THE HANDBOOK FOR

HOME MECHANICS

THE HANDBOOK FOR HOME MECHANICS

By

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Preface

Every man and woman who lives in a house has to be something of a home mechanic nowadays. The many mechanical and electrical devices which are essential equipment of our homes must be kept in order, or repaired when out of order; their care and repair must be understood by the home owner.

This book aims to give a clear picture of the way in which the mechanical and electrical equipment of the home operates, and to explain how and why the various devices perform the way they do. It points out what to do to keep the equipment working smoothly; also what to do and what not to do when trouble develops in one or another mechanism or device. If there is a sudden leak in the plumbing, or the temperature of the water at the faucets is unsatisfactory, or an electric switch fails to function, or the furnace provides inadequate heat—this book will show you how to correct the difficulty. The Table of Contents and Index will give you immediate reference to the page containing the information which you need.

THE HANDBOOK FOR HOME MECHANICS is more than a repair manual. It affords you a real acquaintance with the mechanical parts of the home. It is planned so that it can be read advantageously from beginning to end. Those who read through these chapters will discover that mechanical and electrical devices are not as mysterious as they may seem; even without any talent for things mechanical, you will find that you can understand your home equipment.

The book is divided into nine parts. Part One is introductory, explaining the characteristics which all mechanical devices have in common, and then discussing the basic tools which the home mechanic should be able to use.

Part Two deals with the *Plumbing* system, including both the incoming fresh water (cold and hot) and the outgoing wastes; then individual plumbing fixtures are considered in detail.

Part Three, on *Gas* as used in the home, discusses the gas pipes and the appliances which work by means of gas.

Part Four is the section on *Electricity*. The house electric wiring system is studied; then the many important appliances using electricity—lighting fixtures, switches, heaters, toasters, irons, vacuum cleaners, bells, buzzers, motors, radios.

Part Five, on *Heat*, commences with house insulation. Then the various major methods of heating a house—hot water, steam, hot air, vapor-vacuum, etc.—are taken up, with instructions as to the care and repair of both manually operated and thermostatically controlled systems.

Part Six deals with *Ventilation and Air Conditioning*, from the simplest fan ventilating device to the complete conditioning system, indicating just what is suitable for the average home.

Part Seven is devoted to *Kitchen and Laundry Appliances*—stoves, refrigerators, washing machines—some employing electricity, some gas, etc. The method of operation, points where trouble may develop, and recommended care are stressed.

These seven Parts cover the mechanical equipment of the interior of the home very completely. The two final Parts, Eight and Nine, are additional features. Part Eight considers equipment to be used outdoors—outdoor wiring for outdoor lighting, outdoor plumbing for watering the garden and grounds, and the care and repair of lawn mowers, sprinklers, etc.

Part Nine, on *The Automobile*, explains the mechanisms which make up the car, and indicates the best methods of caring for the various parts and systems.

It is the author's hope that the book will serve the reader effectively in three ways: (1) as a handbook for mechanical first aid and repairs; (2) as a source of information about the mechanical and electrical devices and systems in the home and the way they operate, so that the home owner can discuss needed changes and improvements more accurately with specially trained persons; (3) as a stimulus to interest in mechanical things in general, which will make the use of tools and the care and repair of many types of equipment an enjoyable and satisfying hobby.

In accomplishing these purposes an important part will be played by the illustrations, which have been drawn especially for this book. The house diagrams and drawings of all equipment are by Henry H. Walsh; the tools in Chapter II are by Lionel Freedman. The author wishes to express his appreciation to both of these men.

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PART ONE

Introduction

CHAPTER I

The Nature of Mechanical Devices

HUMAN BEINGS have been building buildings for a great many centuries; that is, erecting walls and covering them over with a roof to enclose a living space. Structurally these buildings have been very much the same through all the centuries that have elapsed since the skins of animals were abandoned as building material and rigid wood and masonry walls replaced tents. The main and striking difference between modern buildings and those built years ago is not in the structural methods or materials used to build the shell of the house. The difference is that today when a building is completed for occupancy it consists not only of the structural shell; within the shell an amazing collection of mechanical equipment has been added.

The modern house consists not only of walls and roof, but of these plus the water pipes and plumbing fixtures, the electrical wiring and electrical devices and fixtures, the gas piping and gas appliances, the mechanical refrigerator and radio and vacuum cleaner, and a host of other mechanical servants.

Now houses, like all physical things, deteriorate and break down in time; and so do all types of mechanical equipment within houses. When the mortar slowly crumbles from the joints of a brick wall, the structure may be neglected for a time at least, and repaired at leisure. The wall will stand and function meanwhile.

The Importance of Keeping Mechanical Devices in Repair

But when some mechanical contrivance fails, it usually becomes both suddenly and totally inoperative, and our dependence on it often requires that it be repaired or replaced at once. Sometimes the very possibility of continuing to live in the house depends on this being done. That is a penalty attached to the enjoyment of these mechanical servants which our ancestors' homes lacked. Now either to repair it or to be sure that it is repaired properly, one must understand how a device is made and how it works; and this is more than can be learned merely from inspecting it. The repair must put the mechanism into precisely the same condition it was before it broke down, or it will not work again regardless of its superficial appearance or the neatness of its repair.

A rotted-out porch column can be replaced with a rough-hewn post propped into position, and the roof will thereby be supported, but knotting together the ends of an electric cord will not cause the electricity to flow again through the broken wires. One must understand a bit more about the nature of electric cords to repair them.

This book, as its name suggests, concerns itself with the mechanical rather than the structural elements in your home. Its purpose is to help you to an understanding of them, and to show you how simple and easy it will be for you yourself to keep this equipment in order, to repair it when it fails, and to use the equipment in such a way as to forestall its breaking down unexpectedly.

When we say "mechanical device" we are apt to think at once of motion, and of something which is used by being put into motion, rather than by standing still. Of course the motion of a mechanical device is generally a series of separate motions of its various parts working together. It is from this characteristic of most mechanical things that both their usefulness and their shortcomings flow. Just as "mechanical" suggests motion, so motion implies wear, and wear terminates in breakdown. It is inherent in the nature of most mechanical contrivances that through the wear of motion they should be less long lived or enduring than non-mechanical or structural things which serve us in our homes by standing static. In a sense it is perfectly normal for machines which have had considerable use to break down. When a layman asks in exasperation, "*Why* did that machine have to break down—it was working perfectly?" the mechanic answers simply and truthfully, "Because it *is* a machine."

UNDERSTANDING MECHANICAL DEVICES

Not so long ago one often used to hear it said—almost boasted—that a person "had no talent at mechanics, and couldn't understand or repair the simplest mechanical thing." One hears such a statement much less frequently today. Perhaps the years of the twentieth century and the latter part of the nineteenth century during which we have increasingly lived with and used such a wide variety of mechanical devices have finally made us feel more familiar with them, and it is no longer fashionable to admit, or claim, that one knows nothing about mechanical things.

Perhaps the automobile has had as much to do with this change of attitude toward mechanics as any other force in our lives. Certainly the simple and emphatic demonstrations of the laws of physics and mechanics which using an automobile (and seeing it break down) impart to us have made physical and mechanical things more real and understandable to many of us than any school courses we may have had in the physical sciences.

At any rate our position here is that anyone can easily learn enough about mechanics to repair the equipment with which his own home surrounds him, and can enjoy it thoroughly,—make a sort of hobby of it if you please. And it is the purpose of this handbook of home mechanics to help you.

Now basically we think of a handbook as a sort of abbreviated list of specific directions with detailed information about certain subjects on certain pages. This book is that, as an examination of the table of contents will show, but it is more.

The Basic Patterns of Mechanical Devices

There is a basic pattern of mechanical thinking and mechanical practice which underlies the design, manufacture, operation, and repair of practically all mechanical things; and understanding this pattern makes most of them extremely simple. This fortunate circumstance is a great time saver because it permits us to apply what we learn about one device to a great many others.

Merely for purposes of being able to navigate a busy street an illiterate person could quickly be taught to recognize and know the meaning of the few specific words "Danger" and "One Way Street" and "Traffic Go" and "Traffic Stop"; but seeing such a person apparently able to read these words we would indeed be surprised to learn that he knew only these few words, and was really unable to read any of the other words which knowing the entire alphabet of letters would open up to him.

In the same way a man could learn reasonably rapidly by memorizing an exact method for assembling some simple machine, but he would not be really "mechanically literate," when confronted with another machine, any more than a person who could "read" only certain printed capital letters arranged to spell "Stop" "Go" etc. would be literate.

Mechanics like language has its alphabet, and once we learn this alphabet we can "read" most machinery. Machinery, all of it, has great similarity. It is made up of strangely simple and persistently recurring little elements. It has differences too, yes. But the similarities are great and important and the differences small and easy to perceive. Accordingly, in applying any of the specific advice contained in the later chapters, it will be helpful to keep in mind the simple mechanical generalities, the striking similarities between most all machines, the alphabet as it were; and then to watch for the small variations and neat and interesting minor changes which differentiate the various devices.

You will find that examining, studying and really understanding mechanical things is not dull business, but interesting. These things are only dull when we don't understand them, or when we try to understand them by hearing or reading dull and meaningless information about them without getting our hands on them and really manipulating them. Even the simplest mechanical devices are interesting when we become acquainted with them in person.

How Mechanical Devices Do Their Work

Every mechanical device has a specific function—a certain very definite job to do. And according to the nature of that job, the device will have a certain necessary structure, that is, it will be made in a certain way so as to do *that* job. Its structure will *not* depend—except perhaps for its decorative treatment or art design—on any whim of the maker, but rather on its function. A mechanical gadget may be richly overlaid with decorative chromium plating (such as the "trim" on an automobile body), but you will soon learn to recognize this for what it is, and cut through it to the meat of the matter. You may have noticed that while some people are very much impressed by the decorative trim on a gadget, and stand in admiring awe of it, the mechanic starts his investigation of a device by stripping the decoration off and laying it aside so he can get a clear view of the really important elements of the machine.

Having then a certain job to do, and a structure which permits it to do that job, every device has a specific way of doing that particular job, or as we say, a certain method or cycle of operation. In simpler words than function, structure, and operation, what you want to learn about any device is: First—Just exactly *what* is the thing supposed to do? Second—How is it made? That is, what are its parts, and how do they fit together? Or, how do you take it apart and get it back together again? Third—Just *exactly* how do its parts work together to do the job for which the mechanical device is intended?

Function, Structure, and Operation

Let us apply these generalities to a simple specific device: A cloth for cleaning a floor, or a mop. Function? To remove dirt from the floor. Structure? A piece of cloth, moistened. Operation? The cloth is applied to a section of the floor (which is bare except for some dirt) and is moved about. Operating according to reputation this mechanical device removes the dirt *exactly* as follows: Brought into contact with the floor, an adhesive affinity between the moist surface of the cloth and the particles of dirt causes the particles to attach themselves to the cloth, and when the cloth is removed the dirt comes with it, leaving the floor clean. Let us assume a failure in operation. The dirt fails to cling to the cloth. Knowing the principle on which it operates, we diagnose that the cloth is not in fact damp enough. Repair? Immerse it in liquid to replace the all-important moisture which has apparently evaporated since its last successful use. Or, to assume a disfunction: The cloth picks up not only the dirt but the floor finish as well, or so alters its structure or softens it that it discolors. Well, we have evidently dampened the cloth with a liquid which not only gives it an affinity for dirt, but acts as a solvent. Repair? Dip the cloth in cooler water, wring it drier, and rub less vigorously and more rapidly.

This example may seem almost childish in its simplicity; but in addition to illustrating function, structure, and operation, it suggests another very important principle common to the operation of all devices having motion, even the very simplest. That is this:

Motion can be induced only by the application of energy. The energy applied in this example, it is true, was manual energy; crude animal power supplied by the operator's muscles, whereas the home mechanical equipment with which this book is concerned is energized by power other than human energy; but energy it must have.

There are various types and sources of energy. Our study of the various mechanical devices, beginning with chapter three, gives first an explanation of the energy involved and its service to the machine, and second the mechanics and operation and repair of the machine.

The Vacuum Cleaner as an Example

But let us return for a bit to the floor cleaning job in the example above, and substitute in place of the damp cloth a device admittedly mechanical—and one that you may have occasion to repair—that is, a vacuum cleaner. The job is the same: the removal of the dirt from the floor. But the structure of the machine used is different, it being a vacuum cleaner instead of a damp cloth; and of course the principle of operation is different too. The vacuum cleaner, instead of depending on the adhesion of dirt to a damp cloth, depends on the fact that when air is moved briskly enough (that is, in this case, sucked into the machine) the dirt goes along. Then the dirt is trapped in the machine, while the air used to convey it, filtered of the dirt, is passed through and out of the machine.

It is quite a train of events which gets that air into motion. The vacuum cleaner does it in this way. Electrical energy is served to the machine through its wires—the cord and plug as we call them—which are attached to an electric outlet. This energy moves through the wires, enters an electric motor, and the motor is put into motion. Attached to the motor is a kind of fan, which is thus also made to move. The fan in turn puts the air about it in motion; and because the fan is surrounded by a metal housing with two spouts, one leading to the dust bag and the other to the sucking nozzle, the air is guided through the spouts and moves from the nozzle to the bag. As the air in the suction nozzle is thus removed, more is sucked in from near the floor to replace it; and this air in turn puts the nearby dirt into motion and sucks it too up into the machine.

Important Similarities Between All Vacuum Cleaners

That is how your vacuum cleaner works. The process is the same whether the maker devised its design so that the dirt is trapped in a small bag concealed in a horizontal tank with a long flexible rubber hose connecting the machine with the sucking nozzle, or with a larger bag hung exposed from the handle of the machine. Both machines will be found to have a cord and plug, an electric motor, a fan, a dust bag, and a nozzle. These are the important things about your vacuum cleaner, and everyone else's too.

For illustrations of both types of vacuum cleaner see Figure 79 on page 221.

Now if every vacuum cleaner were an exact duplicate of all others in detailed design and the arrangement of its parts, as well as in *significant basic structure, one could very easily procure one cleaner, dismantle and examine it,* determine its detailed arrangement and write a handbook showing just exactly how to proceed screw by screw and part by part to dismantle it and repair every ill which the nature of its structure and operation suggested that it could possibly suffer. Aided by a few illustrations the instructions might read something like this: "With the machine placed on its back remove screws marked *A* and *B* and loosen setscrew *C*. This will free part *D* which connects parts *E* and *F*, and these may now be lifted out of place and set aside to expose part *G*—and so forth." The reader could then proceed, but he would not understand why he was doing any of the things specified.

However, because of the multiplicity of manufacturers who make similar devices each to his own design, one cannot give specific and detailed instructions covering all makes and models of all home mechanical devices. Nevertheless one can learn to understand the basic principles of construction and operation underlying all vacuum cleaners as easily and almost as quickly as one could learn to dismantle any one specific model. And, having learned the general procedure for all vacuum cleaners, one may examine any vacuum cleaner, confident of being able to repair it with perfect ease.

Characteristics Common to All Mechanical Devices

In learning to understand vacuum cleaners, moreover, you have learned certain facts which apply to all mechanical devices. The man who made the first vacuum cleaner admittedly had invented something new when he got the parts of the machine assembled so they would remove dirt by sucking air, but he certainly did not invent the parts. He dipped into that common pool of previous mechanical knowledge which everyone else was also using for his various devices, and he drew out an electric motor, and the cord and plug to connect it to the electric source, and the switch to control the motor, and the fan to move the air, and the handle for the machine, and its wheels, and so forth. Consequently, while you will meet his particular combination of mechanical building blocks only in the vacuum cleaner, you are going to meet these basic components time and again, arranged and assembled in various combinations, and forming various quite different machines. By the time you have reached the end of this book, and studied all the devices dealt with here you will be amazed, or rather you will already have ceased to be amazed, at how very like one device another is, and how little original or unique there is in any of them.

Now notice another significant fact which the vacuum cleaner reveals. Not only are the major component parts common to other machines, but the very means and methods of fastening these parts together, or assembling them, are likewise drawn from the pool of common knowledge and universal practice. If the vacuum cleaner inventor did not invent the motor, or wheels, or the other parts of his machine, he certainly did not invent the screws and bolts and nuts and rivets and clips with which the parts are assembled and held together, nor the tools required to place and remove them. They had all been in use for a long time.

Before proceeding to the operation and repair of mechanical devices, some knowledge of the commoner tools and fastening methods is necessary, and this knowledge and these tools will be found applicable to practically all devices. We shall therefore turn now to the tools.

CHAPTER II

Basic Tools for Home Mechanics

The truly marvelous dexterity of the human hand and its fingers has often been noted. Our human brain has the ability to conceive and invent mechanical devices and our human hands and fingers have the ability to build and operate them. And yet, confronted with even a simple device, we would be quite helpless to take it apart or put it together again, with only our knowledge and our bare hands. We need something more. We need *tools*. In fact, tools were invented long before machines, and our climb toward the comfort of a twentieth century home really began with our invention and use of tools.

General Characteristics of Tools

What are tools? They are devices for extending the usefulness of our hands and fingers; much stronger, more delicate and specialized, and ingenious. One "end" of a tool is always shaped to fit the human hand, and the other "end" to fit the work.

Tools themselves are, in a sense, machines. They have certain specific functions to perform; each is built in a certain way to do its own particular job, and is to be operated in a certain way to do it. Like machines, too, they have basic similarities and minor differences in construction and operation, are subject to failure through wear or misuse, are used by being put in motion,—and, as any mechanic will tell you, require energy for their operation. Unlike home machines, however, your home tools will be almost exclusively energized by your own muscular energy: in other words they will be hand tools rather than power tools.

Characterized generally by a beautiful simplicity and obviousness of construction and operation, some tools are however so similar to others in construction and appearance, but so different in function, that it is the differences and not the similarities which you will have to watch in order to use them correctly. For instance, a wrench and a pliers, though quite different in appearance, are alike in that either will encircle and seize a part, and thus permit you to move the part to the left or right; but the correct applications of these two closely related tools are quite different. A narrow wood chisel and a screwdriver are rather alike in appearance, but it would be a serious mistake to loosen a screw with the blade of a chisel, or to use a screwdriver to chisel wood.

Now the subtleties and refinements of really minor differences between tools have been carried to great lengths, and one could own hundreds of tools without having two exact duplicates; but actually the number and cost of tools required for satisfactory home mechanics is modest.

The simplest hand tools are the best, and the so-called combination tools are usually worse than useless for any of the tasks which they are supposed to do. For instance there is a combination tool, of which thousands must have been sold to the unskilled, which consists of a handle into which can be fitted a miniature hammer, a screwdriver blade, a couple of sizes of augers, a scratch awl, a knife blade, etc. Such tools should not be used because the essential proportions which give the proper balance to each individual tool were sacrificed to effect their combination. Even if they worked you would find the annoyance and delay of changing the handle from one tool to another insupportable. Practically nowhere except in the carpenter's claw hammer, where the hammering face and the nail pulling claw occupy opposite ends of the head, do we find a really successful combination of two functions in one tool.

There are certain common tools used in all trades, and then there are some used by only one trade. A hammer, for instance, in one of its many variations, is indispensable for electrical work, plumbing, gas fitting, carpentry, or for almost any other kind of mechanical work you might think of. A Stillson wrench, however, is used only for work requiring the use of pipes and pipe fittings. Most of the tools which we shall recommend are of the common sort.

The tools listed here total about sixty. They are all tools that you will want to be familiar with, but you will not need them all right away. Many you will find you already own; some are very low in cost (being available in satisfactory quality at the ten cent store). You will notice that the tools are listed here by the function they perform.

Important Tools and How to Use Them

The section which follows the list gives illustrations of the various tools, with explanations of their use. As you examine the pictures you will probably find that you are familiar with many of the tools without having known their names.

List of Basic Tools for Home Mechanics

(Classified According to Function)

Fastening Tools

Screwdrivers

Straight screwdriver
Close quarter screwdriver
Offset screwdriver
Screwdriver bit
Automatic screwdriver
Phillips head screwdriver

Wrenches

Coes wrench
Box wrench
Open end wrench
Socket wrench
Setscrew wrench
Parallel jaw pliers
Locking pliers-wrench
Stillson wrench

Other Fastening Tools

Soldering iron
Riveting hammer

Squeezing and Holding Tools

Pliers
Hand clamp
Hand vise
Bench vise

Measuring Tools

Zig zag rule
Steel spool rule
Square
Plumb bob
Spirit level

Marking Tools
- Center punch
- Chalk line
- Scriber
- Scratch awl

Shock Tools
- Machinist's hammer
- Sledge
- Carpenter's claw hammer
- Mallet

Cutting Tools

Shearing Cutters
- Cold chisel
- Snips
- Compound snips

Pinching Cutters
- Pincers
- Side cutting pliers
- Diagonal cutters

Scoring Cutters
- Knife point
- File for scoring
- Cold chisel for scoring
- Glass cutter
- Pipe cutter

Kerfing Cutters
- Hack saw
- Crosscut saw
- Ripping saw
- Coping saw

Surfacing Tools

Paring Cutters
- Knife
- Wood chisel
- Plane

Attrition Cutters
Files
Rasps
Abrasive cloth
Abrasive paper
Abrasive wheel

HOLE-MAKING TOOLS
Piercing Hole-Cutters
Awl
Punch
Attrition Hole-Cutters
Gimlet
Twist drill
Auger bit

SCREW-THREADING TOOLS
Tap
Die

TRACTION TOOLS
Pinch bar
Hammer claw
Pincers for traction
Screw extractor

FASTENING TOOLS

First on this list of tools are the SCREWDRIVERS and WRENCHES, which are the screw fastening tools; and any study of things mechanical must start off with the *screw* which these tools are used to manipulate, because if we were asked to name the very commonest mechanical device, which recurs time and again in one form or another, it would certainly be the screw. Generally speaking no simpler nor more satisfactory means of fastening rigid bodies together has ever been devised, nor is any other nearly so widely used.

