. It begins with a short review of those elements of safety practice that are of importance to the heating specialist. This is followed by instruction on blueprints, specifications, scales, diagrams, bills of material and similar guides that are used in the installation of heating equipment. The lesson devoted to basic electricity includes discussion of circuits, conductors, and insulators. These topics are followed by an explanation of the oxyacetylene and metallic arc welding processes used in installing pipes, valves, and fittings. The final lesson deals with types of insulation and with the refractory materials that are installed in furnaces and boilers.

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

Lesson 1. Blueprints and Specifications.
2. Tools and Piping.
3. Electricity.
4. Insulation and Refractory.

Examination.

Fifteen credit hours are allowed.

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 564, Heating and Ventilating I (Introduction to Heating).

LESSON 1

BLUEPRINTS AND SPECIFICATIONS

CREDIT HOURS 3

TEXT ASSIGNMENT .... Memorandum 564, chapters 1 and 2.

LESSON OBJECTIVE .... To remind you of a few basic safety practices, and to teach you how to read and understand blueprints and specifications.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. The background of an ammonia print is

a. blue
b. black
c. white
d. maroon

2. What color pencil is used to make notations on a blueprint?

a. red
b. blue
c. black
d. yellow

3. The negative for a blueprint is known as a

a. diagram
b. tracing
c. print
d. drawing

4. How many prints could you make from one blueprint tracing?

a. 10
b. 20
c. 30
d. any number

5. A blueprint is usually made up of how many views?

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

6. What blueprint view would you need in order to learn the internal arrangements and the outside shape of a building into which you would install a heating plant?

a. plan
b. front
c. detail
d. sectional

7. Blueprint elevation views show an object viewed from

a. in front of each of the four sides
b. the top
c. a distant, higher point
d. inside the structure

8. Solid lines that end in arrowheads indicate

a. hidden edges of an object
b. measured distances
c. visible edges of an object
d. center of an object

9. On which of the following would you find measurements expressed in tenths and hundredths of a foot?

a. architect's drawing
b. graphic scale

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c. engineering drawing

d. metric scale

10. Short-dash lines on a blueprint are used to represent

a. hidden edges

b. visible edges

c. center of object

d. measured distances

11. When an object drawn on a blueprint has been cut away and one portion removed, the remaining portion is

a. colored red

c. rescaled

b. redrawn

d. crosshatched

12. What type view is drawn upon a blueprint in order to clarify the invisible lines of an object?

a. sectional

c. side

b. plan

d. top

13. How many subordinate scales are on the architect's triangular scale?

a. 5

c. 11

b. 8

d. 13

14. A crosshatching on a certain section indicates type of sectional lining. To determine the meaning, you check

a. symbols of materials

b. stock list

c. bill of particulars

d. specifications

15. You are installing a steam-heated, hot-water tank. What type plans do you use for installing the piping?

a. cutaway and pictorial

b. flat or perspective

c. flat and pictorial

d. schematic and block

16. A blueprint has a scale of 1" = 200'. You use an engineer scale (10 divisions per inch) to measure between two objects on the blueprint. The blueprint distance covers 20 divisions on the engineer scale. What actual distance in feet does this represent?

a. 50

c. 200

b. 100

d. 400

17. Specifications are details of construction that, among other things,

a. set up the heating plan

b. give the scales for each drawing

c. establish working hours

d. give types of building materials to be used

18. You need to know the nomenclature and the stock numbers of some materials that you will use in constructing a furnace. You get this information from the

a. post engineer

b. bill of materials

c. specifications

d. blueprint

19. The fittings used in figure 23 of the text are

a. welded

c. bell and spigot

b. screwed

d. soldered

20. What is the type trap installed in figure 22 in the text?

a. bucket

b. thermostatic

c. float-thermostatic

d. float

LESSON 2

TOOLS AND PIPING

CREDIT HOURS 4

TEXT ASSIGNMENT .... Memorandum 564, chapter 3.