It is a fact that no matter what manner of mechanical thing you have to repair, you are almost sure to start out by removing some screws which hold it together. There are many sizes and types and variations of screws, but they all have two common characteristics. These are the *thread*, which is a helical rib surrounding the cylindrical shank, and an *end* so shaped that it can be got hold of and turned. In strict accuracy *this* screw is only half of any screw fastening. Properly it is called the male or external screw, and the other part, into which it turns (called the female or internal screw), has the reverse image of the same rib or thread shape projecting from the inside of a cylindrical or conically tapered hole.

As used in the familiar pointed tapered wood screw, with its slotted head, the female thread is cut directly into the fibers of the wood itself by the male screw, while in metal screw fastenings the female thread may be either in a separate piece, called the nut, or it may be cut directly into the wall of the hole in which the male screw turns.

The beauty of the screw device lies in its simplicity and in the fact that you can remove the screw and then put it back exactly as it was before. You won't have damaged it by removing it, and you will have no difficulty replacing it, providing you employ the correct screw fastening tool—if the screw requires a tool. Two familiar applications of the screw fastening principle—which happen not even to require a tool—are the metal end of an electric light bulb, and the upper end of a glass Mason jar. If you can "screw in" a light bulb, or "screw on" a Mason jar lid, you can manage any other screw fastenings.

In the illustrations of screws given here, the commoner sorts which you will meet in home mechanics are shown as they actually occur in some common applications, with the various kinds of heads and of nuts used, and each shown with the proper kind of screw fastening tool engaged with it, whether it be a screwdriver or a wrench.

The captions accompanying the pictures of the various screw fastening tools will explain these differences as they are revealed in the pictures, but you will find it helpful to examine actual examples of as many types of screws as you can find about you in your home mechanical appliances.

Screwdrivers

An ordinary STRAIGHT SCREWDRIVER, of the type most commonly used, is shown in Figure 1, with the so-called

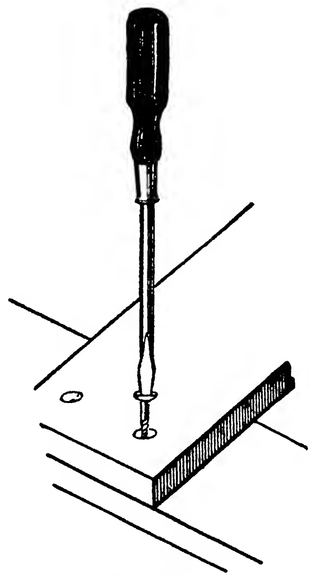


FIGURE 1

standard blade and tip. The drawing shows the screwdriver being used to drive an ordinary flat-headed bright iron woodscrew with the usual slotted head through one piece of wood into another piece, to hold the two pieces together. Notice that the top piece first had a hole bored through it so the screw would not bind in going through this piece. This screw holds the pieces together by pressing *downward* on the top piece only, with the underside of the head of the screw and pulling *upward* on the bottom piece by the engagement of the screw threads with the female threads which they cut into the wood. Notice also that the top edge of the pilot hole in the top board is bevelled to the same angle as the underside of the head of the screw so that when the screw is screwed tight into place its head will not stick up above the surface of the board. This bevelling is called countersinking, and it is done with the *countersink bit* (shown in Figure 43 at *A*) used with the *bit brace* also shown at *C* in the same illustration. All flat-headed screws, whether in wood or metal, are always countersunk to finish flush.

Figure 2 shows a straight blade "CLOSE QUARTER" SCREWDRIVER, very short, for use in close quarters, and with a

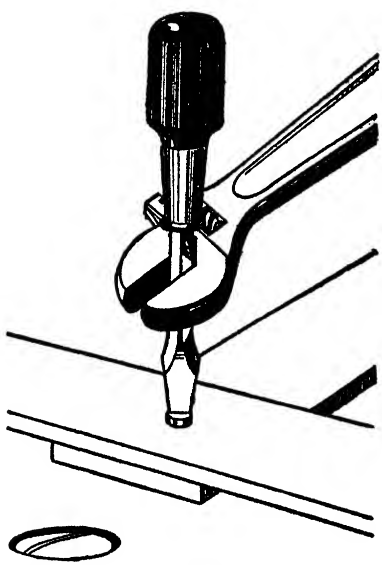


FIGURE 2

so-called square blade, driving a filisterhead capscrew through one piece of metal into another. Notice that the hole in the upper piece of metal is not countersunk. These metal screws also hold by pulling downward with the underside of the screw head and upward with the threads, but they finish with the head above the surface of the top piece, unless it is counter*bored* as shown in the small picture. Notice also that a wrench adjusted to fit the square blade of the screwdriver is being used so as to get leverage enough to turn the screw. Here, as with all fastenings into metal, the screw is not tapered and pointed like the woodscrew in Figure 1, nor does it cut its own female thread in the lower piece. This piece is first drilled and then the female threads which will engage the male threads of the screw are cut or "tapped" into the walls of the hole with the tool illustrated later on under the Screw Thread Cutting Tools.

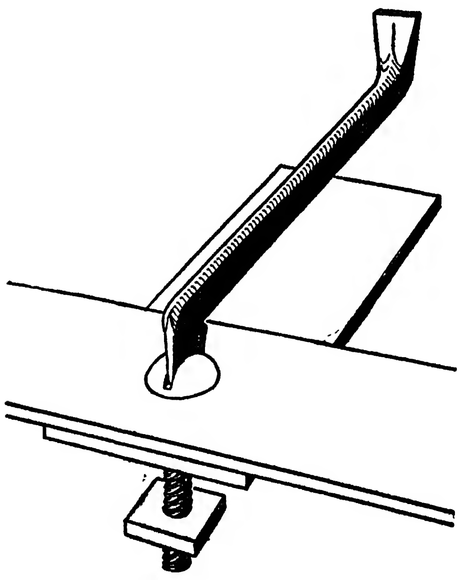


FIGURE 3

In Figure 3 we have an OFFSET SCREWDRIVER. It has two working ends to engage the screw slot. One is set at each end of the blade, and they are offset at an angle. This construction permits you to work in a tight corner where a straight screwdriver could not be used, and gives you more leverage. The screw fastening shown here is called a *round-headed stove bolt*, and it is being used to fasten the two pieces together, but it does not thread into the lower piece. In cases where the lower piece is too thin to receive enough female threads to engage the screw properly, as here, a bolt such as this is passed through smooth holes in both pieces and a threaded nut is screwed on its lower end. To loosen or tighten a nut and bolt fastening such as this, both the bolt head and the nut must be held, one with a wrench and the other with a screwdriver. Stove bolts, like woodscrews, are also made flatheaded, to be countersunk into the work.

A SCREWDRIVER BIT is shown in Figure 4. It is a screwdriver without a handle. It is used by being held in the bit

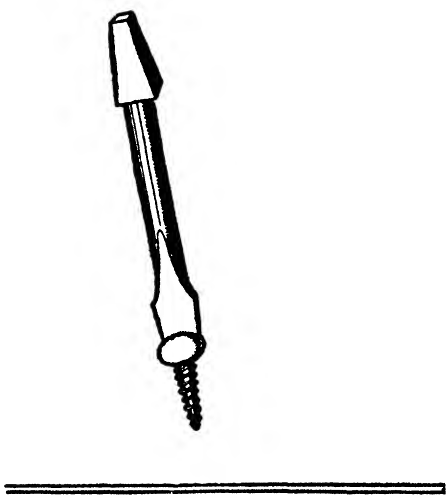


FIGURE 4

brace, which furnishes more leverage than can be got with a straight screwdriver, a wrench on the screwdriver blade, or an offset screwdriver. The screw shown here looks like a roundheaded woodscrew, but it is really a metal screw of very special type. It is called a *self-tapping screw.* For certain applications in metal which is not too hard, a hole is drilled in the upper of the two pieces large enough to admit the screw without its shank binding, and a smaller hole is drilled in the lower piece. But this lower hole is not tapped (grooved) to engage the screw threads. Instead the self-tapping screw, which is made of extremely hard steel, is inserted and screwed into place, cutting its own female threads as it goes, just as the woodscrew does. These self-tapping screws are also used instead of nuts and bolts or rivets, to fasten two sheets of thin sheet metal together. This is made possible by piercing a hole through the metal and leaving the burr or skirt which is formed on the lower side of the holes for the screw threads to engage with. In using the screwdriver bit in the brace, care must be used not to exert too much force or the screw may be literally twisted in two, or the screw head split apart.

Figure 5 shows a mechanical screwdriver, which is used when many screws are to be driven. It is called a SPIRAL AUTOMATIC or *spiral ratchet* screwdriver. Merely by pressing on the handle, the blade will be made to revolve in the desired direction either to drive or remove a screw. The blade, or bit, is removable, so a bit of different size or pattern may be used. The bit in the screwdriver is called a cabinet tip bit. Notice that the tip of this blade is as wide as any point on the shank. It is not a strong type of tip but is needed when a screw is to be sunk into a hole below the surface of the work, and the screwdriver tip must follow it in. The screw shown here is a setscrew. It has no head but only a slot to engage the screwdriver blade. Its purpose is to fasten the hub of the pulley shown to the shaft. This might be the belt pulley of an electric refrigerator. The setscrew operates by its point, which may be pointed or ground to a sharp-edged cup shape, pressing against the shaft as it is screwed down tight. Another type of head may be used on a setscrew, which requires a wrench instead of a screwdriver. It is illustrated among the wrenches.

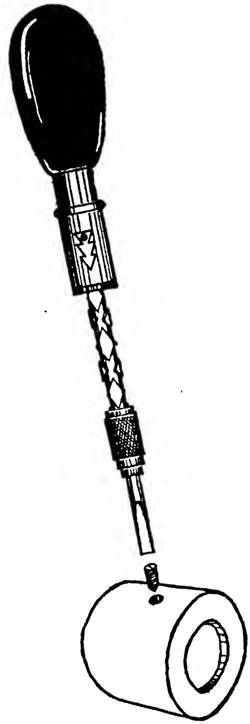


FIGURE 5

A screwdriver called a PHILLIPS is shown in Figure 6. The important point about it is not the shape of the handle or the type of blade, but the peculiar shape of the tip, which as you can see is made like a cross. Phillips tips are available not only on straight screwdrivers like this one, but on screwdriver bits for both braces and automatic screwdrivers. Phillips screwdrivers will engage only with a special screwhead called a *Phillips head*. This head is used for all the various types of wood and metal screws, and it has several advantages over the slotted head screw. In driving slotted screws, care must be taken to use a screwdriver with a tip no wider than the head of the screw or the work will be marred as the screw is sunk home flush. Likewise, too narrow a tip must not be used or the screw slot may be

FIGURE 6

damaged or the head split in half. Even then a screwdriver sometimes shears off a sliver of metal from the edge of an ordinary screw slot, and in doing so may slip from the slot and gouge the work. The cross shaped depression in the Phillips head overcomes these difficulties, in addition to its being considered more decorative.

Wrenches

Figure 7 is a COES WRENCH. Perhaps you know it by its popular name of *monkey wrench.* Until the general use of automobiles made wrench manufacture a mass production industry, and called for lighter, more compact wrenches for use in tight places, the Coes wrench was probably the most widely known and generally used of wrenches. It is still a good tool, being of simple design and adjustable to fit various sizes of nuts or bolts, and very sturdy. It is a heavy tool to handle, however, and can be used only where there is plenty of clearance around the bolt head or nut. The shape of the square face opposite the jaws is misleading. It looks like a hammer head, and this, plus the fact that it has

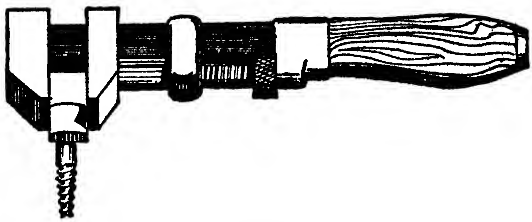


FIGURE 7

something of the balance of a rather clumsy hammer when held in the hand, often leads to its being used as a hammer. This is a mistake. It will ruin the wrench in time, and will not work half so well for hammering as a good *hammer* of equal weight costing considerably less. The wrench is shown engaging a lag screw, which is very much like the woodscrews with which you are already familiar, except that it has a four sided head and no screwdriver slot.

In Figure 8 we have a BOX WRENCH, engaging the hexagon shaped head of a machine bolt. As you can see, it bears on all the faces of the bolt head instead of only two, and requires very little clearance around the head. Holding the nut in the picture is an OPEN END WRENCH with an S handle. Both these types of wrenches are also made double ended, that is, with jaws of different size at either end of the wrench. Notice the washer beneath the nut. It is called a *lock washer* and as the nut is tightened its sharp points bite into the metal to prevent the nut from being loosened by vibration. If you remove a fastening using a lock washer, you must remember to replace the washer when you replace the fastening.

Notice that the open end wrench in this picture has a curved or an S handle. This type of handle is also made for box wrenches and for open end adjustable wrenches of both single and double end design. When a nut or bolt is set near a vertical obstruction preventing the wrench from being turned more than a few degrees, an S handle wrench

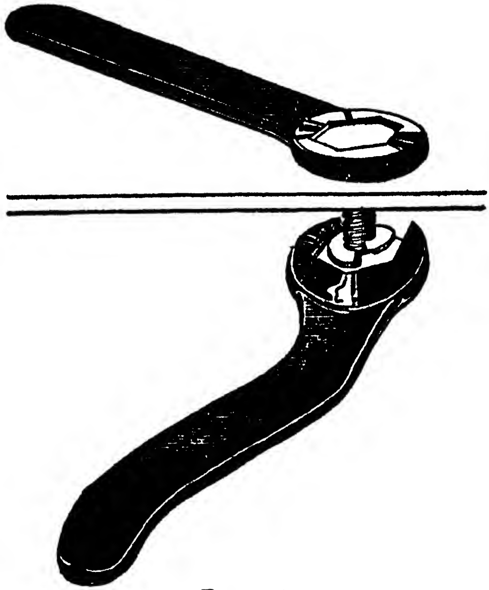


FIGURE 8

can be used for a short stroke, removed, replaced with its opposite face downward, and again moved forward.

Figure 9 shows a SOCKET WRENCH. It engages with its handle in the same manner as it does with the bolt head or the nut, and can be used on either end of the handle. As used here it exerts less leverage but will work in a tight corner, and on the other end of the handle exerts much more leverage. The same handle is used with several sockets of different size. Holding the nut is a double open end non-adjustable wrench. These wrenches, like the sockets, are sold in sets, and a set of four would fit any of eight sizes of nuts or bolts. A small stove bolt is often sold with the sets to hold them together when they are not in use. Notice the construction of the nut. It is called a *castle* or castleated nut, through its resemblance to the turret of a castle. This nut does not depend on a lock washer to prevent its loosen-

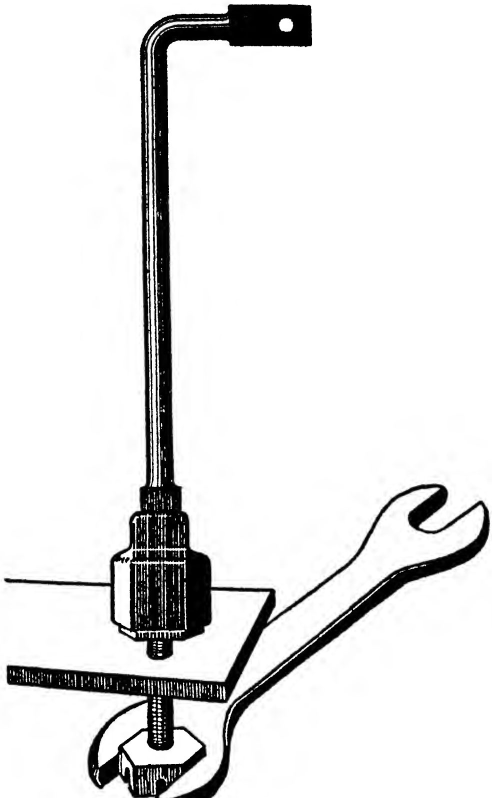


FIGURE 9

ing through vibration. Instead, the shank of the bolt has a small hole drilled through it, and through this hole and across two of the slots in the nut is placed a cotter pin. Of course the cotter pin must be removed before the nut can be screwed off.

Here in Figure 10 is perhaps the simplest wrench of all. It is a hexagon SETSCREW WRENCH, and is used for a type of setscrew or capscrew which has a hollow head instead of a slot. These hollow heads are noted for their strength, and when tightened into place down in the hole they will

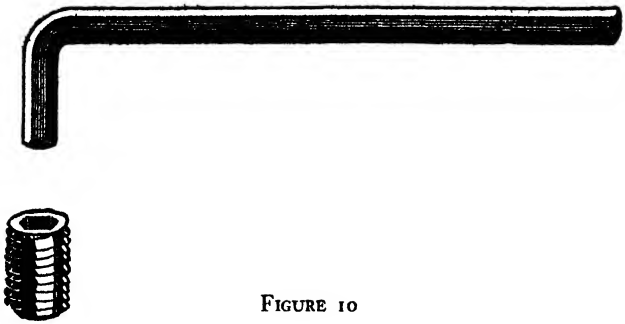


FIGURE 10

not split as a slotted setscrew sometimes does under the pressure of the screwdriver. If you encounter an assembly using a hollowheaded setscrew, do not attempt to loosen it until you have secured the wrench which fits it. A screwdriver blade will not budge it, and will damage the socket so the wrench may not engage properly.

As a rule the use of hollowheaded setscrews and capscrews is confined to heavier machinery because of the thinness of the wall around the socket in a screw of small diameter. Small setscrews such as are used to fasten the tuning knob of a radio to the shaft, or a pulley to a light motor, are generally made with slots.

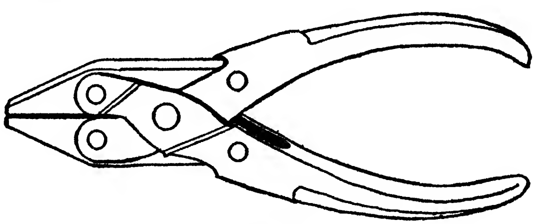


FIGURE 11

Figure 11 shows a pair of *pliers*, listed and illustrated here among the wrenches, although the ordinary types of pliers are not suited for substituting for a wrench. But *these are pliers of a special design. Ordinary pliers, or tongs or pincers, consist of only two parts riveted together so* their jaws open at an increasing angle; but *these* pliers are made so that their jaws open parallel. They are called PARALLEL JAW PLIERS. They will seize a nut or bolt without damaging it, and more quickly than one can adjust a wrench or locate one to fit the nut, but they will not exert as great a pressure.

There is a LOCKING PLIERS-WRENCH (Figure 12) which is really neither a pliers nor a wrench, but a distinct improve-

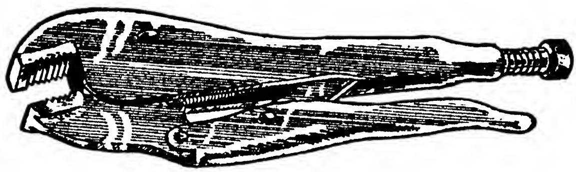


FIGURE 12

ment over either for certain work. It has the handles and tong-seizing action of the pliers, and the (almost) parallel jaw relationship of the wrench, but in addition it has a very simple screw adjustment which when a seize has been taken on the work, can be tightened up until, unlike either the pliers or wrench, the jaws will hold the work with a vise-like grip even if one lets loose the tool. For this reason it is sometimes called a *vise wrench*. This tool will handle work of any size within a good wide range, is convenient for working in close quarters, and is not too expensive in view of its usefulness.

A STILLSON WRENCH is shown in Figure 13. It may resemble a Coes wrench somewhat, but it is really very different from any of the other wrenches. It is an adjustable wrench, but its jaws are not smooth, nor do they open parallel or hold their adjustment when the wrench is used. A Stillson wrench was designed especially to grasp screw fastenings which offer nothing to get hold of but their own smooth cylindrical shanks, and it operates by its rough teeth biting into the material and its jaws coming tighter and tighter as the wrench is turned *in the proper direction,*

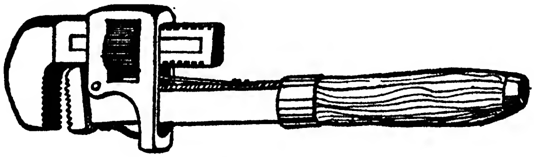


FIGURE 13

until, no slippage occurring between the tool and the material, the threaded engagements are screwed tight or loosened. The prime application of the Stillson wrench is in plumbing work, where the hollow pipes are joined end to end with threaded sleeves called couplings. The chapters on plumbing will elaborate this. Meanwhile, *do not* use a Stillson wrench on any nut or bolt.

Other Fastening Tools

In Figure 14 we have a SOLDERING IRON, a small one heated by electricity, and shown held as it would be in soldering two pieces of metal together with their edges overlapped. Although called an iron it is really made of copper, and its function is to convey enough heat to the metal parts to cause the solder to melt and run into the joint between the two parts which are to be joined. Solder is an alloy containing lead and tin, and it has a much lower melting point than the metals which it is used to join. Soldering irons are made in various sizes, small ones for delicate work and large ones for heavy work where more heat must be transferred to the metal. Not all of them are heated by electricity. Sometimes a small portable furnace burning charcoal is used, or a torch, or in shop work a gas flame.

As the work is heated by the iron, after being cleaned to permit the solder to adhere to it, it is approached and touched with the solder, which melts and fills the joint. On cooling, the solder again hardens, binding the parts together with a bond of metal, which is watertight if applied to the

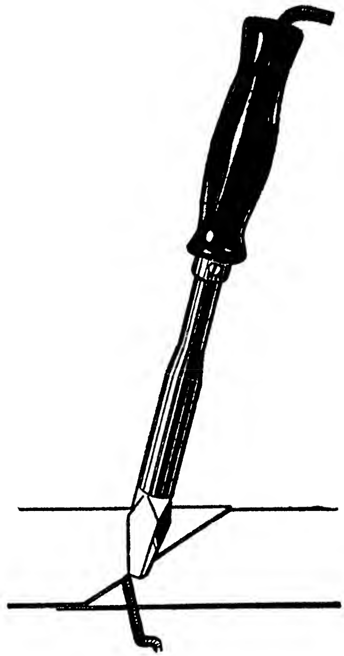


FIGURE 14

entire seam. A soldered joint is disassembled simply by heating it, either with the iron or with a torch or flame, whereupon the solder melts and the parts can be pulled apart.

Figure 15 shows a RIVETING HAMMER. A riveted fastening is something like a bolt with no threads and a head on each end. It is made by drilling the work, inserting a rivet a bit longer than the total thickness of the parts to be riveted, and hammering the exposed tip of the rivet into a head. This is done by tapping it first with the cross peen of the riveting hammer, then with the flat face, and then, if it is desired to shape the head to a neat dome instead of a battered swelling, with the rivet set shown beside the hammer. The use of a riveted joint should not stop you from taking an assembly apart if this is necessary to repair it. Simply

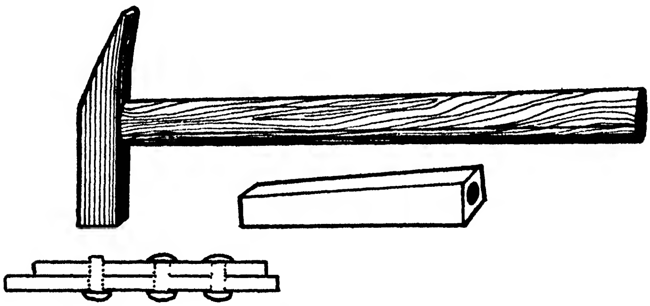


FIGURE 15

shear the head of the rivet off with a cold chisel, or file it off, and drive the shank of the rivet back through the hole. A new rivet of proper length will of course be required to reassemble the joint.

SQUEEZING AND HOLDING TOOLS

PLIERS (Figure 16) are, along with the screwdriver and hammer, the amateur tinkerer's main tools. Here is a popular type, known as the SLIP JOINT PLIERS. It has the ad-

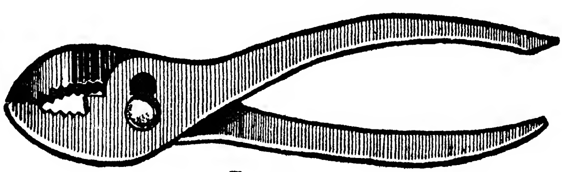


FIGURE 16

vantage that the opening range of the jaws can be changed to seize a thin or a thick object, and within limits it can be used somewhat like a small Stillson wrench to encircle round rods or small pipes by grasping them with the back part of the jaws. Pliers should not be used, however, as a wrench on a nut or bolt, since they are almost sure to slip and when they do the sharp teeth in the jaws will mar the work. Basically they are for holding a piece of material which cannot be held tightly enough in the fingers to permit its being worked on, and which cannot be brought to a vise. Another good type of pliers is the electrician's pliers with side cutters, which are illustrated under the cutting tools.

Here in Figure 17 is one type of HAND CLAMP, which because it uses a threaded screw arrangement will grip a piece of work more firmly than a pliers, and will hold it without further attention. There are many places where the hand clamp can be used more conveniently than the pliers, but it

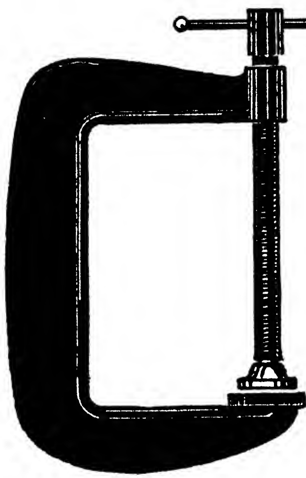


FIGURE 17

is of course not good where the piece is being held to be guided into position. For instance, you could never push a cotter pin home, or withdraw it, with the clamp as you could with the pliers. Mechanics who are unfamiliar with hand clamps do not seem to miss them much, while those *who have used them—cabinet makers for instance, who use a slightly different type—learn to make the widest use of them in the most ingenious and labor saving applications.* Often, for instance, a part to be repaired can be held firmly simply by clamping it to the bench with a hand clamp, though it might not be possible either to hold it with pliers nor to get it in the vise. This tool is also known as a C clamp.

In Figure 18 we have a HAND VISE, also called a jeweler's vise. Its operation will be apparent from the picture. It is

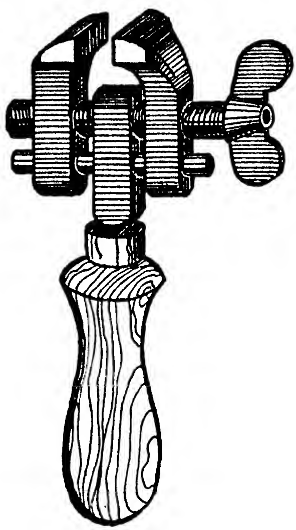


FIGURE 18

not a substitute for a pliers, because its jaws open parallel and to an extent making it useful only for holding relatively thin work, but for many jobs it is better than either a pliers or a clamp. Its jaws are broader than the squeezing faces of a clamp for one thing, and are usually rough to help it hold securely. The handle is particularly convenient. Like the clamp the vise employs a threaded screw to tighten the working jaws, and an interesting thing about the screws of both of them is the fact that they require neither a screw-

driver nor a wrench to operate. Instead the two little wings are smooth enough to be turned with the fingers and wide enough to furnish as much leverage as it is safe to use. In the form used on the vise, the screw is called a wing screw, and you will encounter it in other devices, as you will also the cross handle used on the vise. The wing nut or wing screw is used wherever it is desired to remove a fastening frequently without a tool, (as for holding the lid of a pressure cooker in place, or on a ship, to fasten a port-hole window).

If you tried to do any amount of home mechanics work without a BENCH VISE (Figure 19) of some sort, you would

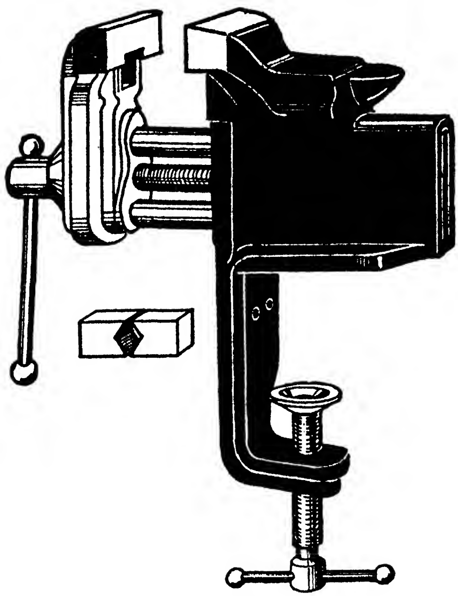


FIGURE 19

be greatly handicapped. Here is one intended for light metal work. It is clamped to the bench or table top with a screw clamp attachment. Now notice that it has in addition to the flat jaws a pair which are shaped to seize a round pipe in doing plumbing work. There are special pipe vises just as there are large wood vises, but this one is probably the most convenient type for general all 'round home work. In spite of the great force they can exert on a piece of work, vises can be damaged by misuse. They are not anvils, and should not be used by being pounded on.

Measuring Tools

Figure 20 shows two of the commonest measuring tools that you will have occasion to use. Above is the ZIG ZAG OR

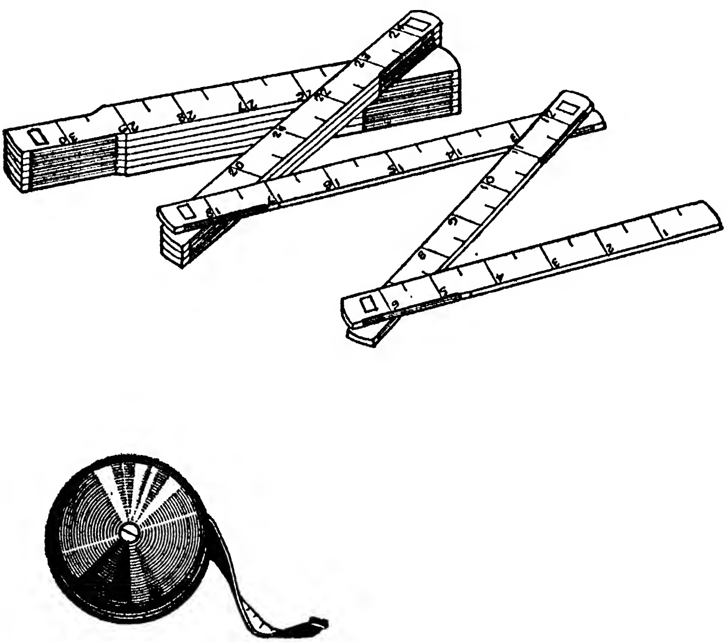


FIGURE 20

folding WOOD RULE, and below is the STEEL SPOOL RULE. The steel spool rule, which is now made either with the inner end attached to the container or loose so it can be removed entirely for use, comes closer to being a precision instrument, although neither the steel nor the wood folding rule is very convenient for accurate measurements of short distances, as in bench work, since they are six feet long. The steel rule is really a modern, sturdier and more accurate version of the old cloth tape measure which wound with a spring into a little round container, and it has the advantage over the wood rule that it is flexible enough to measure around a convex curved surface of fairly small radius. For bench work a steel ruler 12 inches long is a most convenient, although a somewhat expensive tool.

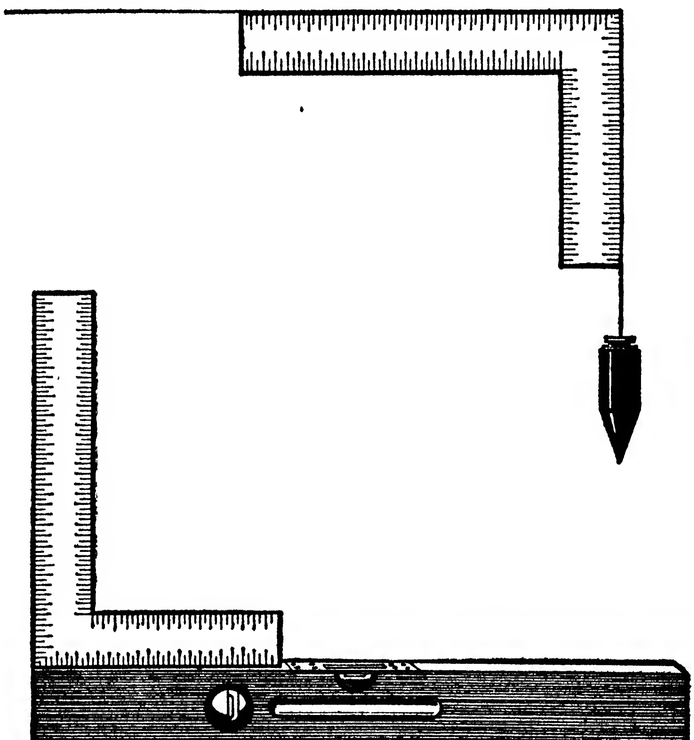


FIGURE 21

Here in Figure 21 are three tools which amateurs don't make enough use of. The STEEL SQUARE, in addition to establishing a 90 degree angle, and indicating other angles to one who understands its use, is graduated in inches and fractions like a ruler. The PLUMB LINE and PLUMB BOB consist simply of a weight attached to a piece of string, which when hung *by the string always points toward the center of the earth and thus indicates a vertical line as it points "straight up and* down." The SPIRIT LEVEL indicates a line at right angles (90 degrees) to the vertical—that is, a horizontal line. As you can see from the picture you can always establish a horizontal or "level" line using only the plumb bob and the steel square, or a vertical or "plumb" line with only the level and the square. Sometimes such jobs of home mechanics as running pipes and wires look as though these tools had been neglected.

To install a long straight run of piping or wiring so that it is really straight, its desired path can be marked—before you begin attaching it to the building—simply by stretching a long piece of cord between two nails. Such a cord is called a *Chalk Line*, which is a stout cord of special twist used for this purpose, and a reel to hold it. But the cord is not left in place to guide you. Instead it is first rubbed with chalk, and after being stretched very tight it is drawn back from the wall or ceiling as though it were a long bow string, and then let loose so it snaps back taut, leaving a line of chalk where it hits, much straighter than you could make by any other means. It is also called a snap line.

The two-legged tool in Figure 22 is called a SCRIBER or DIVIDER, and is used to mark a line parallel to another line and a certain distance away as determined by the opening of the legs. It is also used for taking measurements from the rule and transferring them to the work.

It is often necessary to mark a metal part, to identify it or indicate its position before dismantling a machine; or to guide you in sawing or filing, and a pencil will not mark metal either accurately, legibly, or lastingly. The tool shown here in Figure 23 which looks like an ice pick is

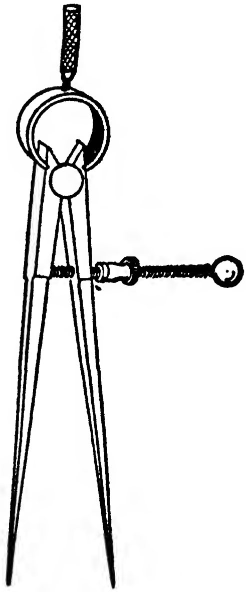


FIGURE 22

used for this purpose. It is called a SCRATCH AWL, and has a very sharp, delicate point.

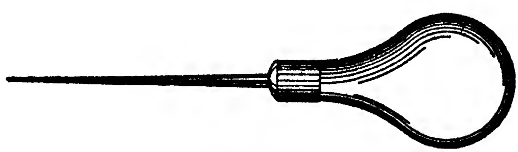


FIGURE 23

The tool illustrated in Figure 24 is called a CENTER PUNCH, but it is not used for punching holes *through* a piece of metal, but for making a slight indentation before drilling a hole with a twist drill. It is held against the work vertically and struck as light a blow as will suffice with the hammer. The center of the twist drill is then placed in the *resulting depression so it will begin drilling when it is re-*volved without wandering about over the smooth surface of the metal.

FIGURE 24

SHOCK TOOLS

The smaller of the two tools in Figure 25 is a machinist's BALL PEEN HAMMER. Its balance, the shape of its flatter face,

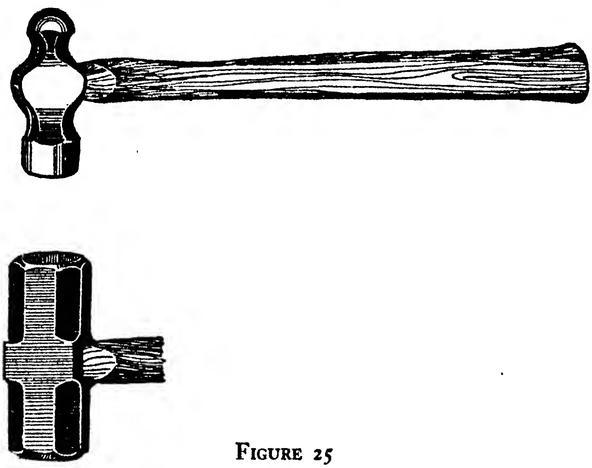


FIGURE 25

and the temper of the steel of which it is made fit it for practically all striking or hammering which you will find necessary except for heading of small rivets or for driving nails, and for all but these purposes it should be used in preference to the riveting hammer or the carpenter's claw hammer. The metal heads of steel cold chisels should always be struck with the machinist's hammer, or for heavier work with the light SLEDGE HAMMER shown below. Sometimes in repairing a piece of equipment it is necessary to strike it with a hammer. It is important to bear in mind in such work *not to strike directly with the steel hammer head.* Interpose a piece of hard wood, or of soft metal such as a billet of lead or brass, between the hammer head and the work, or secure a soft metal hammer whose head is made of lead.

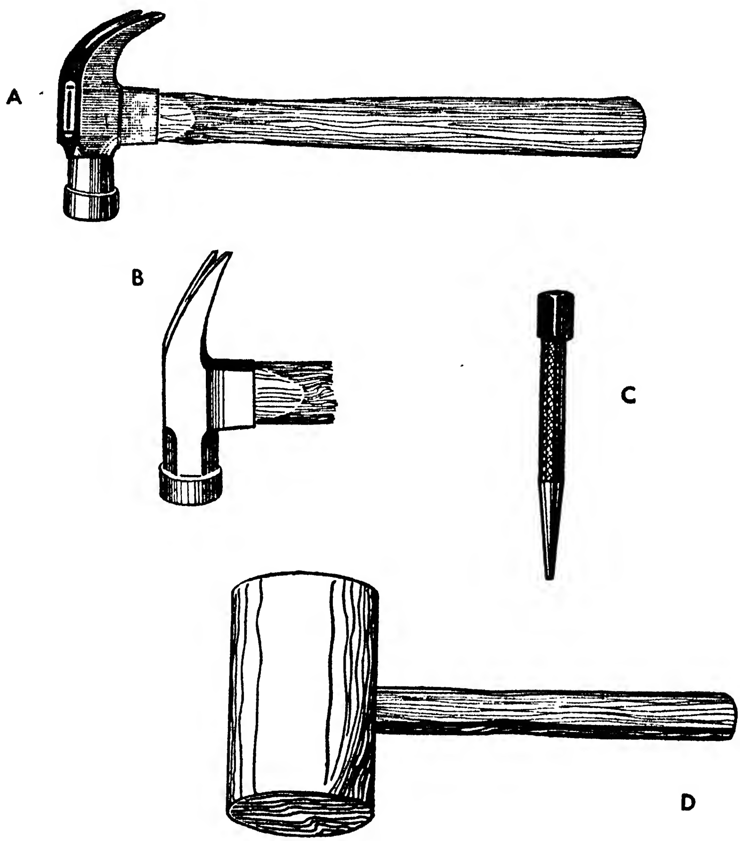


FIGURE 26

Shown in Figure 26, at *A*, is a carpenter's CLAW HAMMER. It has only two proper jobs. One is to drive nails and the other is to pull them out. It is also used of course to drive wood up into position before nailing it when this is necessary, and when thus marring the wood by a hammer blow is not objectionable. About the only metal object aside from a nail which should ever be struck with a carpenter's hammer is a NAIL SET, shown at *C*. It is used for sinking nails home. Always strike a nail set with light and well aimed blows. A good quality claw hammer, well balanced, and of a weight suited to the user and the work, is a most agreeable tool to use, and one that requires some degree of skill and practice, for all its simplicity of appearance. A handy and a very cheap tool which will save the claw hammer a lot of abuse in home mechanics is the simple wooden MALLET shown at *D*. Notice also the *other* hammer head, which is shown at *B*. It has a nail claw, but it is not effective for pulling nails because the straightness of the claw prevents getting the leverage required. This straightness is deliberate, to fit it for its real job, which is ripping out chunks of wood in house framing to accommodate electric wiring. It is called a ripping hammer, and is used by electricians in roughing work, wielded as though the edges of its claws were a cross bladed hatchet. It is shown and described here to suggest that you avoid it.

Cutting Tools

Shearing Cutters

Once upon a time, when metallurgy was far less advanced a science than it is today, it was necessary to heat a piece of metal and thus soften it, before it could be cut with a chisel. The COLD CHISEL shown in Figure 27 derives its name from the fact that, due to the nature of the steel from which it is made, and its temper, and the angle at which the edge is ground, it will cut a piece of cold metal. There are several sizes and minor variations in cold chisels, but with one exception they are a shearing tool, just as much so as any pair of shears, and they should be used to cut with a shearing action. The picture of the piece being cut in the vise shows how this is done, the vise jaw acting as the second of the two blades required for shearing. As with any other shearing operation, you start the cut at one edge of the work and move across the line to be cut, and

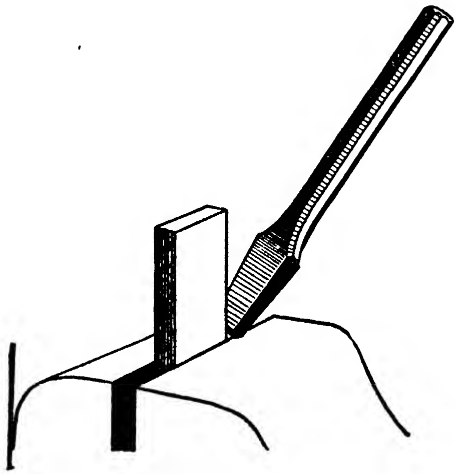


FIGURE 27

the chisel blade is held so as to form an angle with the work, just as the partially closed blades of a pair of shears do in cutting.

Also like double bladed shears, the cold chisel is limited in the thickness of material which it can shear. Its use is indicated for material too thick to cut with double bladed shears and too thin to saw with a hack saw without chattering. Only in cleaning or deepening a channel is a chisel (narrow bladed) used as a paring tool. Even in removing rivets by cutting off the heads, the chisel action should be a shearing one to get a clean smooth job so the rivet shank can be driven back through the hole with a machine punch.