LESSON OBJECTIVE .... To teach you the use and care of common handtools and how to cut, weld, and fit pipes.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. When sharpening a cold chisel, you would maintain the cutting angle at about

a. 30 c. 60
b. 45 d. 90

2. What type screwdriver would you use to drive or remove small screws rapidly?

a. spiral ratchet c. offset
b. Phillips d. standard

3. You are working on a heater-installation job that requires you to measure the amount of pull that you should use in tightening some nuts. What type wrench do you use for this measurement?

a. adjustable c. monkey
b. box end d. torque

4. Which of the following is not used as a basis for classifying metal files?

a. name c. grade
b. material d. cut

5. What file would you use for enlarging circular openings?

a. round c. hand
b. mill d. flat

6. Cold chisels are classified according to their

a. weight c. length
b. points d. circumference

7. How many teeth per inch should a hacksaw blade have for sawing brass and copper?

a. 14 c. 24
b. 18 d. 32

8. You are using an electric soldering iron. The time to stop heating this iron is when it

a. sputters c. melts slightly
b. glows d. turns blue

9. What type valve would you use for throttling?

a. nonreturn c. check
b. gate d. globe

10. You are installing a steam boiler. What type valve do you use on the boiler header?

a. nonrising steam globe

b. nonreturn

c. rising stem

d. check

11. Which of the following is not used for pipes and fittings in a heating system?

a. wrought iron c. steel

b. aluminum d. brass

12. You are joining two pieces of copper pipe. The melted solder will be drawn into the joint by

a. capillary attraction

b. gravity

c. flow rate

d. brushing

13. You have cut and threaded a 3/8-inch pipe. The number of threads per inch of pipe will be

a. 12 c. 16

b. 14 d. 18

14. You must be a certified welder before you are allowed to weld a

a. boiler shell

b. firebox door

c. water line

d. pressure vessel

15. The acetylene connection hose on the oxyacetylene outfit has

a. a quick-disconnect fitting

b. black and white stripes

c. left-hand threads

d. green and white stripes

16. The neutral or balanced flame that is used in welding is produced when the mixed gases consist of approximately

a. 1 vol oxygen, 1 vol acetylene, 1½ vols outside air

b. 3 vols oxygen, 1 vol acetylene, 1 vol atmosphere

c. 2 vols oxygen, 1 vol acetylene; ½ vol atmosphere

d. 1½ vols oxygen, 1 vol acetylene, no outside air

17. Which of the following is not a part of the portable oxyacetylene welding outfit?

a. torque wrench

b. flint igniter

c. pressure regulator

d. CO_2 fire extinguisher

18. The wire solder used on copper is composed of

a. 100% lead

b. 50% lead and 50% tin

c. 40% tin and 60% lead

d. 10% copper, 10% spelter, 80% lead

19. At the tip of the inner cone, the temperature of a neutral flame is approximately

a. 400° F c. 600° F

b. 585° F d. 625° F

20. The pure acetylene flame is

a. unsuitable for welding

b. short and bushy

c. a bluish color

d. colorless

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LESSON 3

ELECTRICITY

CREDIT HOURS 4

TEXT ASSIGNMENT .... Memorandum 564, chapter 4.

LESSON OBJECTIVE .... To teach you the electrical controls used in the operation and repair of heating equipment.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. The smallest particle of an element that can be identified as that element is

a. an electron

b. a compound

c. a molecule

d. an atom

2. The smallest particle of a compound that can be identified as that compound is

a. an atom

b. an element

c. a neutron

d. a molecule

3. Which of the following is not a constructional part of an atom?

a. neutrons

b. electrons

c. nucleus

d. protons

4. The atom of one element differs from an atom of another element only in the number and arrangement of the

a. nucleus

b. positive electrons

c. electrons, neutrons, protons

d. negative protons

5. What atom is the simplest of all atoms?

a. copper

b. hydrogen

c. uranium

d. carbon

6. An atom normally is electrically neutral because

a. protons and electrons are in opposition

b. positive and negative charges cancel each other

c. positive charges attract like charges

d. neutrons counterbalance electrons

7. When a substance gains electrons from an outside source, it becomes

a. negatively charged

b. radioactive

c. neutral

d. positively charged

8. The opposition which either a conductor or an insulator offers to the flow of electrons is called

a. resistance
c. coulomb
b. pressure
d. capacitance

9. The difference in potential that causes electron movement through the conductor is called an

a. electromotive force
b. electrical firing
c. electric-magnetic field
d. electrical failure