For cutting light gauge metal, along either a straight or curved line, SNIPS or *shears* are used. Figure 28 shows two types, one with straight blades and a simple tong action, for straight or mildly curved light cuts, and the other with a multiplication of leverage and blades shaped to turn a small radius. The latter are particularly good for cutting very tight curves which would bind the edges of the ordinary snips. In this tool the pressure applied to the handles

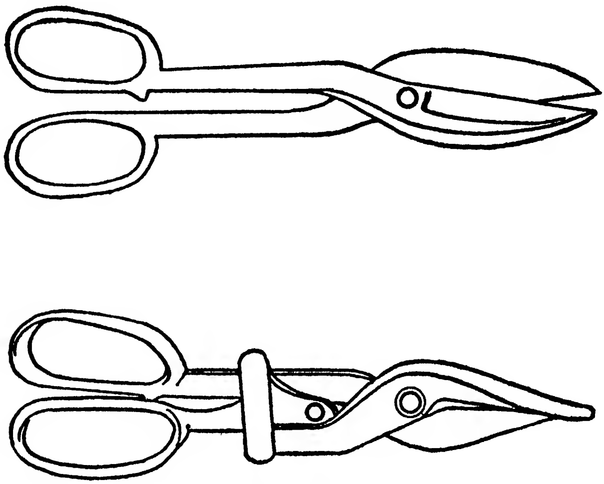


FIGURE 28

is compounded or multiplied at the jaws, while the amount of opening between the cutting edges is reduced. These snips will take a much heavier cut than the single jaw model, applying the same pressure to the handles.

One very good test of the quality—and the condition—of a pair of snips is how *thin* a piece of material they will cut cleanly, without its folding over between the blades. If the blades are sharp and free of nicks, and are so fastened together at the pivoting point that they slide past each other snugly without play as they are opened and closed, and without binding or working too stiffly, the snips are good ones.

But to keep them in this condition their limitations should be borne in mind. Do not attempt to cut metal which is too thick, or too hard tempered. The handles of a pair of snips are of a length proportioned to deliver the maximum force which it is safe to apply, and if you are of average strength and cannot cut a given piece of stock then it is too thick, too hard, or the snips are dull. Use a chisel, or hack-saw the material. Do not cut wire or nails with the snips either. There are pinching-cutting tools designed especially for such work.

Pinching Cutters

The pinching cutters are those tools which cut by subjecting the material to pressure between two sharpened jaws whose cutting edges meet along their entire length when closed, and are parallel when opened. In its simplest form this principle is illustrated by the familiar simple joint end cutting PINCERS or *nippers* shown in Figure 29 at *A*, which you may have seen a cobbler use for clipping nails. Some variation of the pincer is used for almost every trade and kind of work.

A

B

C

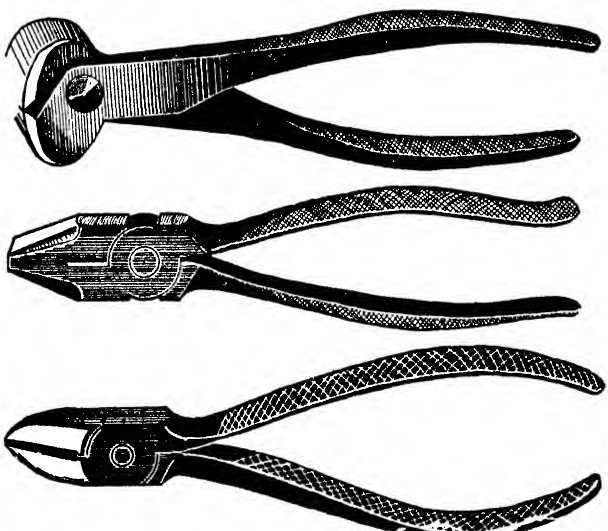


FIGURE 29

Nippers will cut the entire length of their blades at the same time, and depend on the material separating as it is cut to permit penetration of the blades, and thus are limited to cutting material no wider than the cutting edges of the blades. In practice they seldom take a cut this wide, being mostly used for cutting nails, rods, pins, etc. Besides their cutting function nippers have another use described under the Traction Tools. A modification of the nippers' pinching-cutting action is often combined with a pliers in the tool shown at *B* in the figure. This is the electrician's SIDE CUTTER PLIERS, whose jaws and cutters do not close parallel.

At the bottom (*C*) is shown a tool called a DIAGONAL CUTTER, invaluable for nipping in tight corners and inaccessible places. Now both of these retain the nippers' meeting rather than passing-and-shearing action of the cutting blades, but they lose the parallel closing action, and work tends to slide out of the jaws as they cut.

Scoring Cutters

Sometimes it is desirable to cut material, even metal, by first *scoring* it or plowing a furrow along the desired line of the cut to so weaken the material that by bending or stressing it to the breaking point the break will follow the scored line. Sometimes it is possible to score the work on both its faces to good advantage, as shown in Figure 30 at *A*, where a TRIANGULAR FILE was used to score the narrow metal across its width. For soft material the *point of a knife* is sometimes used, or a *cold chisel.* There are two ways to use a chisel for this work. One, shown in the drawing at *B* in Figure 30 requires a degree of skill. The chisel is placed against the work at an angle with only its corner in contact, and moves along the desired path on being struck repeatedly with the machinist's hammer. The other method is to hold the chisel vertically, as shown in the sketch at *C*, strike it with the hammer, and move it along the width of the blade between blows.

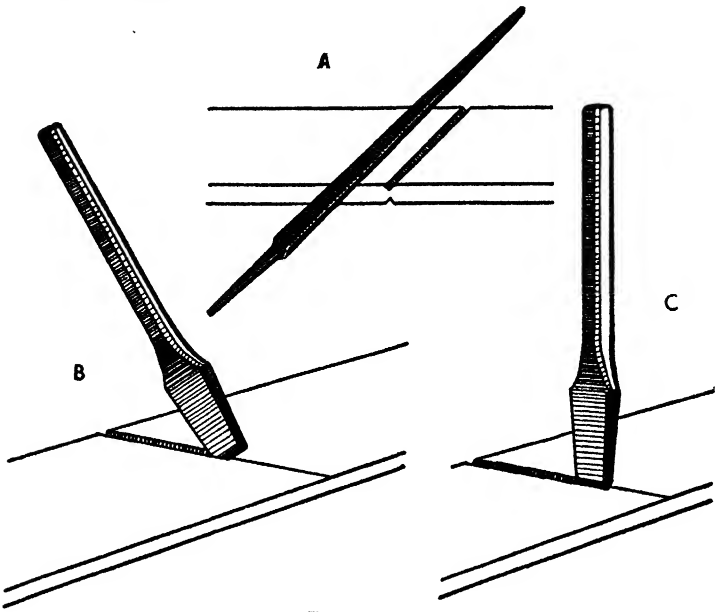


FIGURE 30

There are two common wheel scoring cutters which utilize pressure on bevelled wheels to cause them to bite into the material as they roll across its surface. In Figure 31,

FIGURE 31

the GLASS CUTTER, which is stroked across the work just once, and not too heavily. Beginners find the behavior of glass under the cutter rather erratic, and lose a good deal due to its failure to fracture cleanly along the cut.

With the plumber's PIPE CUTTER shown in Figure 32, sharp wheels are forced into the pipe by applying pressure

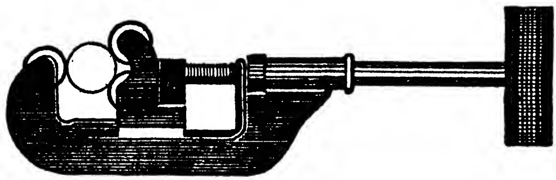


FIGURE 32

to the jaws of the cutter through the screw-threaded handle which is progressively tightened as the cutter is revolved around and around the pipe. Here the scoring continues and grows deeper and deeper until the full thickness of the wall of the pipe has been penetrated. This is the approved method of cutting pipe to length, rather than by sawing it with a hack saw.

Kerfing Cutters

The cutting tools which we have so far considered operate by separating the material into two pieces, but without really removing any of it. The *kerfing cutters*, however, nibble up the material along the path of the cut into small pieces, thus removing some of the material as they cut it. In other words if you cut a piece of paper six inches wide in two halves with a *shear*, you would have two pieces three inches wide. But if you *sawed* a piece of material you would lose an amount equal to the thickness of the saw blade. In Figure 33 is a HACK SAW, for cutting through any kind of metal. The open space it leaves in its wake is called the *kerf*. Hack saws are used to cut metal along a straight line, and when they become dulled or broken the blade is removed from the frame and discarded, and another inserted.

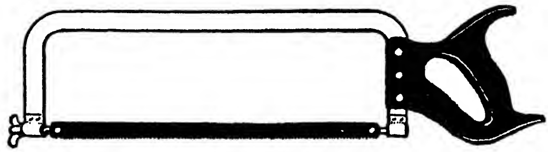


FIGURE 33

For cutting wood two basic hand saws are used: the RIPPING SAW, and the CROSSCUT SAW. As shown in Figure 34

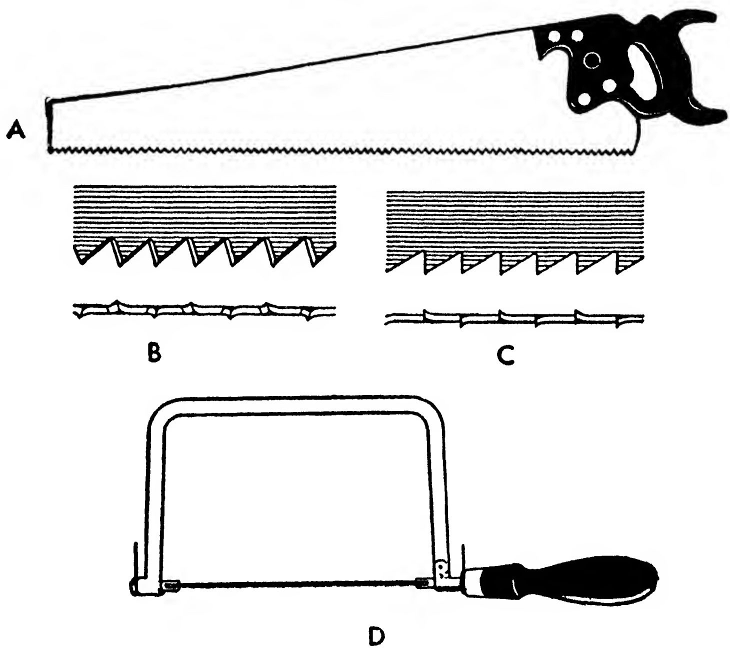


FIGURE 34

they differ only in the shape and number of their teeth.

Crosscut saw teeth are like a series of several hundred keen little knives one behind the other in a row, all sharpened to a point and with the cutting edges bevelled alternately, one to the right and the next to the left, to remove bits of wood with a shearing cut as the saw is pushed forward, as shown in the enlarged view at *B*, while the teeth of a ripping saw resemble a series of little chisels set with their cutting edges at right angles to the saw blade, as shown at *C*.

Hand saws are sized in terms of the number of teeth to the inch, the smoothness of the cut secured increasing with the number of teeth, or the "fineness" of the saw. A crosscut saw will rip wood with the grain, but a ripping saw is practically useless for crosscutting. Good sizes for home mechanics are a "seven point" ripping saw and a "ten point" crosscut. They are delicate tools and should be used carefully, sharpened by an expert, and protected from damage to the teeth, bending of the blade, and rusting when not in use. They are intended to cut in a straight line, and where a curved cut is required the small inexpensive COPING SAW shown below them, at *D*, is used.

SURFACING TOOLS

Paring Cutters

The cutting tools so far described do not necessarily work near the surface or the edge of the material but divide it into two parts of any desired size. The surfacing cutters, however, are used to remove a relatively small amount of material from the surfaces or edges of a piece so as to bring it to the desired shape and size. The paring cutters include the KNIFE in all its specialized sizes, shapes and forms, which work by slicing or paring off layers or chips of the material. Like the hammer, the knife is one of the very oldest of …an tools, and its use has been universal in every branch …ctivity, domestic, agricultural, industrial, artistic, …any of our other hand tools, and our power tools and machines as well, have sprung from adaptations of the knife blade.

The WOOD CHISEL (Figure 35) is a sort of knife, with the cutting edge moved around to the end of the blade and a

FIGURE 35

handle arranged to permit us to apply a good deal more effective pressure over a smaller cutting width than is possible with a knife. Chisels are used both by pressure from the hand, and by being struck with a mallet, and their blades are variously shaped to remove parings of different shapes and sizes.

A PLANE is really a chisel blade firmly supported in a block to permit removing material in regular even layers from the surface of wood. The one shown in Figure 36 is a "Smooth" plane. There are many others for special types of work, but this one is adequate for most home mechanics involving comparatively little woodwork.

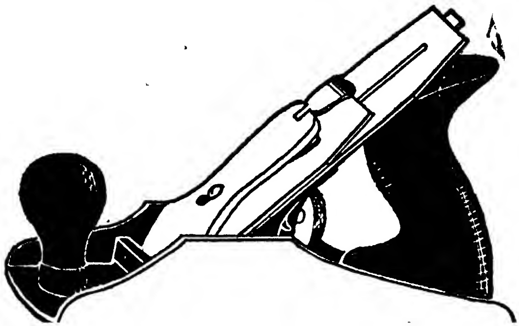


FIGURE 36

Attrition Cutters

When surfacing work cannot be done with the paring cutters, the attrition cutting tools are used. These shape the work by grinding down the surface, reducing the material to small bits as it is removed. Commonest of these tools is the FILE, made in a wide variety of shapes, sizes, and tooth patterns, to work various materials to various smoothness of finish. Shown here in Figure 37 are the three most

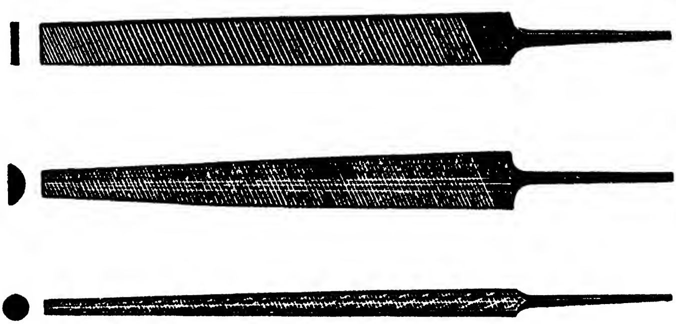


FIGURE 37

familiar shapes. They are the *flat*, *half round*, and *full round*. In home mechanical work the most useful metal files are the flat hand or mill files about eight inches long, in the following degrees of fineness: Coarse, bastard, second cut, smooth. One of each of these plus perhaps a bastard and a second cut half round, and a second cut or smooth full round should suffice.

For woodwork a half round body is generally best, also about eight inches long, and the degrees of fineness offered are: *wood rasp, cabinet rasp, cabinet file.* In spite of their appearance files are *not* sturdy tools. Though the teeth are very hard, they are brittle, delicate, and sharp, and should always be protected from damage, and frequently cleaned with a small metal brush called a file card, to prevent their becoming clogged or glazed. Rusting entirely ruins a file.

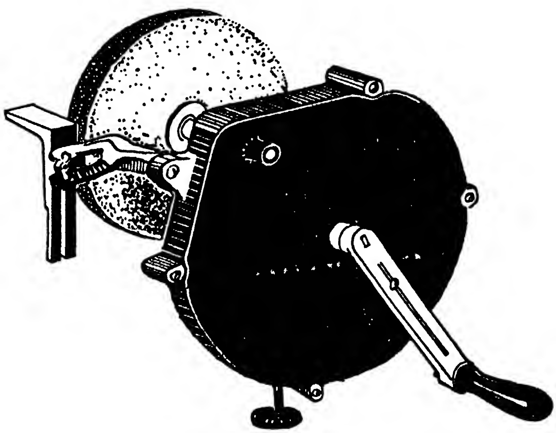


FIGURE 38

Many surfacing jobs lend themselves to the use of abrasive coated paper or cloth, of which *sandpaper* is a familiar example. Formerly natural abrasives, such as flint and garnet for wood and *emery* for metal, were most widely used. Nowadays synthetic abrasive particles are also used, some of which are suitable for either wood or metal, and in many cases they constitute an improvement over the natural grits. The name of the abrasive used and its degree of fineness or grit number are always printed on the uncoated side of the paper or cloth. Synthetic abrasives are also bonded or molded together into the shape of disks or *wheels* which are mounted on a shaft and revolved with a hand crank and gears. This tool, illustrated in Figure 38 is known as a HAND GRINDER or ABRASIVE WHEEL. It is used not only for sharpening edged tools but occasionally for shaping small parts.

HOLE-MAKING TOOLS

Piercing Hole-Cutters

Holes, when they are to be round holes, and small ones, are either pierced, punched, drilled, or bored. Here, in Figure 39, are two piercing tools, which operate by pushing

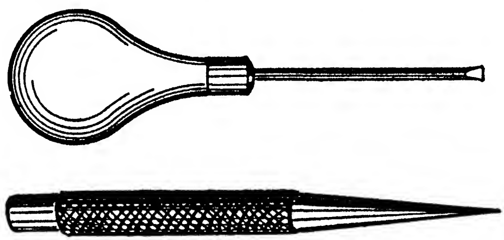


FIGURE 39

the material aside rather than by removing it as is done in punching, drilling, or boring. Above is a BRAD AWL. It is used to make a starting hole for a brad, which is simply a nail so small it cannot be held between the fingers and struck with the hammer. Instead a shallow hole is pierced with the brad awl, the brad is stood up in the hole and then driven home with the hammer. An ordinary ice pick of good quality makes a satisfactory awl. These awls are not struck with the hammer but simply pressed into the material with the hand.

Below the brad awl is shown a tinner's PRICK PUNCH, which is used for striking small holes through sheet metal. Drilling thin sheet metal is difficult because the drill binds in the hole as the metal bends. It breaks through, leaves a rough burr on the underside of the hole, and makes no better a job than the prick punch. Where a fastening is made in sheet metal by the use of the self tapping screw illustrated under the Screwdriving Tools, the hole is pierced so the threads of the screw may engage in the burr which the piercing forms.

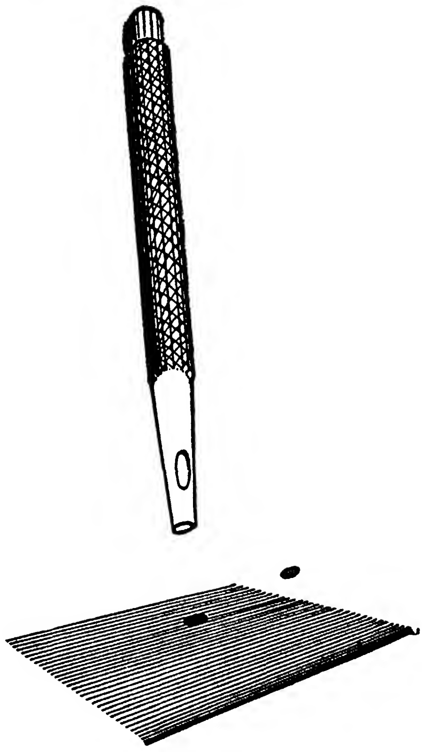


FIGURE 40

In shop work, to avoid either piercing or drilling holes, a different kind of punch is used. This PUNCH, which removes a disk of material, is shown in Figure 40. It is meant to be struck with a hammer, and operates on the same principle as a round cookie- or biscuit-cutter. It is used only for soft materials such as leather or fiber and is called a disk punch.

Attrition Hole-Cutters

Most of the holes which you will have occasion to make will be too large to be pierced and too deep to be punched, so you will make them with hole-cutting tools which will grind the material up and remove it in small chips. This operation is called drilling when it is done in metal, and boring when it is done in wood. Figure 41 shows one of

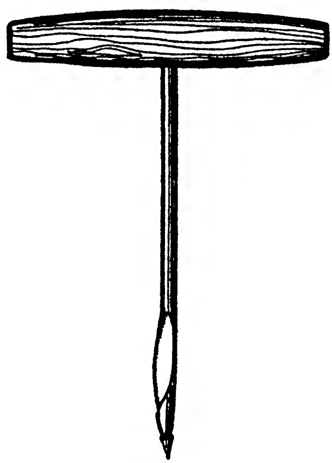


FIGURE 41

the simplest and oldest of the hole-making tools—the GIMLET, or gimlet bit. Its point has a thread like a wood screw to hold it firmly in the work as it is used; the shank above the point is shaped something like a corkscrew but with sharp edges, and it terminates in a wooden cross-handle so that it is complete in itself and requires no drill stock or brace to use. In fact it is used for drilling shallow holes of more or less indeterminate size (as for starting wood screws in soft wood) in the same manner as a cork-screw. Although professional mechanics have come to prefer the twist drills and drill stock for the slightly greater speed and the fine gradations in hole sizes which they offer, there is no reason why an amateur should not use a gimlet.

Metal is drilled with the tools shown in Figure 42, called TWIST DRILLS, and FLUTED DRILLS. The twist drills, such as

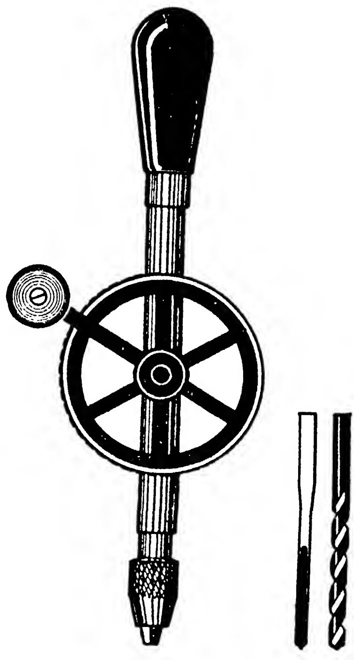


FIGURE 42

shown at *C*, are used by being clamped in the jaws of the drill stock, and revolved by turning the handle. The fluted drills, shown at *B*, which are confined to the smaller sizes, and to softer metals and wood, are used in the automatic screwdriver shown under the Screw Fastening Tools, or in the tool shown at *A*, called a DRILL STOCK.

To bevel or *countersink* the mouth of a hole in metal to permit a flatheaded screw to be sunk home flush, the

COUNTERSINK shown in Figure 43 at *A* is used. Notice that the top end of this tool is tapered to fit the BRACE (shown at *C*) and even for metal work it is used in the brace because the power required to make it cut is greater than can

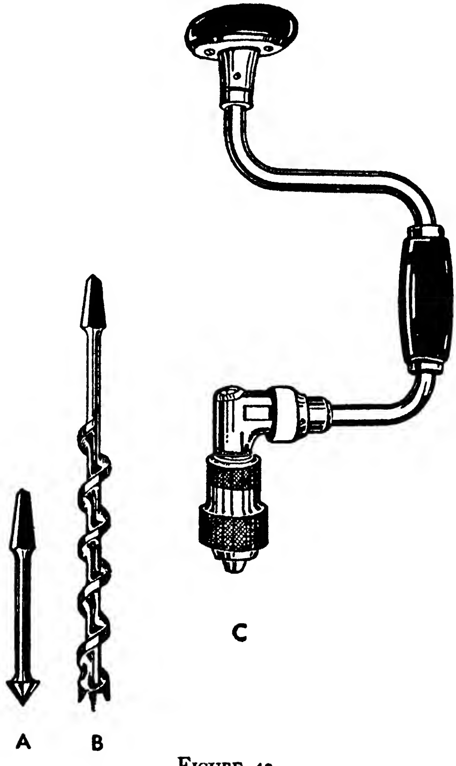


FIGURE 43

be delivered with the drill stock or push drill. Enlarging a hole already drilled in metal is called *boring*, if the enlargement is through the entire hole, or *counterboring* if it enlarges only a portion of the hole. In other words a counter bore is a countersink whose walls are parallel, and is used to get the head of a screw below the surface of the work.

Round holes in wood are said to be *bored*, and the tool used is the AUGER BIT, shown in Figure 43 at *B*, except for small holes which are made with gimlets or with the drills shown in Figure 42. Though drills are made in large diameters, and even with tapered shanks to fit the brace chuck, they are not practical for wood. Notice that the *bit* shown has a small tapered screw point, and scoring cutters or lips. These are necessary to make the bit bite into the fibers of the wood as it is revolved.

SCREW-THREADING TOOLS

Figure 44 shows a THREADING TAP. It is the tool used to cut or tap the female screw thread in the inside wall of a

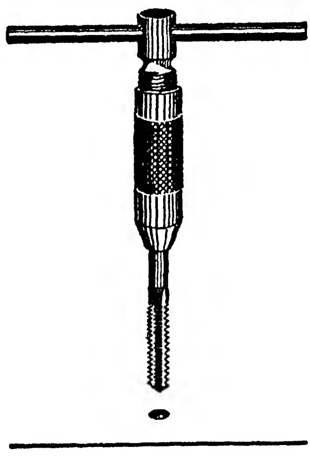


FIGURE 44

drilled hole to receive and engage the male screw thread of a screw fastening. It is operated by locking it in its handle, which is called the tap wrench, engaging its other end in the drilled hole, and revolving the wrench. As this is done the tap screws itself down into the hole, cutting the threads as it goes. Under the Screw Fastening Tools we spoke of a woodscrew cutting its own female thread in the wood, and also spoke of the so-called self tapping metal screws. In strict accuracy neither of these screws *cuts* or *taps* the female threads. Instead they push the material aside with a scoring action rather than by cutting the threads and removing the material cut away. The tapping die does not simply impress or score the shape of a screw thread into the hole as the woodscrew and self tapping screw do. It cuts the material away, grinding it into little chips. Now this tap is not illustrated nor its operation described here merely so you may know how the female threaded parts of your home mechanical equipment were made. As a matter of fact they were made with complicated power tapping machines, rather than with a simple hand tap such as this one. The purpose of showing this tap is so you may know how to tap a hole to receive a screw fastening yourself in your own work. Screw threads are a mechanical device which sometimes require repair through two causes, first actual wearing away of the threads through use, and second the literal stripping off of the thread.

If either of these things occurs to a threaded nut it can be discarded and a new one substituted; but when it occurs to a thread tapped directly into the metal of some part of a piece of equipment, it might be very expensive, and would certainly be entirely unnecessary to discard the entire part because a thread was worn or stripped. Instead you would *retap* the hole as good as new. Although we did not mention it when discussing them, all screws and nuts and bolts are made to accepted and standardized sizes, and the threads are always of some standard measurements, and so too are hand taps. They are sold singly in the various sizes, and in sets suited to various types of work, along with their companion tool shown in Figure 45, the threading die, which is used to cut the male screw thread on the shank of a screw fastening.

In Figure 45 we have a THREADING DIE, used with its handle or stock, to cut a male screw thread. According to its size and the type of thread its teeth are shaped to cut, it will thread any male screw fastening devices except the tapered wood screws. Because you almost always have the choice of rethreading a bolt or buying another cheaply your chief use for the threading die will be in the large size shown here which is used to thread the end of a pipe for a

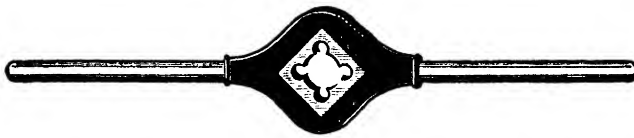


FIGURE 45

plumbing job. Obversely, however, because the *female* threaded members used to effect the screw attachments between plumbing pipes are readily available so cheaply that even plumbers do not thread their own, you will probably not need large sized taps. So generally speaking you will use small taps and large dies. You need not learn all the technical details regarding thread sizes, thread types, and the pitch of threads to do satisfactory home mechanics.

You can always take a screw fastening to the store to secure the needed tap or die if you do not care to go too deeply into learning the details, but the ability to use a tap or die when it is required, and enough knowledge to buy the right one or order the threading work done is the sign of skill in home mechanics which opens up a whole field of interesting possibilities. As a matter of fact, for large work such as plumbing it is often not necessary to spend the money for the cutters and pipe vises and threading dies required for a repair job. Knowing what is needed you can sketch the work, and have the plumbing shop, which has all the equipment, do these operations for you when they sell you the pipe and other materials required, and you can then install them.

A number of tools are shown together in Figure 46 which vary widely in form but all have one function in common. That is they are used to exert a pressure against a part so

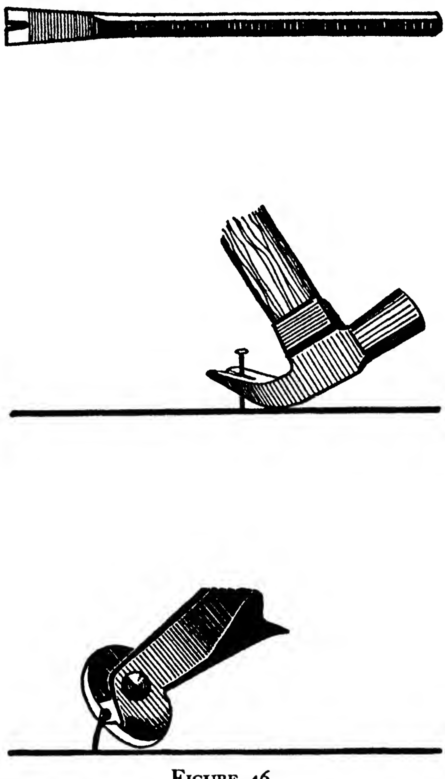


FIGURE 46

as to change its position. A hammer changes the position of a nail in driving it, but it is with a more or less violent shock intermittently and repeatedly applied that it does so. The tools shown here, however, are often referred to by mechanics as the "persuaders" and that indicates their operation rather well. In the top sketch is a small PINCH BAR, a simple lever which you might use to slide or "inch" a very heavy article into position; a section of a furnace boiler, for instance, which the force available for the job would be inadequate to move in any other way.

Next is shown the *claw of a hammer* in the act of withdrawing a nail, with a steady even pressure multiplied to a really tremendous magnitude by the leverage afforded by the shape of the curved claw pressing downward against the wood.

The *pincers* (in the bottom drawing) are not cutting the nail off as you might think. Instead, they are being rocked over on the curve of one jaw to withdraw the nail. It is surprising how obdurate a nail—often so located as to be beyond the grasp of a claw hammer—can be withdrawn with a pair of simple pincers. Of course a nice balance is required to squeeze the sharp jaws together just hard enough to bite into the shank of the nail well so it won't slip as you rock the pincers over, without actually clipping it off before it is withdrawn.

Notice that in all these operations a real compounding or multiplication of the muscular force applied is involved. Now whenever this is done, care must be taken that too much force is not applied. The ease with which a movement can be induced when leverage or the compounding of the force is involved is misleading. For instance, you might run a nut onto a bolt, and with your fingers tighten it as much as possible. This, incidentally, is called setting the nut "finger tight." Now unable to tighten it further with the fingers, apply a wrench with a handle six inches long and it will be seen to move a bit with relative ease.

Draw it very tight, lengthen the wrench handle to 12 inches long and again it will move as if loose. However, as the leverage is increased by longer wrench handles, the nut, or its bolt, or some part of the assembly will break. In this connection, remember that the handles of wrenches should *not* be lengthened. They are proportioned by the maker, as are other tools, to apply only a safe amount of force to the work.

Shown in Figure 47 is a small device somewhat resembling a tapered screw, but with a square head as if to be turned with a wrench. Notice that the thread of this screw

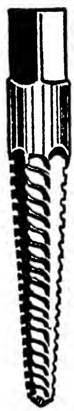


FIGURE 47

is much steeper than those shown on any other screw devices, and that the threads run around the shank in a left-handed way. In other words, to insert this screw it would be necessary to turn it to the left instead of to the right as with the others shown elsewhere in this book. As we have mentioned, screws and bolts are sometimes broken off part way in the hole in which they are being driven. The little tool shown here is made to extract the imbedded part of such a screw, and it is called a SCREW EXTRACTOR. It is operated by first drilling a small hole in the broken end of the buried screw, and then inserting the extractor in this hole and turning it *to the left*. Like the self-tapping screw, the extractor will cut itself some threads in the hole, and as it gets tighter and tighter it will begin causing the imbedded screw to revolve to the left. Since the imbedded screw loosens to the left it will thus be backed out of the hole. On rare occasions screws and nuts are used which are threaded *left-handed*, and to extract such a one you would require a right-handed screw extractor, but it is most unlikely that you will need one.

The Importance of Caring for Tools

Considering the length of time, the long years and centuries—the ages actually—during which man has used tools, it is a baffling thing how he persists in his refusal to learn to care for them decently. I am not referring now to misuse of tools. I hope that what was said in the first part of this chapter about the nature and uses of various tools and the differences of their functions, was sufficient to enable you to judge the proper use of even a strange or unfamiliar tool. What I speak of here is the damage tools suffer through not being cared for properly when they are *not in use*. A great many more tools are spoiled in this way than are worn out or broken even in heavy or constant use.

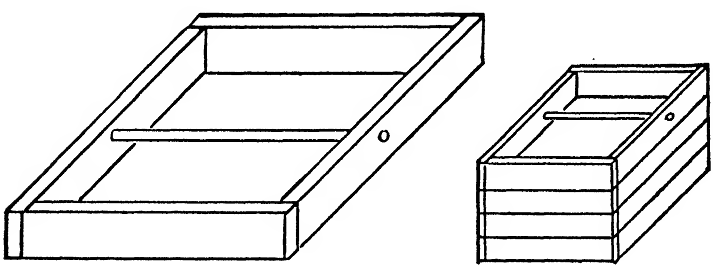
It is said that the first mark of a good workman is the way in which he cares for his tools. The fact is that caring for one's tools is simply the first mark of a sensible person, because the elements constituting decent care are very simple and obvious.

A specific suggestion or two may help you in caring for your tools properly. Perhaps the best reason for caring for tools is the fact, very pertinent to your mechanical activities, that a damaged tool will not function properly, and may damage the article you are working on. If you do damage a tool materially, you will probably be better able to afford to replace it than would have been the case years ago, because the cost of tools has been consistently lowered as their manufacture has become more a mass production activity. And this you should do, rather than trying to work with a damaged tool which you cannot repair or have repaired at reasonable cost.

The essence of caring for tools is protecting them first from each other, and second from the elements, while they are in storage. Beginners are always projecting elaborate tool racks fastened to a wall, or in a hanging chest, with a hook or slot or shelf for each tool, and perhaps a painted outline to suggest the place for each. This may be fine if it is carried through, though in my experience it is too elaborate to be practical except in trade shops for certain types of tools, and it is inconvenient in actual use, because the tools are so often used far away from the rack. What is needed is a means of both storing and carrying the tools, so they will be reasonably accessible without digging for them, and still protected from each other.

Boxes for Storing Tools

For this purpose I have found nothing so practical as a series of boxes such as those shown in Figure 48, shallow



A B

Figure 48

rather than deep, and not too large to carry about flatwise by the dowel handle (which is below the top edge of the box, so the boxes may be stacked). Several of these are suggested so the tools may be divided among them both to reduce the weight and bulk which you carry to the job, and to permit their division more or less according to their type and use. A good practice is to have one more box than is needed to accommodate all the tools, and to load it up by selecting tools from the other boxes when starting a job, and to unload it, redistributing the tools to the other boxes when you are finished working. Special compartments within the boxes are, like special racks and hooks, impractical in use, with few exceptions. Much better is to secure scraps or remnants of carpeting, new, or used if cleaned, and to cut one piece as large in area as the bottom of each box, and several pieces about half this size or less. Then the tools can be spread about in the box on the large piece and protected from each other with the smaller pieces. Do not fasten any of the pieces into the box. They will have to be removed and shaken out and cleaned occasionally. A second large piece of carpeting will be found more practical as a covering for the box than any type of stiff wooden cover, which would be annoying to use whether hinged or left loose.

Padding tools against each other may seem an extreme suggestion, but it is a fact that all tools will either be injured by being struck or rubbed against, or will cause injury when they strike another tool. If you could insure that only such sturdy tools as ball peen hammers and cold chisels lay together, you could permit this and only pad the delicate ones, but it is really easier to make a practice of treating them all the same, and these pads, which are a simplified adaptation of the cloth rolls with pockets which mechanics used years ago (and still use for such things as sets of auger bits) are very easy to use.

Protecting Tools from Rust

No authority I have ever encountered in print has ever omitted to advise covering each steel tool with a film of oil before putting it away, to protect it from rusting. However, the greasy feel of an oiled tool is so unpleasant to the touch and so certain to soil anything that you are working on, and the task of de-oiling the tools when you start work and *re-oiling them when you finish is so tedious that I would advise not oiling a tool except to really slush it down if it is to be out of use for a long, long time. Instead, I am* careful to leave my tools perfectly dry when I am finished with them, and to store them, covered up, where it is warm enough and dry enough to prevent the precipitation of atmospheric moisture on them: that is in the living quarters of an un-airconditioned house, not in the kitchen, the bathroom, the basement, nor on an open porch where dew might condense upon them. In seacoast regions the residents will need to take more than average precautions, as they do with any metals which rust easily.

When tools are not oiled one special precaution must be observed, that is to remove all traces of perspiration. The salt in perspiration will absorb moisture from the air, forming a particularly corrosive brine.

PART TWO

Plumbing

CHAPTER III

The Water Pipes

The Four Main Elements of a Plumbing System

The plumbing system of a house is really a very simple thing mechanically; and its function, structure, operation, and repair are all well within the grasp of any home mechanic. The entire system comprises five main elements. These are: 1) the *pipes* and *valves* which distribute the water throughout the house; 2) the *soil line* which collects and disposes of the waste or sewage; 3) the plumbing *fixtures* such as sinks, washstands, and so forth, which aid in using the water efficiently and guide the waste into the soil line; 4) the *faucets* and other *outlet valves* which control the flow of water from the pipes at the fixtures; and 5) the hot water *heater*.

The function of modern plumbing is of course to serve clean water, conveniently, effortlessly, and noiselessly, just where it is wanted, in ample volume and at the desired temperature; and to dispose of the wastes incident to the use of the water.

When a plumbing system fails to do this job it will be for one of two reasons. The first and most obvious reason is the simple mechanical failure of one of its parts. In a mechanism as extensive as a plumbing system, and with as many component parts, this type of failure may occur at one or more of several points. Consequently its proper maintenance is likely to involve comparatively frequent minor repairs.

The second reason is that there are certain limitations in any domestic plumbing system which in time interfere with its performing perfectly. A number of such instances will be shown as we proceed, and recommendations given for overcoming these limitations.

PIPES AND FITTINGS REQUIRED FOR PLUMBING WORK

Figure 49 shows how the structural parts of the piping system are linked together to conduct the water to various rooms where it will be used.

In Figure 50 are shown close-up views of the various fittings which go to make up the completed plumbing installation. An examination of these sketches should remove most of the mystery from this part of the plumbing system. At *A1* and *A2* are shown two pieces of pipe with simple *male* screw threads cut into both ends. The shorter piece, little longer than the length required to accommodate threads enough to insure a sound joint, is called a *nipple.* The longer piece, which might be of any required length up to the maximum commercially available, is called simply a *length.* The other parts shown are all called *fittings.* They are tapped with *female* threads which fit the threads on the pipes and nipples, and are used to couple pipe lengths together, which accounts for their also being called *couplings.* At *B* is shown a straight coupling, used to connect two pipe lengths in a straight line. At *C* is shown one of the couplings used to effect a turn in a run of pipe. These are called *elbows* when they turn 90 degrees or 45 degrees as at *C* and *D;* and they are called *return* or U bends when they reverse the direction of the pipe as at *E*. At *F, G* and *H* are the couplings most frequently used to effect a branching in a one line. They are very descriptively named, being the Y branch, the Tee, and the cross. For capping off the end of a

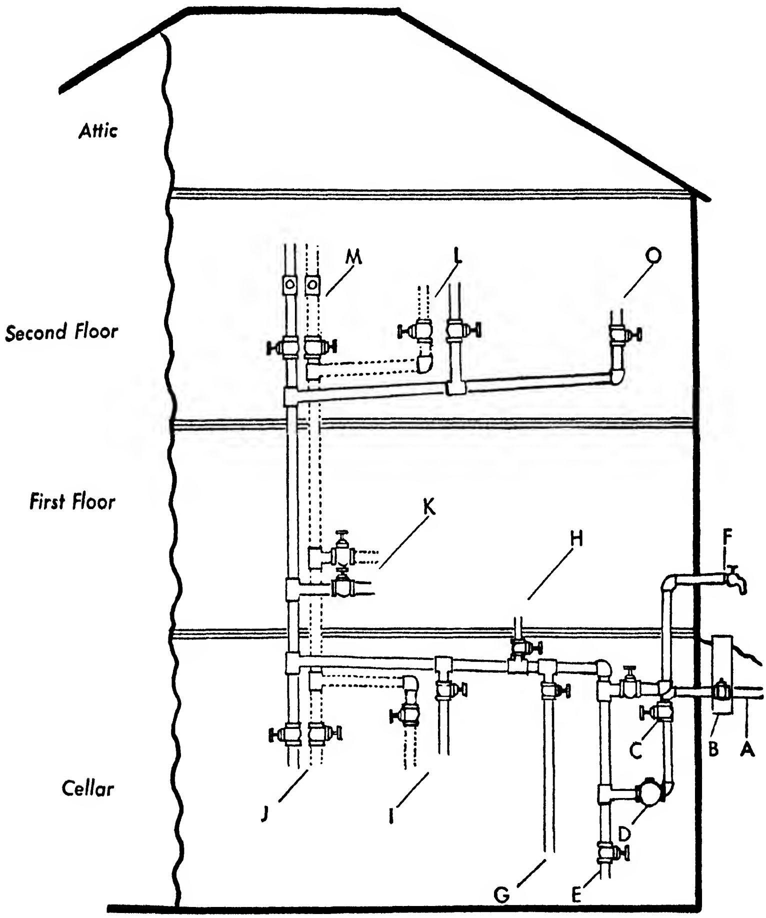


FIGURE 49—House Diagram Showing Arrangement of Water Pipes

line a *cap*, shown at *I* is used, provided the line terminates with a pipe length. Sometimes, however, a coupling is screwed to the last length of pipe, or it is desired to close an unused branch fitting outlet, and in such a case a *plug*, shown at *J*, is used, instead of the cap because the plug, having male threads, like the pipe, will engage with the female threads of the couplings.