10. An electrical circuit in which the current has only one path to follow is a

a. capacitance
c. parallel
b. series
d. series-parallel

11. What electrical law governs the relationship between voltage, current, and resistance?

a. Boyle's
c. Ohm's
b. Henry's
d. Hertz's

12. The voltage in an electrical circuit is 200 volts and the current is 40 amperes. What is the resistance in ohms?

a. 5
c. 30
b. 8
d. 40

13. Which of the following substances are good conductors?

a. mica, paraffin
b. wood, rubber
c. glass, shellac
d. gold, silver, copper, aluminum, platinum

14. Which of the following would you use as an insulator?

a. copper
c. silver
b. gold
d. paraffin

15. Which of the following would you use to shield instruments against magnetism?

a. soft iron
c. steel
b. glass
d. nickel

16. You must check a faulty electrical circuit. Where is a good place to start?

a. power source
b. switch
c. supply line
d. using device

17. You must measure the resistance in a circuit while a known voltage is applied across an element. Which of the following would you hook with the circuit being checked?

a. ammeter in series
b. ammeter in parallel
c. ohmmeter in parallel
d. ohmmeter in series

18. What must be passed through a coil in order to produce electricity in it?

a. magnetic field
b. null current
c. a latent flux
d. an induced EMF

19. One lamp is rated 115-volt, 40-watt, and another lamp 115-volt, 20-watt. Both lamps will be operated on a 115-volt circuit. What power is required to operate the first lamp compared to the second?

a. twice as much
b. same
c. half as much
d. four times as much

20. An electrical circuit that has more than one path through which current can flow is a

a. complete series
c. series
b. multiple
d. parallel

LESSON 4

INSULATION AND REFRACTORY

CREDIT HOURS 2

TEXT ASSIGNMENT .... Memorandum 564, chapter 5.

LESSON OBJECTIVE .... To teach you the purpose and kinds of insulation and to explain how refractories contribute to efficient combustion.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. Which of the following insulations would you use to cover warm-air and cold-air ducts in a warm-air heating system?

a. blanket c. powdered
b. block d. sheet

2. Which of the following types of insulation would you use to cover the outside surface of a boiler?

a. rockwool c. sheet
b. block d. blanket

3. How would you mix powdered insulation by volume?

a. 4 parts insulation, 1 part oil
b. 2 parts insulation, 2 parts water
c. 4 parts insulation, 1 part water
d. 1 part insulation, 4 parts water

4. What is the most common type of insulation used to cover heating equipment?

a. block
b. sheet
c. rock wool
d. magnesium asbestos

5. The dead air trapped under ribbed metal installed on a boiler

a. is an aerator
b. is a heat exchanger
c. is a cooling medium
d. gives higher insulating results

6. Asbestos cement may be applied to a boiler in one or two coats. If you decide to use one coat, how thick in inches would you make it?

a. $\frac{1}{4}$ c. $\frac{3}{4}$
b. $\frac{1}{2}$ d. 1

7. What type of insulation would you use to cover warm-air heating ducts?

a. sheet c. blanket
b. tube d. powdered

8. When insulated pipes will be exposed to the weather, with which of the following would you cover them?

a. powdered asbestos

b. tar paper

c. glass fibers

d. cloth

9. What type of insulation is referred to as asbestos paper?

a. roll

b. sheet

c. magnesium asbestos

d. blanket

10. You find that the tube insulation at floor level in a post dining hall is being damaged by splashed water. How would you protect the insulation?