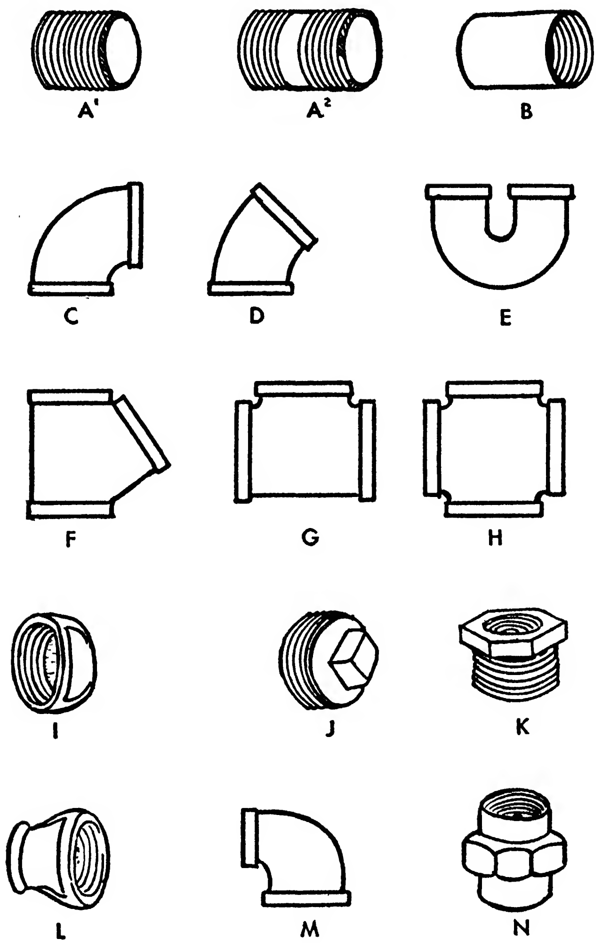


FIGURE 50—Structural Parts of the Plumbing System

To economize on the cost of pipe and fittings, house systems are run in various pipe sizes, the branches being smaller than the main line. This requires a fitting which will and couple a reduced size of pipe to a larger one. The simplest type of reducer is a plug, bored out and with its inner wall tapped with a female thread to fit the smaller pipe diameter. This fitting is shown at *K*. It is called a *bushing*. In addition to the bushing, however, which is little used except on alteration work to avoid disturbing a fitting, all the couplings are made as *reducers*. The straight reducing coupling shown at *L* and the 90° elbow reducer at *M* are two examples.

To assemble a pipe line with the simple screw couplings described above requires that each succeeding part added to the system must be free to revolve so its threads may engage with the coupling and be screwed up tight. Now it is obvious that there will be situations in every plumbing system where this cannot be done. A hot water tank, for instance, could not be picked up and threaded onto the water pipe by being revolved around and around the pipe. To meet such situations, a special coupling called a *union* is used. It is shown at *N*, and it is the one indispensable fitting. You may not always find the unions indicated in plumbing sketches, but you will certainly find them in the pipe lines.

Now working these various simple integers together to repair or extend a piping system is just as easy as it would seem. In fact although plumbers traditionally report for work with an awesome collection of tools (and often have to return to the shop for still others), one could do a simple job of pipe fitting with little more than two Stillson wrenches and a ruler.

Perhaps you have seen signs in plumbing shops reading "Pipe Cut to Sketch." What the plumber means is that if you will measure the job up and make a simple sketch showing the various fittings and pipe lengths needed, he will cut the pipe to length for you, thread its ends, and sell you the fittings required, which you can then take home and connect up. Thus you could avoid the purchase of the pipe cutter and threading die described in the chapter tools, and do home plumbing jobs with a very minimum tools. Or perhaps you could rent all the tools needed from the plumbing shop.

How the Water Pipes Are Arranged in the House

Before launching on a repair job, however, let us first examine the house piping system diagrammed in Figure 49 on page 75 in some detail. It starts at point *A*, several feet underground, where it connects to the public water main which furnishes the water, and runs, still buried, to the basement wall and into the house. Although water service is a public utility, it is by no means free. It is paid for either by an annual tax, varying according to the size of the house and the elaborateness of the plumbing system, or by being metered before it is used.

Main and Branch-Line Cutoff Valves

Whether the water is metered or not, the line which connects the public main with the house pipes will be provided with a valve, which when closed (as it should be if the house is unoccupied), will shut off water from the house pipes. This main *cutoff* or *shutoff valve* is shown located at *B*, outside the house and below the ground, at the bottom of a metal shell called a *curb box*, which is covered with a small iron plate. A valve is really just a sort of faucet, but with both its inlet and outlet ends threaded like the couplings described above, and it is inserted in the pipe line between two lengths of pipe just as couplings are. The construction and the repair of valves are illustrated and explained in Chapter V because of their close mechanical resemblance to the faucets which are dealt with there.

This valve has no handle, but instead the stem which is turned to open and close it is shaped like the head of a bolt, and is operated by means of a long-stemmed, cross-headed socket wrench. The presumption is that only the water supply agency will possess this wrench, and that the householder will let this particular valve severely alone.

In addition to this *main* cutoff or shutoff valve, a well plumbed house will have several more shutoff valves throughout the piping system. One should be located in each branch line to permit that branch to be closed off from the house line in case of emergency, and yet not leave the entire house without water. These valves will all be equipped with regular handles or handwheels, to permit their being closed without a wrench, as will a main indoor valve controlling the entire house. This valve is shown at *C.*

The Water Meter

Where water is sold by the gallon, a very ingenious measuring device is inserted in the line, perhaps in a larger outdoor curb box than is shown here, along with the main shutoff, or just within the house, where our diagram shows it at *D.* It is called a *water meter,* and like the main shutoff it is most emphatically not to be tampered with by the householder. In fact its exposed assembly bolts and coupling unions are wired into position and sealed against removal with a leaden seal, the breaking of which is punishable by law. Just looking at the meter, however, is a different matter, and a very valuable practice for any home mechanic, because reading its dials can tell you things about your plumbing system and water using practices just as important to you as the information conveyed by other meters which you consult, such as the gasoline meter (or gauge) and speed meter (speedometer) on your automobile. Lifting the little hinged metal cover which hides the top of the water meter will expose the dials which record the amount of water used, and by reading the dials twice, at intervals of a week or month or year, and comparing the readings, you will know the amount of water consumed in that time.

Should you read the meter and find it difficult to credit the water consumption indicated, do not presume that the meter is inaccurate. The probability that you really used that much water is overwhelming, because the accuracy and the dependability of these meters are really amazing. On complaint or demand the water supply agency will test any suspected meter and if necessary adjust both the meter and any billings predicated on its faulty operation.

Reading the Water Meter

Reading a water meter is simplicity itself for anyone who has mastered reading time from an ordinary clock. Just as a

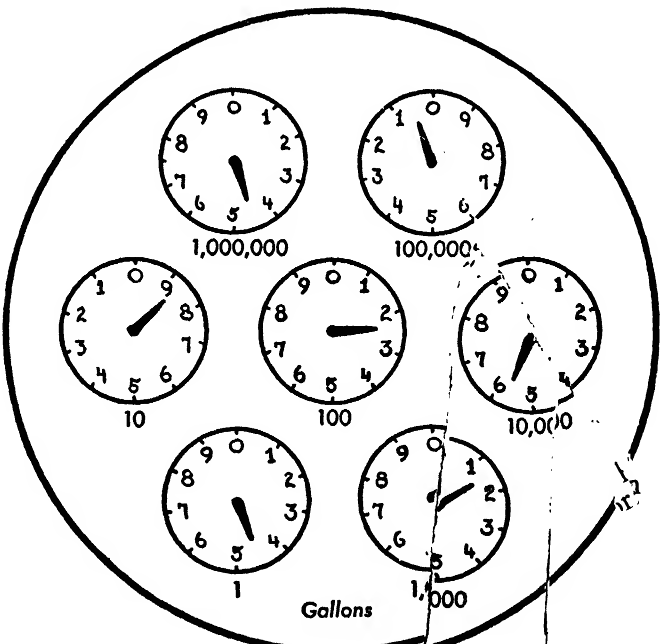


FIGURE 51—The Water Meter

clock is equipped with pointers, or hands, one to indicate time in units of hours, one in minutes, and, frequently, one in seconds, so a water meter has several pointers which indicate quantity, either in units of gallons or of cubic feet. But the water meter is simpler than the clock, because each pointer or hand has its own dial or face, and all the dials are graduated from 1 to 10, whereas with the clock the dial for the hours reads from 1 to 12, the one for minutes from 1 to 60, and the one for seconds also from 1 to 60. (See Figure 51.)

The pointers of a water meter are read just as the *hour* hand of a clock is; that is, no matter where the pointer may lie between any two numbers around the rim, you always read the lower of the two numbers. Each dial of a water meter is labeled, and a seven dial meter will have its dials labeled

1,000,000
100,000
10,000
1,000
100
10
1

and will of course register any quantity up to 9,999,999 gallons or cubic feet. To read a meter, simply write down one behind the other from left to right the readings of the several dials beginning with the one bearing the highest label. Whether the number you have written represents gallons or cubic feet (one cubic foot contains a bit less than 7½ gallons) you will know by which of these words is stamped on the face of the meter.

Arrangement of Branch Lines

Just beyond the meter will be found another most important valve, marked *E* in the diagram. It is needed to drain the water from the house pipes, and so is located at the lowest point in the system.

Up near the cellar ceiling beyond *E* is shown the first of the several branch lines. It takes off from the main house line with a Tee coupling, and runs upward and back through the house wall to terminate outdoors at *F* where a faucet is attached to draw water for irrigating the lawn or garden and for other outdoor uses.

Beyond this branch another takes off to terminate at *G*, where it will connect with the water feed line of the house heating boiler. Water delivered here will be used to transfer heat from the boiler fire to radiators located throughout the house, through another entirely separate steam or hot water piping system which is dealt with in Chapter XII.

Beyond the boiler supply branch another is shown rising through the kitchen floor to connect at *H* with a water cooled, gas operated mechanical refrigerator. Here again, as at the furnace, the water will be used to transfer heat, in this case the heat being taken by the water from the refrigerating mechanism and carried off.

Beyond *H* a branch takes off to connect at *I* with a domestic hot water heater which heats water and stores it in a storage tank from which it flows as needed through the hot water branch of the house piping system to the various fixtures where it is desired to have hot as well as cold water.

Thus from here on in the diagram are shown two water lines, the cold water line as before, paralleled now by the hot water pipe shown dotted. The first branches taking off both cold and hot water are shown ending at *J*, the basement laundry tub sink, where the water will be used for washing clothing, and at *K*, in the kitchen, where it will be used in washing food and dishes; also for its prime human use which is as drinking water; and again as a heat transfer medium, for boiling food. Rising beyond *K* into the second story of the house, branches are taken off both pipes at *L* for the washstand, *M* for the bathtub, and *N* for the shower bath. Here the hot water line terminates while the cold line continues on a bit to end at *O*, the sanitary flush toilet.

Water Pipe Troubles

That then is the domestic water piping system, and the uses to which the water is put. What sort and number of troubles might a system this simple suffer, consisting as it does of merely a number of lengths of pipe connected together, its only moving parts being the shutoff valves of the branch and main line, and the only energy involved that which causes the water to flow through the pipes? Very simple troubles, and very few too, and easy ones to remedy, as we shall see; they are these five:

1. Unsatisfactory flow of water.
2. Discolored water.
3. Noise in operation.
4. The water being of undesirable temperature.
5. Leaking of the system due to damage.

Unsatisfactory Water Flow

It is an annoying situation when a faucet is opened, and instead of a brisk flow of water taking place, only a sluggish stream comes forth. This is a common difficulty too, especially in older houses, but it is an easy one to remedy. Its cure can be best explained in terms of its cause. To begin with, the energizing agent which impels the water to flow from the pipes is the pressure under which the water is held in the system. The greater the pressure, the brisker the flow. So it is that when the flow is sluggish one says "the pressure is too low." Or, if a faucet is opened and the water gushes forth in a violent stream, one says "the pressure is too high." Accordingly a sufficient increase in the pressure under which the water enters the house pipes at point *A* in the diagram would at once remedy a sluggish flow. But this is an academic rather than an actual possibility, because when water is supplied by a public agency it is going to go right on delivering it under the same pressure under which it now comes regardless of complaints. When water is secured from a well, it would be an expensive remedy to increase the pumping capacity of the water supply system. Luckily the cure lies elsewhere. Pressure *effects* the flow of water, but it is only one factor affecting the *rate* of flow. Others are the diameter of the pipe through which the water must be made to flow, the length of the pipe, and to a lesser degree the number of turns or bends in the pipe, and its internal smoothness.

Loss of Pressure Due to Clogged Pipes

Now it is almost certain that when your house was built the flow of water was satisfactory, else the plumbing job would not have been accepted; and it is almost certain that the pressure in the *water mains* is the same today as then, since the satisfactory operation of public water systems is predicated on the maintenance of a certain standard pressure. How does it happen then that the plumber installed a system which was only temporarily satisfactory? What happened was that as the years passed, and more and more water flowed through the system, the effective inside diameter of the pipes was reduced by their becoming partially clogged by material deposited there as the water flowed through them.

Finally, although the house still had many more years of usefulness left to it, and the pipes themselves (some of them buried inaccessibly within the very walls) might still be sound and sturdy enough for additional years of service, they became such "small" pipes that they impeded the flow of water. This is simply another way of saying what is obviously true, which is that the pipes were too small to begin with, because had they been larger in the beginning the same amount of water flowing through them in the same number of years and depositing the same volume of obstructing material, would still have left them an open passage large enough to pass water in satisfactory volume.

The initial economy realized by this use of pipes too small for satisfactory operation over a reasonable period (which is the entire probable useful life of the building) and the further complication of using even smaller pipes for the branches was certainly less than the cost of replacing the pipes would be. Perhaps it is true that only the practice of such short term "economies" as this in house construction have made it possible for us to enjoy such services as plumbing, yet even today a recognition of this shortcoming in our very standard and accepted plumbing practice is by no means general. This you might confirm by inquiring of a plumber regarding the replacement of clogged pipes, and noting that his recommendation would in all probability (and merely out of the habit formed of long practice) be for the re-use of the same sizes which had already been found inadequate.

Rust Versus Mineral Deposits

Or he might suggest the use of a piping other than the galvanized iron most commonly used, on the representation that the other material being rustproof would be less subject to the obstructing deposits, and hence safely usable in the standard or even smaller than standard sizes.

This suggestion, which would be for the use of brass or copper pipe or flexible copper tubing, would *seem* reasonable enough, since neither brass nor copper are subject to rusting, while galvanized iron should its internal armoring of zinc prove defective at any point, would of course rust, and old piping *does* invariably *look* rusty. But as a matter of fact, except where particularly corrosive water is encountered (in certain parts of the country where its rusting proclivities are well known to builders and architects), the chief difficulty is not rust at all but a deposit of rust colored mineral matter which precipitates out of the water. Now since no known material possesses to significant degree any ability to make the mineral matter remain suspended in the water until after it leaves the pipes, the indication is not so much for a non-rusting pipe (which to be competitive in price must be of small size), but rather for a good large-sized pipe of whatever material.

Discolored Water

Manufacturers of non-rusting pipe have used an advertising program exerting a powerful appeal based on the undesirability and the presumed health hazards of ingesting or even washing with "rusty" water or water from "rusty" pipes. As a matter of fact when the discoloration is due to rust the rust is usually not in the water one draws and uses. It is in the pipes, rather firmly adherent, and there it remains until it stops the flow of water. Occasional minute flakes do loosen from the walls of the pipe, and are carried along and deposited in corners and low points in the system, where they accumulate until some disturbance to the flow of water as by the pipes being drained and refilled dislodges them, when they are carried on out through the branches and fixtures. You will find that by letting the water run—usually for a short time only—you will clear the water of such discoloration.

The presence of rust or of mineral scale in pipes serving water is generally held to be harmless as regards any physical effect on anyone drinking such water; and even were this not so the changing of one's own pipes would offer a very incomplete protection against using water from rusty or mineral encrusted pipes so long as one ate or drank the least bit away from home.

The *discoloring in hot water* is usually due to causes different from those affecting cold water; consequently this problem will be discussed further in the section on the hot water supply.

Improving Unsatisfactory Water Flow

Aside from the possible aesthetic appeal of temporarily clean new pipes, then, what improvement might be expected from the replacement of the obstructed pipes? The measure would be an increased flow equal to the *difference* between the partially obstructed pipes and new ones of like diameter but unobstructed, or a *gain* of perhaps half the capacity of the new pipes, but at the cost of discarding the still useful half capacity of the old ones and the work of installing the new ones.

If in spite of the cost one still intended replumbing the entire house, then the use of flexible copper tubing instead of iron pipe might well be an economy in spite of its price being higher than iron, because it can be bent and fished through walls which, to receive rigid pipe, would have to be torn out and then repaired. Copper tubing, too, is pleasant stuff to work with. A type of joining union both ingenious and simple has been developed to replace the threaded couplings used with harder pipes. It seizes the ends of the tubing and clamps them in a watertight grasp. If you use copper tubing the supplier who furnishes it will also supply the needed couplings, and their method of use will be obvious without explanation, and of course many less of them will be required than for rigid piping because the tubing comes in long lengths.

The complete replacement of encrusted water lines then, is one way to overcome an inadequate flow of water, but another method, just as effective and much cheaper, is possible, and indeed is customarily used in industrial piping work although it is not often suggested to private customers for domestic use. This less expensive system is simply to *add* to the capacity of the pipes, rather than to replace them.

Adding Another Cold Water Line

Supposing the pipes in the house shown in the diagram on page 75 to be so badly clogged that almost no water could be drawn from point *O*, the place most remote from *A*, it would still be found that the faucet at *F* would deliver a brisk flow. Why? Because, while the branch feeding *F* might by similar clogging have been reduced in inside diameter to a size as small as *O*, it would still be a much shorter distance from *F* back to the water main (where sufficient pressure to insure adequate flow remained available) than from *O* to the main. In other words, the long run of constricted main pipe from *A* to branch *O*, and in lesser degree from *A* to the intermediate branches, as well as the resistance offered by the branches themselves, would be decreasing the rate of flow at these fixtures.

The cure would be most simply, effectively and cheaply accomplished by leaving the old line alone, continuing to utilize what water-carrying capacity it still possessed, and running a new one parallel to it from the house side of the drain valve *E* to the end of branch *O*, and connecting this new line to the old piping at both ends. To do this would require only a Tee, a close nipple, and an elbow to be inserted in the pipe line at both ends, and a union at one end, to take the new line, as suggested in the sketch given here in Figure 52, plus a cutoff valve at *each* end of the new line. By studying the course the water would take, in a loop through the altered system, the necessity for the two cutoffs in the new line will be apparent. By realizing that the connection of the new pipe of adequate size to the system at *O* would be the practical equivalent of moving *O* much closer *to the water source at A, it will also be seen how this would improve the flow at all intermediate fix*tures nearer to *O* than to *A*.

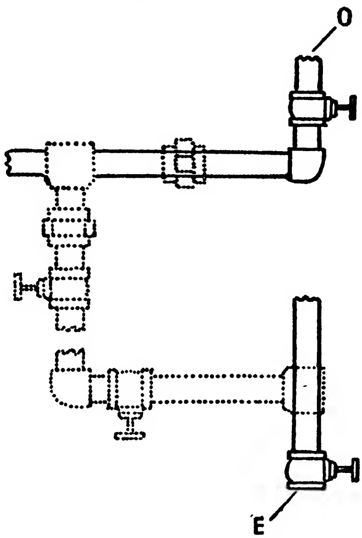


FIGURE 52—Adding Another Cold Water Line to the Piping System

An interesting and a very easy experiment to perform before launching on this repair job would be to attach temporarily a threaded faucet of the type used at *F* to the cold water pipe at the washstand *L* to replace the regular one there, and to drape garden hose from the garden faucet *F* (or another outlet near *A*) to *L*, connecting it to the two, and opening both faucets. With this temporary parallel line in the system you could, by opening the various other faucets in the house (both the hot and the cold), observe the improvement which the new pipe would make.

It should be noted that using a permanent pipe larger than the experimental garden hose would improve the rate of flow, and one smaller would of course give less results. Likewise, should it prove very inconvenient to get the new line all the way to point *O*, a satisfactory improvement might still be effected by cutting it into the old line at a point a bit nearer *A*. Also, though it was suggested to run it "parallel" to the old line, should the old line do any considerable meandering in its course from *A* to *O*, finding a more direct and shorter route (as in the sketch) would improve its performance directly as its length was shortened. Now the recommendation of this repair is based on practical rather than theoretical considerations. Quite obviously the rate of flow would be still further improved by also adding new branch lines to each fixture, and for that matter by supplementing the line from *B* to the water main, but this would be an entirely pointless expenditure so long as the loop from *A* to *O* delivered enough water.

There is another reason for letting the line from *B* to the main alone. Water agencies generally dictate the size of pipe which may be used here. This is done where water is unmetered by refusing to permit a pipe above a certain size for a house of a certain size, and where it is metered, by insisting on the use of a larger than usual meter and charging a formidable sum for the larger meter. The justification of this practice is rather interesting. Proceeding from the admitted fact that one who uses a great amount of water must be served by a large pipe, it is reasoned that one who has a large pipe will therefore use a great amount of water. The fallacy of this reasoning and of domestic pipe-size regulations based on it are of course obvious. The real determinant of the amount of water used (as regards its maximum) is not the size of the pipes which convey it, or the rate of flow at which it leaves the fixtures, but the number and type of fixtures a house contains and more particularly the number of people in the family using the fixtures.

The fact that larger pipes would permit one to draw a bathtub of water in half the time required with smaller pipes certainly would not mean that one would thereupon begin to draw twice as many tubs of water as before.

Reducing Excessive Water Pressure

Converting the cold water line into a loop as suggested here is a simple plumbing job for a home mechanic to do, and a much less messy and expensive one than replumbing the entire house; and where the water flow is unsatisfactory through being sluggish it will cure the difficulty. In fact it may in rare instances prove too effective and induce the opposite kind of unsatisfactory flow.