a. remove insulation

b. double present insulation

c. cover with canvas

d. add sheet metal sleeve

11. The refractory lining in a firebox protects the

a. boiler lining
c. crown sheet
b. fire tubes
d. insulation

12. What kind of refractory material would you use for emergency patching?

a. standard firebrick

b. plastic firebrick

c. mortar

d. insulating brick

13. Insulating firebrick is made of calcined diatomaceous earth with high insulating value. It can withstand a direct flame up to a maximum of

a. 1500° F
c. 2500° F
b. 2000° F
d. 3000° F

14. Insulating block will not stand exposure to direct flame, but it withstands temperatures up to

a. 800° F
c. 1200° F
b. 1000° F
d. 1500° F

15. You have used mortar to set brick in the firebox of a furnace. What is the least number of hours that you would allow this mortar to dry before you fired up the furnace?

a. 12
c. 36
b. 24
d. 48

16. Building brick normally is used to form the outside portion of the boiler combustion chamber wall. What are the dimensions in inches of this brick?

	Long	Wide	Thick
a.	6	3	2
b.	8	4	2
c.	9	4	3
d.	9	5	3

17. What would you install in the combustion chamber in order to prevent cracking?

a. plastic filler

b. expansion joints

c. iron guards

d. metal covering

18. Anchor bolts are used to hold some brick courses in a wall. The bolts are of different lengths and are staggered so that they

a. are more easily cooled

b. are easier to repair

c. prevent cleavage planes

d. provide 4-8 cleavage planes

19. Which of the following would you cut into 1/4" strips for use in making uniform expansion joints in a combustion chamber?

a. magnesium asbestos
b. plastic firebrick
c. plywood
d. sheet insulation

20. With the proper maintenance, a boiler should last about how many years?

a. 10
b. 25
c. 40
d. 50

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 564-1 ---------------------Heating and Ventilating I.
LESSON 1 ---------------------------Blueprints and Specifications.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 564.

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

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. "Blueprints" can be white, brown, black, gray or other colors. Ammonia prints, for example, have black, maroon, purple or blue lines on a white (c) background.

2. When it is necessary to mark on a blueprint, a yellow (d) pencil is used.

3. The negative for the blueprint is known as a tracing (b). It is made by placing a sheet of special translucent tracing paper or cloth over the drawing.

4. Any number (d) of prints can be made from one tracing if it is handled carefully. Large numbers of prints are made in a special blueprint machine.

5. A blueprint is usually made up of three (b) views: top, front, and the side, or end, views.

6. A plan (a) view usually shows the outside shape of the building, arrangement of rooms, and location of mechanical equipment, such as heating plants, radiators, and plumbing.

7. Elevations are merely pictures of an object viewed from positions directly in front of each of the four sides (a). Figure 4 shows an elevation plan of the four sides of a cottage.

8. Dimension lines are solid lines of fine width that end in arrowheads used to indicate the measured distance (b) between two points.

9. On engineering drawings (c) the dimensions are designated in feet, and in tenths and hundredths of a foot.

10. Hidden edges (a) are shown by a line of short dashes about 1/8-inch long, as shown in figure 8.

11. The remaining portion of the object is crosshatched (d) in the view. This crosshatching indicates by symbols (figure 16) the materials from which the crosshatched part is made.

12. This interior view is called a sectional (a) view, and it is obtained by imagining that a portion of the exterior of the object has been removed to expose the internal construction.

13. Architect scales are generally used in scaling blueprints for machine and structural work. The scales usually contain 11 (c) subordinate scales, each subdivided differently.

14. You would check a list of symbols of materials (a). The crosshatching would be compared with the symbols. Figure 16 shows a number of symbols used to indicate materials.

15. There are two types of piping diagrams. When either is used by itself, the installation is difficult to make. The drawings are easily understood, however, by having both flat and pictorial (c) piping diagrams.

16. If the scale of the print is 1″ = 200′, then a blueprint dimension that measures 20 divisions or 2 inches on the engineer's scale (10 divisions per inch) represents a distance of 400 (d) feet.

17. Specifications are details of construction of an installation not shown on an architect's drawing. They contain information on labor, types of building materials to be used (d) and the like.

18. In addition to quantities, the bill of materials (b) must include the correct nomenclature, the stock number, and the status and unit of issue.

19. Appendix A, column 3, shows that the fittings are screwed (b) fittings.

20. The list of traps shown in Appendix B indicates that a float-thermostatic (c) trap has been installed in the plan shown in figure 22.

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 564-1 ____________________Heating and Ventilating I.

LESSON 2 __________________________Tools and Piping.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 564.

1. *c* (par 10-48)
2. *a* (par 10-3)
3. *d* (par 10-7)
4. *b* (par 10-22)
5. *a* (par 10-24)
6. *b* (par 10-42)
7. *c* (par 10-55)
8. *d* (par 10-64)
9. *d* (par 11-3)
10. *c* (par 11-2)
11. *b* (par 12-1)
12. *a* (par 12-7)
13. *d* (par 12-22)
14. *d* (par 13-1)
15. *c* (par 13-5)
16. *a* (par 13-12)
17. *a* (par 13-3)
18. *b* (par 12-7)
19. *b* (par 13-12)
20. *a* (par 13-11)

For further explanation, see Discussion.

DISCUSSION

Exercise:

1. The cutting angle should be maintained at about 60° (c) and the edge slightly rounded. Sharpening is usually done on an ordinary coarse grinding wheel. If the angle is ground much over 60°, the tool will not cut properly.

2. The **spiral ratchet** (a) screwdriver is used to drive or remove small screws rapidly.

3. The wrench that measures the amount of pull is called the **torque** (d) wrench. On some makes a scale indicates the amount of force being applied. On other makes, the amount of pull desired can be set on a dial. Figure 28 illustrates both kinds.

4. Files are classified by name, grade, and cut. **Material** (b) of which the file is made is not a basis of classification.

5. The principal use of **round** (a) files is to enlarge circular openings or form concave surfaces.

6. Cold chisels are classified according to the shape of their **points** (b), the most common being flat, cape, roundnose, and diamond.

7. Use a hacksaw blade with 24 (c) teeth per inch when cutting brass, copper, channel iron, and sheet metal over 19 gage.

8. Overheating the iron will cause poorly soldered joints. The heating should stop when the iron **turns blue** (d).

9. Globe valves are generally used where there is need for controlling a gas or liquid, and the globe (d) valve can be used for throttling.

10. The **rising stem** (c) valve is commonly used on boiler headers so that the boiler operator can tell at a glance whether the valve is open or not.

11. **Aluminum** (b) is not in the list of materials commonly used in installing heating and pipe fitting systems. The materials used are wrought iron, steel, brass, and copper.

12. The end of a strip of wire solder is applied to the edge of the joint while it is being heated, and the melted solder drawn into the joint by **capillary attraction** (a).

13. The number of threads cut per inch will be determined by the size of pipe which is to be threaded. Pipe sizes 1/4- to 3/4-inch will have 18 (d) threads per inch.

14. At first you will probably be called upon to weld pipes, hangers, and perhaps some heating system components. Do not expect, however, to be allowed to weld on **pressure vessels** (d) until you have become a certified welder.

15. The nuts for the oxyacetylene welding outfit are the same size. But they have different threads. **Left-hand threads** (c) are standard for the acetylene hose connection, and right-hand threads for the oxygen connection.

16. The neutral or balanced flame is produced when the mixed gases, suppled from the torch, consist of approximately 1 volume of oxygen, 1 volume of acetylene, and 1½ volumes of outside air (a).

17. The torque wrench (a) is not a part of the portable oxyacetylene welding outfit, as can be checked in the list in the latter part of par 13-3 of the text.