The water then leaves the fixtures with too much force and violence. There are two remedies. One is the installation of a device known as a *pressure reducing valve* where the water enters the building, which will operate automatically, and the other is simply to throttle the line by partially closing the valves, which will control the flow just as effectively as does opening and closing a faucet. The best result will be obtained by closing each branch valve a bit and the main inside cutoff a bit, experimenting until the desired effect is produced, rather than adjusting only the main valve. In this way the most precise adjustment can be obtained, to exactly suit the requirements of each fixture. The only advantage of the reducing valve lies in its operation being automatic and its setting not subject to being disturbed by opening or closing it, as a manual valve might be.

Noise in Operation

The next trouble which afflicts water lines is noise in operation. Like inadequate flow, this defect creeps up on a plumbing system with the passing of time. Its cure is comparatively simple and very important, because long neglected it may damage the pipes. Here is how it comes about. Water moving through a pipe, like every other moving body in the world, exhibits a reluctance to stop moving once it has been started. It is this inertia or momentum which keeps a moving body moving after the moving force has been removed, until friction, gravity, or other forces external to the body itself overcome the inertia. The greater the speed, the greater the momentum.

Now *rate* of flow depends both on the speed of the water through the pipe and on the size of the pipe, so when pipes are new, and hence moving a good sized column of water through their bore, one can get a satisfactory flow by opening a faucet just part way, thus preventing the water from ever moving through the pipe at any great speed. But as the pipes crust up inside, it is necessary to open the faucet wider and wider, and the water must flow faster through the smaller diameter to deliver the same amount of water in the same time. And then, when you suddenly cut this rapidly moving stream off by flicking the faucet closed quickly, the water keeps right on moving for a bit, coming up finally with quite a jerk. The water, literally slamming against the faucet valve and finding no escape there, tries to move in another direction, hammering at every inch of the pipe wall and every joint and elbow.

Water Hammering

It delivers a physical blow to the system, just as would hitting the pipe with a metal hammer. (This phenomenon is in fact called *hammering.*) And in time leaks may be sprung, or the whipping of long straight runs in the pipe may damage couplings or unions. If only the water were compressible, as gases are, the energy would be dissipated in harmlessly and noiselessly compressing the fluid. Since it is not, a "cushion" is inserted in the system to absorb the shock. A *cushion of air*, confined in a section of vertical pipe is attached to the system as suggested in Figure 53.

It is only necessary that the cushion column pipe rise vertically from the water line, and that its upper end be

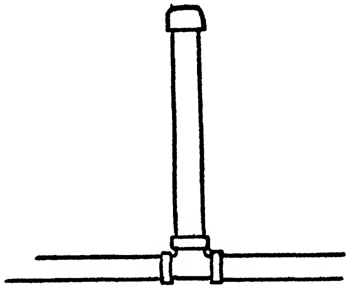


FIGURE 53—Air Cushion to Stop Water Hammering

capped as tightly as any other joint in the system. Where the cushion is put is a matter of convenience in introducing it into the system, and the number required is arrived at by starting with one and adding more until the water system behaves. However, the loop line should be installed first (if it is needed), with plugged tees inserted at convenient places, and the system tested before adding the cushions (at the tees) since the loop alone will sometimes cure hammering.

Humming in the Pipes

Another type of noise sometimes encountered in water pipes is a constant *hissing* or *humming* which may be so soft as to be no nuisance or so loud as to be a real annoyance. Although, unlike water hammer, it occurs while water is being drawn from the system rather than when the flow is cut off suddenly, it too is caused by the water flowing with considerable velocity through too small a pipe, and accordingly its practical cure lies in enlarging the capacity of the pipe. The one repair job of increasing the pipe capacity, whether this is done by re-plumbing or by the addition of the loop line, should cure the three difficulties of inadequate flow, water hammer, and hissing.

Water of Undesirable Temperature

In the case of the difficulties dealt with above it would not be right to blame them *entirely* on poor plumbing, since they had their basis in a physical phenomenon (the encrustment characteristic of the flow of any impure liquid through a pipe) the correction of which would have added substantially to the initial cost of the installation. We now come, however, to a situation whose prevention would have been so simple and so inexpensive that it is difficult to find an excuse for it. That is the matter of the water being delivered at the fixtures at an undesirable temperature. The cost of inadequate water flow can be measured largely by the inconvenience it subjects the user to, waiting for enough water to have flowed from a fixture, and the degree of annoyance might well dictate whether or not to stand the cost of correcting the situation; but with undesirable temperature the difficulty causes a real financial loss of substantial proportions. When you open a cold water faucet and have to let it "run" until you have exhausted all the heated water from the house line and are getting cool water brought all the way from the point where it enters the house, you are buying, paying for, and wasting a good many gallons to get perhaps a few cupfuls. That is bad enough. But when you open a hot water faucet and must let it run until the cooled water is exhausted from the pipes all the way back to the water heater, you are not only wasting the water but also the cost of the fuel consumed to heat the water.

Additionally, where it is de[illegible]ed to cool water for drinking (as of cou[illegible] may be the [illegible] in t[illegible] even when one is fortunate enough to get the water as cool as might be expected from the water main), both the time required to cool it and the burden placed on the refrigerator in cooling it increase with its temperature. And in the case of hot water, both for culinary and laundry use, it is simply impossible to do a really efficient job of cleaning with lukewarm water, no matter how much soap one may use. To see the near boiling temperatures at which water is used in commercial establishments for scullery purposes, and the difference it makes in the work, is a startling revelation for many a person who has never known the pleasure of having really hot water available in his or her own kitchen. It should be noted here that the use of very hot water, and especially its unexpected availability at domestic plumbing fixtures, does present certain hazards when the family is unused to it, just as would electricity or gas to one unfamiliar with its proper use; and this will be discussed further in connection with the plumbing fixtures and the water heater.

The acuteness of this problem of the temperatures of the water in the hot and cold lines approaching each other as though seeking to agree on a common point of disagreeable tepidness will vary from one house to another, but it can be said flatly that no householder can afford to tolerate the condition. Its cost is too great and its remedy too simple and inexpensive. All that is required is the insulation of the pipes against the loss or gain of heat by its transfer to or from the air surrounding them. There is nothing either original or novel about this suggestion, and in fact the same architects and plumbers who omit water pipe insulation in domestic practice regularly employ it in the planning and construction of commercial and industrial buildings, where its effects on operating costs are a matter of common knowledge to the owners,—or the owners' engineers. In large hotels drinking water is often cooled by refrigerating machines located in the basement, and delivered to rooms in the upper stories of the building through well insulated pipes, still chilled. Long runs of hot water and steam piping are treated in the same way.

How Heat Transfer Occurs

Problems connected with heat and heat transfer occur again and again at many points in connection with home mechanical equipment, and an understanding of the operation and repair of these devices will be helped considerably if you understand something of heat and its behavior. At first glance perhaps the most striking characteristic about heat is its seeming restlessness and instability. It is always in motion, and though its movement from one place or one material or substance to another may seem erratic, it actually follows a quite definite pattern. First it may be thought of as traveling in only one "direction"; that is from where it is to where it is not, or more accurately from where there is more of it (a hotter place) to where there is less (a cooler place). Now this accounts for the fact of the change in the temperature of the water in both the hot and the cold water pipes, but in opposite manner. When the cold water entered the house pipes it was cooler than the air in the house surrounding the pipes, or inversely the air was warmer than the water, and accordingly heat flowed from the air to the water in the pipes. The water in the hot water pipes, however, was hotter than the air surrounding the pipes, and accordingly heat flowed from the water to the air.

Heat Transfer by Conduction

There are three means by which heat is transferred. These are by conduction, by convection, and by radiation. When one part of a solid is heated and the heat travels through the material to the other less hot parts we say the material has "conducted" the heat, or that the heat has traveled by conduction. If you were to immerse only one end of a metal spoon in boiling water and keep hold of the other end you would very soon become sensible of the conduction of the heat along the spoon. Repeating the experiment with a wooden spoon would emphasize the fact that all materials do not exhibit the same rate of conductivity.

In the case of the hot water piping then, conduction through the iron pipe would account for the heat flowing from the water to the outside surface of the pipe. Here a second means of heat transfer would begin to operate in addition to conduction. As the heat moved from the surface of the pipe to the surrounding air, the air would not remain motionless and pass the heat along merely by conduction.

Heat Transfer by Convection and Radiation

Rather as the air next to the pipe became heated it would rise, and this would bring other cool air into contact with the pipe, and the air current thus set up would be known as a convection current. While the hot water pipe lost heat through conduction and convection, the third means of transfer, by radiation, would also be operating. Hot surfaces will radiate heat to a less hot body nearby without necessarily heating the intervening space. A good example of this method of heat travel is furnished by a radiant electric heater, which is a small electric coil glowing in a big brass bowl and throwing out heat which is focused by the reflector much as a searchlight focuses its rays of light. Now just as materials vary in their rates of internal conductivity of heat, so do various surfaces radiate heat differently, and it is by taking account of these differences and of the fact that unconfined fluids will support convection currents, that heat transfer is controlled.

We have referred here to the heat loss from the hot water pipe, but the same forces, working in a reverse way, apply to the cold water line. That is, in this case, the heat flows from the air surrounding the pipe to the pipe, through the pipe to the water, and throughout the water, and the air here also moves in a convection current, but one which falls as it loses its heat to the pipe.

How To Retard Heat Transfer

In order to insulate both the hot and the cold water pipes then it will only be necessary to secure some material or materials with a low rate of internal conductivity, which does not radiate easily, and will not support convection currents, and which is likewise flexible enough to be manipulated handily; and then to swathe the pipes in it. If it is fireproof, vermin- and moisture-repellant and non-deteriorating, so much the better. Paradoxically air itself is one of the best heat insulators available and all other materials improve as they approach the low conductivity characteristics of dry, still air. But the catch is that it must be *still* air, incapable of being set in motion in convection currents.

Types of Insulating Materials

If only air were a solid so it would remain where placed, it would be just about a perfect heat insulator. In fact what all the various insulating materials do, and derive therefrom insulating characteristics superior to any derived from their own internal conductivity is this: they trap air in a multitude of little pockets where it cannot move about. The result is that you can even select rock for your insulating material and get results as good as with another material of much better internal conductivity, providing it is puffed up into a woolly loose mass shot through with air. There are dozens of these puffy insulating materials available, ranging from treated tree bark and other organic materials to rock, blast furnace slag and even spun glass, and they are so nearly alike in insulating value that the determining factor as to which you should use should be their competitive prices and the convenience with which you can cut them into strips and wrap them about the pipes. Some organic materials possess the trapped air characteristics in their natural state, such for instance as the softer more spongy woods, and of course cork (which is a tree bark), but these materials, and the artificially molded boards known as the rigid insulators, are not practical for wrapping around pipes.

Molded Pipe Jackets

There is a heat insulating material made in long half cylindrical sections, especially to fit pipes of various diameters, which has been on the market for many years. It is made of *asbestos mineral fibers,* felted into a sort of paper which is then laminated in layers with alternate layers corrugated just as is the center layer of a cardboard carton, so as to form tiny tubes to trap the all-important air. Because of its high cost, however, its use is confined almost entirely to insulating very hot pipes whose temperatures would threaten to ignite any burnable substance. It is both a heat insulator and a fireproofing agent, calculated neither to burn itself nor to transmit enough heat to ignite any adjoining or nearby combustible material. It does present a most neat appearance when applied to pipes, as you will know if you have noticed its use in insulating exposed steam pipes, especially when its outer covering of fabric is given an occasional coat of paint. In the corrugated form it is excellent, but it must be noted that in the absence of a structure which will trap air, the material asbestos is itself not a good heat insulator. This is mentioned because the popular confusion resulting from its use as a fireproofing material led many laymen to assume that it possesses unique heat insulating qualities; and some manufacturers permitted the sale and use of thin sheets of the material for application where the need was not fire-retarding but heat insulation. Many a hot air furnace pipe has been wrapped with this thin material, with the net result that the shiny surface of the pipe, which at least conserved heat to a degree by being a poor radiating surface, was changed for an asbestos paper surface having no particular virtue in the prevention of heat transfer from the pipe to the surrounding air.

Wrapping the Water Pipes

The solution then to the cold water becoming warm and the hot water being cooled in the water pipes is to insulate the pipes by wrapping them well with any of the blanket, quilt, or bat types of loose fluffy insulating material ordinarily used for insulating house walls, or with the specially prepared pipe insulating jackets. The actual work involved in wrapping that part of the piping which is exposed will present no particular difficulties, and will go fairly rapidly, but as was the case with the plumbing work, the pipes within the walls and floors will present a problem. To obtain the maximum insulating effect all the pipe should be treated but as a practical matter it may be better to first treat the exposed and easily exposable parts and stop here if this compromise seems to be reasonably effective. If it is not, you may still be able to avoid tearing out much wall plaster by securing a hundred pounds or so of fill-type insulation, cutting a hole in the wall where a vertical pipe run occurs, and pouring the insulation into the hole. This technique calls for a little exploratory work to determine the exact course of the pipes and it requires a good deal of insulating material, but even so it is frequently to be preferred to tearing out a wall.

Heat Exchange Between Hot and Cold Water Pipes

There are two circumstances in which it would most certainly be worth while to open a wall to insulate the pipes. One is when, as often happens in poorly plumbed houses, the hot and cold lines are installed very close together. In this situation, water from the cold line will be found to be much warmer than merely absorbing heat from the air could make it. The seriousness of this situation is indicated by the fact that in recent years many building codes have been amended to require the separation of the pipes by a certain number of inches simply as a water conservation measure. The other circumstance is when the hot water piping layout favors convection currents within the pipe.

This comes about when the hot water line is laid out in a loop (exactly as was recommended here for the cold line), which is done deliberately to avoid the necessity of insulating the hot lines. The result is that while it does save water by making hot water always available at the fixtures, it does so by returning water which has already been heated once back to the water heater after it has lost its heat through standing in the uninsulated pipes. It was for this reason that a loop was recommended only for the cold water system, earlier in this chapter. The hot lines should not be looped unless they are also insulated, but where they are well insulated looping them will both improve the rate of flow and save water and fuel.

Insulating the Hot Water Storage Tank

In insulating the plumbing system the hot water storage tank should be considered as part of the piping system, an enlarged section of pipe as it were, and insulated just as thoroughly as the remainder of the system, since its large surface area will obviously dissipate a tremendous amount of heat. Until recently it was the practice to leave domestic hot water tanks perfectly bare of insulation, but now special jackets are available to fit various sizes of tanks. The popularization of this improvement must be credited to the manufacturers of modern self-contained automatic electric and gas domestic hot water heaters. They found it was desirable to insulate their tanks in order to bring the fuel cost down to more or less competitive levels, and by doing so were sometimes able to show an actual economy in water heating costs over the older systems with uninsulated tanks, especially where the tanks were in a cool part of the house such as the basement.

Leaking Due to Damage

There are three major causes of leaks in water pipes. The first is through their being punctured, which is a rare occurrence with hard pipe but sometimes happens when a carelessly driven nail punctures a piece of soft copper tubing. The second is through the pipe becoming so weakened by rusting that the water pressure bursts it. This will only occur with iron pipe. The third is through water in the system being permitted to freeze; and this is by far the most serious of the three.

How to Repair Leaks

When a small leak is caused by puncturing an otherwise sound pipe, there are any number of ways of mending it. One is by screwing a roundheaded self-tapping screw into the hole, with a fiber, rubber, cork, or lead washer under the screw head. Drawing the screw down tight will generally stop the leak, but the extension of the screw shank into the pipe will present some obstruction to the flow of water and will be an invitation to rust; therefore as short a screw as possible should be used. Another method is to place a *clamping patch* such as is illustrated in Figure 54 over the hole. Such patches are available at hardware stores in sizes to fit pipes of various diameters, and they are sometimes used by mechanics for temporary repairs, or even left in place permanently where the water pressure is not too high

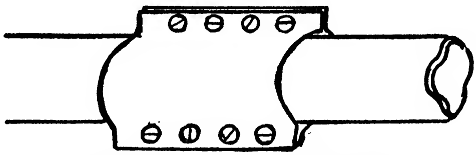


FIGURE 54—Pipe Clamping Patch

and when the location of the damaged pipe is such as to make its replacement difficult. A third type of repair is made by applying a paste made of an iron patching cement which is marketed as a powder and mixed with water. It is worked into the hole or crack and permitted to harden before the water is turned on, because the water pressure would blow the paste out as rapidly as it was smeared on if one attempted to place it with the pipes in use. The criticism of all these methods, and numberless other similar ones, is that they introduce an element into the system which is less durable than the pipe itself, and hence of questionable permanency.

When a pipe leaks through its wall having rusted out, the only practical repair is the replacement of the pipe, and generally all the pipe of the same length of service as well, because the occurrence of one rust leak is usually the signal for the beginning of a whole series.

Leaks Due to Freezing

In northern climates pipes are sometimes split open by the water in them freezing. A mild freezeup may form slush ice in a pipe so as to stop the flow of water without damaging the pipe, and in this case it will only be necessary to thaw the pipes out by any means or combination of means which raises their temperature. There are endless ways of doing this, ranging all the way from holding a candle under the pipe or pouring warm water over it to applying a blow torch or the terminals of an electric welding outfit to it, but about the quickest and the safest way is simply to raise the temperature of the entire house by building a good hot fire in the furnace. Notice that we are discussing frozen water pipes here, and assuming the availability of either a hot air or an unfrozen water or steam heating plant. A frozen steam or water heating boiler *should not* be thawed by building a fire in it. Even lacking furnace heat, however, it will usually be possible to raise the temperature of a house enough with a fireplace or two and a kitchen stove to thaw mildly frozen pipes.

Soft copper tubing will stand one or a few solid freeze-ups without being damaged except at the unions and valves, because it will expand as the ice freezes. But if a hard pipe system is subjected to a low enough temperature to freeze it up solid, the expansion of the water in freezing will burst the pipes. Then when the ice thaws back to water the leaks will be apparent, and they will be found to be in the form of long splits or cracks. The only cure is to replace the damaged pipes and to exercise more care for their protection thereafter, either by insulating them as was suggested earlier in the chapter—completely so that no point remains unprotected—or by draining them entirely every time a dangerously low temperature is expected.

Protecting Pipes against Freezing

In an emergency, with uninsulated pipes which cannot conveniently be drained and with the expectation of a freezing temperature, pipes can be protected by permitting the water to run continuously in a small stream. By this means, as the water in the pipes is cooled toward the freezing point, it escapes and is replaced by warmer water from the main before it can freeze. The objection to this procedure which makes it undesirable except in an emergency is the fact that every single outlet must be opened to protect each branch line and the fixture traps (which will be explained in connection with the soil lines), with the result that a considerable amount of water will be wasted.

Draining the Pipes

A better way is to drain the lines; and this is done by first closing the main house cutoff and opening every faucet in the house including one so located as to be lower than any other point in the entire system. When this is done all the water will drain out of the system, provided every faucet is opened so as to admit air into the upper reaches of pipes above the descending column of water, and, and this is most important, that no water remain in a sagging horizontal run of pipe such as shown in Figure 55. If you study this

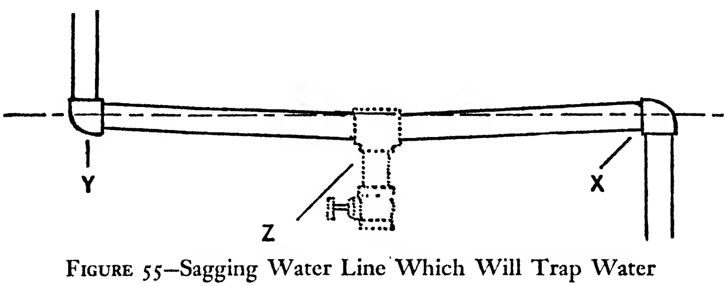


Figure 55—Sagging Water Line Which Will Trap Water

sketch a moment you will see that if the horizontal run of pipe between the points *X* and *Y* sag only as much as the diameter of the pipe, the water in this run will not leave as the pipes are drained, since the water here will not run uphill over the crest of the incline at *X*. This swoop in the line constitutes what is called a trap. You will see this trapping phenomenon used deliberately in the soil line of the plumbing system, but it has no place in a water line.

The indication is to see to it that no run of pipe anywhere in the house be permitted to run at dead level, lest in sagging it form a trap, and also to see to it that the very lowest point of every line has a faucet to permit it to be drained. In other words, if such a situation as shown in the sketch exists and cannot be corrected by pitching the pipe so that one end of the run is a few inches above the other end, with a drain faucet at the lower end, it must be prevented from trapping water by locating a faucet at point Z where the run sags to its lowest.

It must be understood that insulating the water pipes retards, but does not entirely prevent heat transfer and so when a house is to be left long unheated in extreme weather the pipes should be drained even though insulated.

Essential Facts about the Water System

Let us now recapitulate the essential facts about the water system before proceeding to the soil line:

The house water system consists of a pipe originating at the point within the house walls where the water service enters, with branch lines to serve each of the plumbing fixtures in the house, and to serve the domestic water heater, which in turn serves the fixtures with a second water pipe line and branches.

The pipes may be lead, in an old house, or galvanized iron, brass, or copper, in a newer house. The troubles usually encountered with the water pipe system are, first, inadequate flow due to gradual clogging of the pipes with deposits of mineral matter from the water, or with rust in the case of iron pipes. The cure is the replacement of the clogged or rusty pipes, or the addition of a new main line cold water pipe to the system to supplement the capacity of the old pipes. Second, the cold water may become warmed in the pipes and the hot water cooled. The cure is the insulation of the pipes. Third, the pipes may develop leaks. When due to rusting or corrosion the cure is the replacement of the pipes, and when due to damage such as puncture, the leak can be patched. When due to bursting from freezing, the burst pipes and fittings must be replaced, and provision made against their freezing again. The mechanical work involved in repairing water pipes is simple and within the skill of the average person, and can be done with very few tools.