18. The wire solder is composed of 50% lead and 50% tin (b) and is applied to the edge of the joint while it is being heated.

19. At the tip of the inner cone the temperature of a neutral flame is approximately 585° F (b).

20. The pure acetylene flame is long and bushy with a yellowish color. It is unsuitable for welding (a).

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 564-1 ____________________Heating and Ventilating I.
LESSON 3 ___________________________Electricity.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 564.

1. *d* (par 14-3)
2. *d* (par 14-3)
3. *c* (par 15-1)
4. *c* (par 15-2)
5. *b* (par 15-2)
6. *b* (par 15-4)
7. *a* (par 16-2)
8. *a* (par 19-1)
9. *a* (par 17-1)
10. *b* (par 22-2)
11. *c* (par 20-1)
12. *a* (par 20-15)
13. *d* (par 21-2)
14. *d* (par 21-1)
15. *b* (par 25-1)
16. *a* (par 26-12)
17. *c* (par 24-4)
18. *a* (par 25-19)
19. *a* (par 23-6)
20. *d* (par 22-4)

For further explanation, see Discussion.

DISCUSSION

Exercise:

1. The smallest particle into which any one element can be divided and still be identified as that element is known as **an atom** (d).

2. The smallest particle into which any compound can be divided and still be identified as that compound is known as a **molecule** (d).

3. By examining different atoms, we find that all atoms are constructed of protons, neutrons, and electrons. The **nucleus** (c) is not included in this constructional list. The nucleus is a grouping of protons and neutrons.

4. The atom of one element differs from an atom of another element only in the number and arrangement of **electrons, neutrons, and protons** (c). Figure 67 shows some examples of this difference in atomic structure.

5. The **hydrogen** (b) atom is the simplest of all; it consists of a nucleus with only one proton and one planetary electron, as illustrated in figure 67.

6. Under normal conditions each individual atom is electrically neutral because the equal number of **positive and negative charges cancel each other** (b).

7. If by any method a substance gains electrons from an outside source, the substance automatically becomes **negatively charged** (a).

8. All good conductors offer at least some opposition to current flow. The opposition which either a conductor or an insulator offers to the flow of electrons is called **resistance** (a).

9. Since this electrical pressure, or difference in potential, is the force which causes electron movement through the conductor, it is called **electromotive force** (a).

10. A **series** (b) circuit is defined as one in which the current has only one path to follow. All safety devices and controls must be hooked in series.

11. There is one basic relationship between voltage, current, and resistance. This relationship is expressed as **Ohm's** (c) Law.

12. Using Ohm's formula $\frac{E}{I} = R = \frac{200}{40} = 5$ **(a)** ohms.

13. **Gold, silver, copper, aluminum, platinum** (d) are all good conductors. Copper is most commonly used as an electrical conductor because it is relatively inexpensive, strong, and flexible.

14. Substances such as wood, rubber, and glass are known as insulators. Other substances commonly used as insulators are mica, bakelite, shellac, and **paraffin** (d).

15. Materials such as wood, copper, aluminum, rubber and **glass** (b) are not attracted by a magnet and cannot be magnetized.

16. A good way to go about locating electrical trouble is to start with the power source (a).

17. The ohmmeter in parallel (c) is hooked with the circuit being checked. That circuit must be isolated from other circuits to obtain a correct reading.

18. If a magnetic field (a) can be passed through a coil, electricity can be produced in the coil. This is the principle of the transformer.

19. Both lamps are to be operated on the 115-volt circuit, but twice as much (a) power is required to operate the first lamp as the second.

20. A parallel (d) circuit is one in which there is more than one path for the current to flow.

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 564-1 ---------------------------Heating and Ventilating I.

LESSON 4 ----------------------------------Insulation and Refractory.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 564.

1. *a* (par 27-1)
2. *b* (par 27-1)
3. *c* (par 27-3)
4. *d* (par 27-2)
5. *d* (par 27-5)
6. *b* (par 27-9)
7. *c* (par 27-14)
8. *b* (par 27-17)
9. *a* (par 27-18)
10. *d* (par 28-1)
11. *a* (par 29-2)
12. *b* (par 29-9)
13. *c* (par 29-15)
14. *d* (par 29-16)
15. *d* (par 29-20)
16. *b* (par 29-18)
17. *b* (par 29-26)
18. *c* (par 29-30)
19. *c* (par 29-27)
20. *d* (par 29-41)

For further explanation, see Discussion.

DISCUSSION

Exercise:

1. **Blanket (a)** insulation is used to cover the warm-air and cold-air ducts in a warm-air heating system.

2. **Block (b)** and brick insulation materials are most often used to insulate the outside surfaces of boilers.

3. Powdered insulation is mixed with water to prepare it for application. Usually **4 parts insulation to 1 part water (c)** by volume will give a mixture of sticky consistency.

4. **Magnesium asbestos (d)** is the most common type used to cover heating equipment. Rock wool, hair felt, glasswool, fire felt, etc. are used to a limited extent.

5. The ribbed metal that covers the boiler provides a dead-air space next to the boiler and gives **higher insulating results (d)** than the use of the insulation alone.

6. If one coat is applied, the coating should be about ½ **(b)** inch thick.

7. **Blanket (c)** insulation is another form of insulation used to cover warm-air heating ducts and steam- and hot-water pipes. This insulation is usually composed of minute glass fibers.

8. When insulated pipes are outside where they will be exposed to the weather, the insulation should be covered with **tar paper (b)** and this covered with melted tar for additional waterproofing.

9. **Roll (a)** insulation, commonly referred to as asbestos paper, is procured in rolls of various widths. It should be applied to reasonably flat surfaces and pasted to the surface with asbestos cement or other appropriate cements.

10. The insulation around the pipes in dining halls can be protected with a **sheet metal sleeve (d)**.

11. The purpose of a refractory lining is to protect the furnace or **boiler lining (a)** and assist in maintaining high combustion chamber temperatures.

12. Standard firebrick is generally used for normal refractory work, but **plastic firebrick (b)** is recommended for emergency patching and for building furnace openings.

13. The insulating firebrick can withstand a direct flame to **2500° F (c)**.

14. Insulating block withstands temperatures up to **1500° F (d)**. It is used as the first insulating layers against the metal casing.

15. The mortar is air-setting and must be allowed to dry for at least **48 (d)** hours before the boiler or furnace is fired.

16. The ordinary building brick is **8" long, 4" wide, and 2" thick (b)**. It is less resistant to high temperatures and should not be substituted for firebrick or insulating brick.

17. It is necessary to install **expansion joints** (b) in the combustion chamber brickwork to prevent the chamber from cracking because of expansion.

18. Some brick courses are held together by anchor bolts. They are of different lengths and are staggered in order to prevent cleavage planes (c).

19. When installing a refractory, strips of ¼-inch **plywood** (c) are used to make uniform expansion joints. The wood is burned out, leaving room for asbestos rope or other filler that allows movement of the brick.

20. The boiler is the principal and most costly unit in a boiler plant. Preventive maintenance of it represents the difference between a normal useful life extending up to **50** (d) years or a short life with much time lost for repairs.

EXAMINATION

ARMY CORRESPONDENCE COURSE • ENGINEER SUBCOURSE 564-1

HEATING AND VENTILATING I

CREDIT HOURS ______________________2

TEXT ASSIGNMENT __________________Review previous assignments.

EXERCISES

Requirement. Solve each of the following multiple-choice exercises.

1. A plan view of a building shows

a. interior arrangement

b. elevations

c. type of roof

d. cellar dimensions

2. The hidden edges of an object on a blueprint are indicated by

a. leader lines c. solid lines

b. short dashes d. break lines

3. On engineering drawings, the dimensions are designated in feet and in

a. tenths of an inch

b. hundredths of a yard

c. tenths and hundredths of a foot

d. tenths of a yard

4. Which of the following scales is divided into decimal graduations?

a. metric c. architect

b. graphic d. engineer

5. The scale of a blueprint is generally noted in the

a. crosshatching

b. plan sketch

c. piping diagram

d. title block

6. Which of the following indicate the two types of piping diagrams?

a. schematic and oblique

b. schematic and block

c. flat and perspective

d. elevations and sectional

7. The details of construction or installation not shown on an architect's drawing are contained in the

a. blueprint

b. heating plans

c. specifications

d. bill of materials

8. What type screwdriver would you use to implace cross-slot screws?

a. standard c. offset

b. Phillips d. spiral ratchet

9. The size of a monkey wrench and an adjustable open-end wrench is designated by their

a. weight
b. overall length
c. jaw spread
d. thickness

10. Which of the following are the most common hammers for the heating mechanic?

a. ball-peen and claw
b. brass and soft
c. sledge and plastic tip
d. rawhide and mallet

11. Which of the following would you use to cut a light-metal bar flush with a surface?

a. diagonal cutting pliers
b. combination pliers
c. nippers
d. flat-nose pliers

12. The grade of a file refers to the

a. number of cuts per inch of file surface
a. overall length of file
c. thickness of file
d. distance between parallel cuts

13. What type of cold chisel would you use for cutting sheet metal?

a. cape
b. roundhouse
c. diamond point
d. flat

14. You must cut some aluminum piping with a hacksaw. How many teeth per inch should the saw blade have for cutting this type of material?

a. 14
b. 18
c. 24
d. 32

15. Which one of the following valves would you always keep either fully open or fully closed?

a. quick opening
b. gate
c. glove
d. check

16. You have a short piece of pipe left over from a completed heating job. You would not return this pipe into storage until

a. it has been coated with rust-resistant paint
b. both ends have been reamed
c. both ends have been flared
d. threads have been cut at both ends

17. How many pipe wrenches should you use to assure tight joints when you are installing wrought iron or steel fittings?

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

18. You are about to use oxyacetylene welding equipment. Your first action would be to

a. remove protective caps
b. crack cylinder valves slightly
c. secure the cylinders
d. connect hose to torch

19. The color of the pure acetylene flame is

a. yellowish
b. blue
c. red
d. white

20. Which of the following do you consider indispensable when you do welding?

a. fire extinguisher

b. high-top shoes

c. safety screens

d. rubber mat

21. The smallest identifiable particle to which any one element can be reduced is the

a. proton c. neutron

b. atom d. molecule

22. Which of the following revolve around the nucleus of an atom?

a. protons c. core

b. neutrons d. electrons

23. When an atom loses one of its orbiting electrons, the atom

a. disintegrates

b. becomes negatively charged

c. attracts another electron

d. becomes permanently unbalanced

24. Electrons detached from atoms by an external force are called

a. positive c. free

b. negative d. neutral

25. Which of the following would you use to measure the amount of resistance in a circuit?

a. voltmeter c. ohmmeter

b. ammeter d. transformer

26. Which of the following insulations would you use on the outside surface of a boiler?

a. powdered c. sheet

b. block d. tube

27. You intend to apply asbestos cement in two coats to a boiler surface. How thick in inches would you apply each coat?

a. ¼ c. ¾

b. ½ d. 1

28. On which of the following would you use roll insulation?

a. square or round air ducts

b. outside of boilers

c. steam pipes

d. firebox walls in horizontal type boiler

29. What mixture by volume would you make with powdered insulation?

a. equal parts

b. 2 parts insulation, 3 parts water

c. 3 parts insulation, 4 parts water

d. 4 parts insulation, 1 part water

30. You have just installed a refractory lining in the firebox of a boiler. How many hours would you allow the firebox to dry out before starting a fire in it?

a. 2 c. 8

b. 4 d. 12

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