CHAPTER IV

The Soil Lines

How the Soil Lines Are Arranged to Carry Off Wastes

Figure 56 shows the arrangement of the soil (or waste) lines of the house whose water pipes are also diagrammed there. Compared to the water piping the soil lines are very simple, and subject to few difficulties. In the sketch you will notice that a branch soil line serves each plumbing fixture served by the water lines, and carries the wastes from the house to the public sewer.

Traps and Vents

The only "valves" used in the soil lines are the *traps* which are used at each fixture and the main house trap in the basement. These are simply U bend fittings and their function is to seal off the air in the public sewer from passing into the house through the outlets of the plumbing fixtures. This they do by maintaining a water seal. When waste enters the line at a fixture, it flows up over the arm of the trap into the soil line only so long as the water level in the fixture is higher than in the line beyond the trap, and thus the trap is always left filled with water.

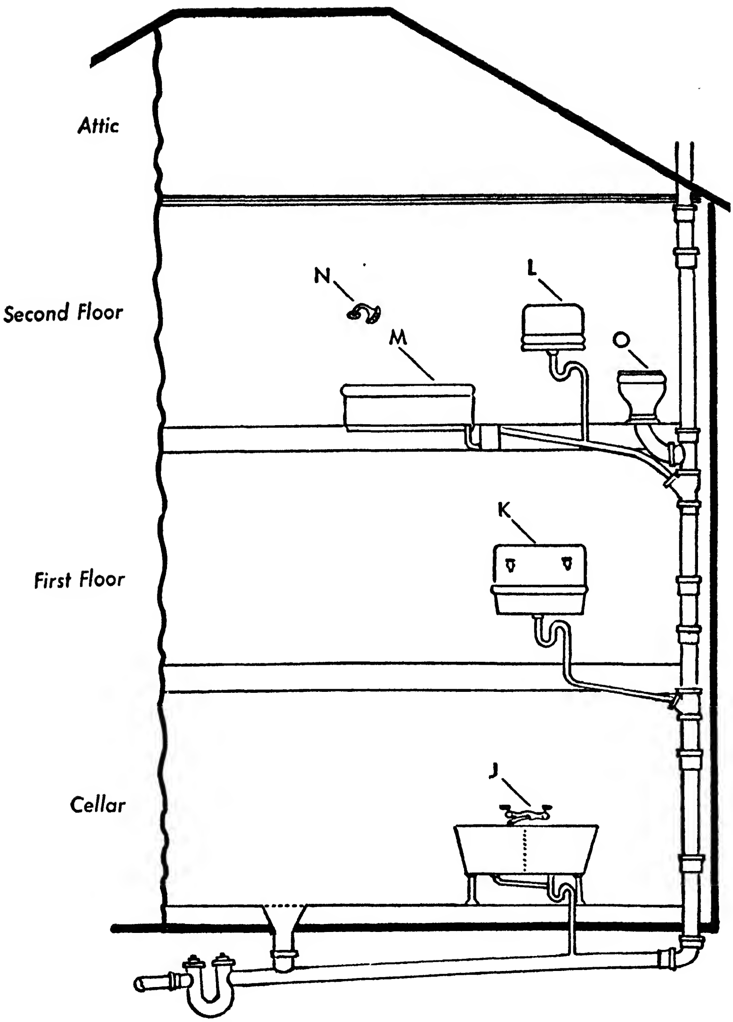


FIGURE 56—House Diagram Showing Arrangement of Soil (Waste or Sewer) Pipes

The diagram of the soil lines also shows the roof *vent*, which insures that the lines shall always be open to the fresh air, lest any pressure in the sewer force sewer gas back through the fixture traps.

About the only troubles which soil lines will ever give are: 1) becoming clogged with sewage solids, either somewhere along the line or at the traps; or 2) bursting of the traps by being subjected to freezing. By far the largest number of calls for the plumber are for him to remedy a stoppage in the soil lines, or in the traps. These are of two types. First is the introduction, generally through toilet fixtures, of insoluble solids which are impelled into the system by the flushing action of the toilet, but which become stuck when the force of the impelling water is spent. The soil lines constitute what is known as a *dry system*, which means that the soil line pipe is not filled with water (as the water lines are) but is rather a sort of enclosed chute, down which, purely by gravity, the wastes are washed.

How to Relieve Clogging and Stoppage

In unclogging a soil line, a plumber may make a great ceremony of examining the lines and removing cover plates of traps to find the stoppage, but the fact is that the real job involved is simplicity itself. Since the lines consist of nothing more mysterious than hollow pipes, it is usually only necessary to introduce a flexible steel strip and push it through the line until it meets and dislodges the obstruction.

The other type of stoppage occurs at sinks or wash stands due to the accumulation of solids which settle in the trap and cannot be flushed through by the normal action of the water being drained from the fixture. In this case it will only be necessary to unscrew the cleanout plug on the fixture trap, having first placed a bucket below the fixture to catch the impounded water from the fixture above. The matter causing the clogging will drop out of the bottom of the trap, which can be further cleaned by means of a short bent wire introduced through the cleanout plug and moved about.

Kitchen traps suffer from material such as bits of vegetable scraps lodging in the bend and being cemented there by a coating of grease which clings to the walls of the trap. A routine often recommended to householders to prevent this grease clogging is the regular use of an extremely potent preparation having lye for its active ingredient. It is used by dumping a bit into the drain, washing it down into the trap with water, and leaving it there, where it dissolves all vegetable and animal matter, and converts the grease into soap.

Unfortunately, however, this substance also practically dissolves the plumbing fixture and trap as well, and its use cannot be recommended here, certainly not as a repeated routine treatment. Much better is to prevent the gradual clogging of the trap by running really hot water through it in the course of one's daily work, to liquefy the grease and carry it into the soil line before it can accumulate to an extent sufficient to act as a gathering place for food waste which would otherwise flush on through the trap. Then, if even with this care the trap becomes clogged, the plug should be removed and the trap cleaned from below. In bathroom wash fixtures the clogging may result from the presence of hair, which must simply be removed periodically through the plug.

To expect a sewage disposal system to function endlessly without an occasional cleaning of the traps is unreasonable because the construction of the traps necessary to their acting as gas seals is such that they will inevitably clog once in a while. That is why the cleanout plugs are provided. And it is advisable to inspect them now and then to prevent them from becoming clogged.

Preventing Traps from Freezing

Aside from the clogging of the traps or the soil line, the only other common difficulty is the freezing of water in the traps, when the temperature of the house is allowed to fall with the weather in winter due to the house being unheated or untenanted. One method of preventing this is to add an anti-freeze material to the water in the traps, just as is done with the water in an automobile cooling system. A cheap anti-freeze for this purpose is ordinary salt, rock or ice-cream salt being the cheapest. This will convert the trap water into brine which has a freezing point far below any temperature to be expected even in the coldest weather. In addition this method has the advantage of being so very cheap that when the system is again put into use the salt can simply be flushed out into the soil line. The salt will not evaporate during the cold weather and leave the water unprotected. Rather as time passes and the water evaporates, the concentration of the solution will become stronger until finally, when all the water has evaporated and there is thus no danger of its freezing, the salt will remain, to be flushed away when water is next introduced into the system.

The other method is to drain the traps, but this is a nuisance, especially with the traps of built-in bathtubs, toilets, and the main house trap in the cellar. It should be noted that just as every point of the water system must be protected from freezing, so every trap in the house must be salted. When using water in a house after the traps have been salted, all the drains should be flushed by a *considerable* running of the water to wash the salt or brine *entirely* out of the lines because it has a corrosive effect on the iron soil lines. One caution should be observed in leaving traps wet. That is to be sure to cut off the water and drain the pipes as soon as the traps are treated with salt, lest someone run fresh water through one of them, thus washing out the anti-freeze leaving that trap filled with plain water, which of course will freeze. Some prefer the use of kerosene to salt, and its use is probably just as satisfactory except for some slight fire hazard which it might introduce.

CHAPTER V

The Domestic Hot Water System

THE HOT WATER SYSTEM (or domestic water heating system, as it is often called) is an apparatus which frequently offers the home mechanic plenty of opportunity to exercise his talents. While it is not particularly complicated it does suffer a rather imposing assortment of ills in the performance of its simple enough job of delivering heated water. To begin with, it may be affected with any or all of the five plumbing troubles discussed in connection with the cold water system, and in addition there are several more which arise in connection with the heating of the water and its distribution to the various faucets throughout the house where it is used.

THE KITCHEN RANGE WATER-BACK HEATER

In the development of the modern plumbing system the idea of furnishing hot as well as cold running water was at first not taken too seriously, and so it happened that in the early hot water systems the heat needed for this job was "borrowed" from the kitchen range by means of a simple but never very satisfactory arrangement known as a fire back and range boiler, or storage tank. The sketch given here in Figure 57 shows the way in which this was done.

The water back shown at *E* consists of simply a few short lengths of pipe coupled together with U bend fittings, inserted right in the fire box of the stove, and connected

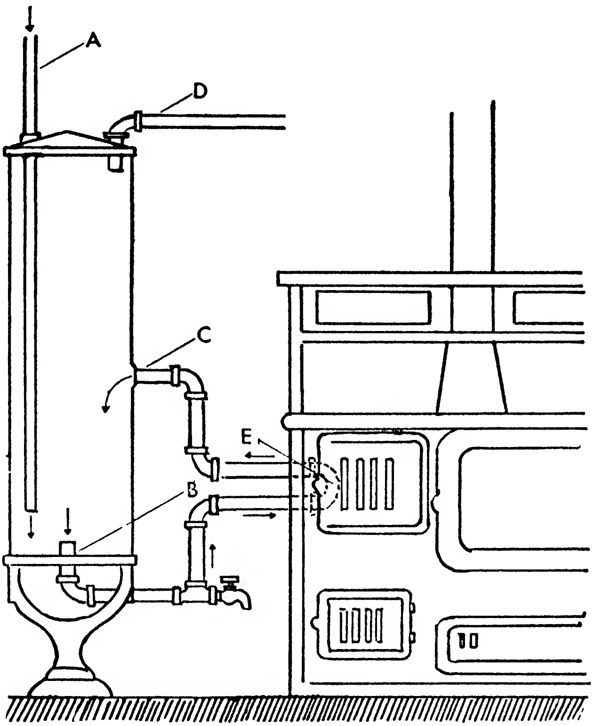


FIGURE 57—Water-Back Heater as Used With a Kitchen Range

with the storage tank by means of the two pipes *B* and *C* (and the necessary couplings). Cold water enters the storage tank through the bottom of pipe *A*, which is a branch line from the cold water system, and hot water leaves the tank at the top through pipe *D*, on its way to the various fixtures. Structurally that is all there is to this simplest of the domestic hot water systems, and there is surprisingly so little more to any of the others which have succeeded it that they can all best be explained in terms of the fundamental operating principles of this one.

It will be obvious to begin with that the storage tank, the cold and hot water pipes *A* and *D*, and the *water-back* and its connecting pipes *B* and *C* will all be filled with water under the same pressure as the house cold water system. and that when a hot water faucet is opened water will flow through it from the tank and be replaced with more cold water entering through pipe *A*. Likewise, assuming a fire in the stove, the water in the back must obviously become hot. Recalling now from Chapter III how adding heat to water will cause it to rise by setting up a convection current, it will be seen that heating the water in the back will cause the water both there and in the storage tank to start circulating in the direction indicated by the arrows.

The Furnace Water-Back Heater

Now it happened that two great improvements in domestic heat devices took place at about the same time, and thereby delayed the improvement of the water heater. The coal and wood burning kitchen ranges began to be replaced by gas cooking stoves; and central heating by coal-fired hot air furnaces became common. The result was that the storage tank and water-back were moved to the basement where the furnace could furnish the heat. The simple zigzag pipe was replaced by a more compact hollow casting called a knuckle, which was inserted in the furnace fire pot and operated in the same manner as the stove back.

The Boiler Indirect Heaters

When hot water and steam boilers came into use for house heating their smaller fire pots made the knuckle a nuisance. A coil, as shown in the illustration of the steam boiler on page 255, was therefore enclosed in a hollow shell, and through this shell steam (or hot water) from the boiler circulated, transferring some of its heat to the enclosed coil.

These are the so-called indirect or auxiliary types of heaters. The quaint premise underlying their design, that a) the kitchen stove would be kept fired 24 hours a day or the furnace 12 months a year, or b) that the householder would want hot water only during cooking hours or winter months, proved their undoing, and ushered in the independent type of heater.

The Independent Heaters

Independent heaters vary from the indirect type by having their own heat source. The least expensive of these

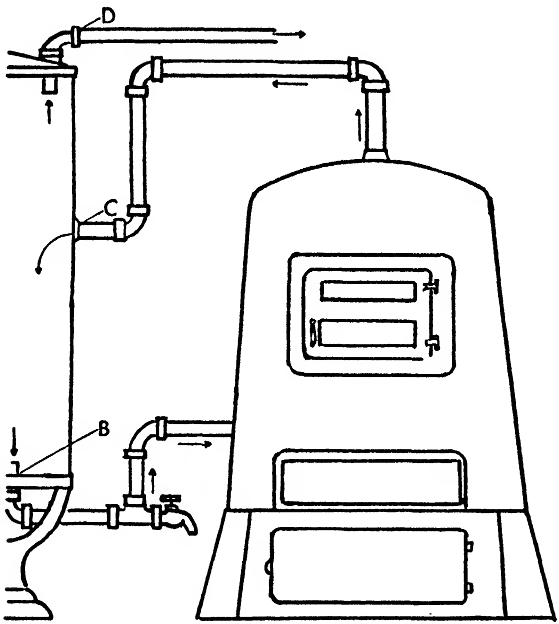


FIGURE 58—The Independent Coal-Fired Water Heater

to operate is the coal-fired type, which simply uses a miniature edition of the house-heating hot water boiler—a small stove with hollow walls through which the water circulates from and to the storage tank as shown in Figure 58. The other common type is the gas side-arm heater. It has a gas burner at the bottom of a vertical metal shell within which a spiral coil of flexible copper tubing is arranged, and coupled of course to the storage tank. These heaters were certainly a great improvement over the auxiliary type but they are a nuisance to use because of the attention required to fire the coal heater or turn the gas burner on and off.

Semi-Automatic and Automatic Heaters

To overcome this the side-arm heater was equipped with a thermostat which in response to the water in the tank becoming heated would shut off the gas flame; and the coal heater was equipped with a thermostat coupled to the drafts so as to retard or encourage the fire. This is the current state with the coal models and it is as far as one can go short of an automatic stoker, the cost of which would be prohibitive. The gas heater manufacturers, however, emboldened by the success of the thermostatic shutoff (which was really introduced not as a convenience feature but to prevent the hazardous and very common occurrence of the burner being left going full blast) ventured further and devised a thermostat and pilot light hook-up which puts out *and* lights the burner, or adjusts the flame, all automatically.

There are two other types of fully automatic heaters. The electric heater—which is practicable only in those areas where the electric supply agencies have found it possible to offer power service at a much lower rate per kilowatt hour than is usually charged domestic customers—consists simply of an immersion type heating element inserted directly in the storage tank, controlled by a thermostat. The other type is a revival of the water or steam boiler indirect heater. It is used the year around with boilers fired by oil burners. A valve or valves shut off the fluid from circulating through the radiator pipes (either manual valves or automatic ones actuated by thermostats) when the air in the house is too warm to require furnace heat and a thermostat in the water storage tank actuates the oil burner. Thus the house boiler oil burner furnishes heat for the domestic hot water heating system right through the summer. This summer-winter hook-up is also used with gas fired boilers; and of course it could be applied to a coal fired boiler as well but there would not be much point in this since its chief appeal is its convenience, and with coal it is obviously easier to tend a small coal-fired hot water boiler than a large house heating boiler fire.

Combination Heaters

Sometimes a water heater is arranged to take heat from a furnace or boiler during the winter months, and a direct heater is used during the summer. This system probably offers the best combination of convenience and economy where the summer heater is a well designed one of the fully automatic type. Notice that all the heaters are alike in that they use a storage tank, and all but the electric type heat the water a little at a time by withdrawing it from the tank into the back or knuckle or coil or stove, by means of the convection current set up in the separate heat exchange element. The convection current in the electric type involves all the water in the tank at the same time. There is one kind of heater in use which omits the storage tank entirely. It consists of a very much oversized heating coil of much the same kind as is used in the ordinary gas side-arm heater, and a very large gas burner with a pilot light. It is called an instantaneous heater, and the burner cock is so arranged that every time a hot water faucet is opened the slight fall in the water pressure which results turns the burner on full blast. As soon as the faucet is closed the burner shuts off.

Difficulties in the Operation of Water Heaters

So much for the construction and operation of the heaters. As to the troubles encountered in their operation, several of the more important ones are common to all the types, and each type has in addition a difficulty or two peculiar to its own design, heat source, and piping arrangement. In repairing a water heating system the entire system should be considered as a whole, and each of the three main elements—the heat source, the storage tank, and the piping—should be suspected as the possible source of trouble. In other words, a list of the troubles would be much shorter than a list of the causes because the same trouble might arise from any or all of several causes.

The two troubles which make all the others seem unimportant by comparison are 1) the inability of the system to deliver an adequate volume of water heated to the proper temperature, and 2) the use of an excessive amount of fuel. Curing the first by causing the second wouldn't be much of a cure, so it would be worth while to look further than the heat source before assuming that it was to blame for lack of enough hot water. In fact, whatever type of heater you use, when looking for the cause of a particular trouble, start by assuming that the cause of the trouble is elsewhere —in the tank or in the water lines—and you will probably end by getting more hot water and using less fuel to do it.

Cutting Heat Losses Through Insulation

The difficulty is that in any system in which the pipes and storage tank and the indirect heater, gas heater, or independent stove are not insulated, the heat which is added to the water is dissipated before the water is drawn and used. The cure for this difficulty is explained in detail in Chapter IV, page 94, where the entire problem of undesired heat transfer in connection with the hot as well as the cold water system is covered.

Rebalancing an Insulated System

Insulating the storage tank and the hot water pipes of a hot water heating system is practically certain to unbalance the system, as it existed when it was losing the heat almost as fast as the heat source could add it. But the disturbing of this balance is a minor trouble when the resultant improvement is seen. How much good a really thorough insulating job will do any particular system is impossible to predict; they are all so different. But it is not at all unusual for the fuel economy to amount to a half or even two-thirds of the amount previously used. This suggests that something drastic will have to be done to reduce the heat input to keep the temperature of the water within reason after insulating the system. How to do this will depend on the type of the system, and here the real beauty of the automatic gas and electric heaters emerges.

The automatic heaters will probably require no further adjustment at all, because the thermostatic control which cuts off the heat will simply act much sooner—as soon as the temperature of the water in the tank rises to the proper point; and the control which starts the heat going again will cut in much later—only after a good deal of the heated water has been drawn and used, or when the system's irreducible heat loss even with insulation cools the water.

With a semi-automatic gas heater of the type which cuts the flame off when the water reaches a certain temperature, it will simply be necessary to learn that the heater can be lit a much shorter time before the hot water is wanted; and with a manual gas heater the same is true, plus the fact that the burner must be extinguished after a much shorter period of heating than before, lest the water actually reach the boiling point.

With a coal-fired stove heater with thermostatic draft controls there is some possibility that the drafts will be held on check so much of the time that the fire may die; but generally after about a week of patient experimentation a new firing technique will be developed which will hold a surprisingly small fire for a surprisingly long time with a most surprisingly low fuel consumption.

With an indirect boiler heater on the thermostatically controlled summer hook-up, the effect will be the same as with the automatic gas and electric heaters, but on the ordinary winter boiler heater it may be necessary to control the boiler water circulation through the heater, and without disturbing the boiler heat source. This can be done only by inserting an automatic thermostatic valve in the pipe between the boiler and heater—the maker's directions will indicate in which pipe. Just remember that the infeed pipe is the *upper* of the two pipes connecting the boiler with the heater, since the convection current of the boiler water in the heater is downward as it loses its heat. These valves have the thermostat coupled to the gate in such a way that they open at a low temperature and close at a high temperature. They are self-contained, and are no more difficult to insert in the line than a coupling or a union.

With a firepot water-back heater there is obviously no practical way of controlling the heat input, whether the back is used in a boiler, a furnace, or a stove, since the water must not be prevented from circulating through the back as it gains heat from the fire or steam will form and an explosion may follow.

Overheated Water

It sometimes happens with an automatic heater that insulating the system improves its operation so much that the water at the faucets is too hot to use. In this case it is necessary to readjust the thermostat so the heat will cut off with the water in the tank at a lower temperature than was formerly needed to balance the heat losses in the uninsulated pipes. The arrangement of the thermostat adjustment is different with different makes of heaters, but in all cases adjusting it is quite as simple an operation as turning the temperature control knob of a mechanical refrigerator.

Thermostatic Control for Manual Gas Heaters

With manual gas side-arm heaters it often happens that the dramatic improvement following a good insulation job so impresses the owner with the former inefficiency of the outfit that he is set to thinking that the heater itself is probably a pretty obsolete and wasteful affair, with the result that he goes out and buys a new fully-automatic heater—and possibly a new storage tank too. That is too bad. There is no startling difference in thermal efficiency between the old type side-arm heaters and the new automatic models, except that which is gained from the regular and precisely adjustable operation of the thermostatic element; and this can be added to any heater for only a few dollars. Every plumbing supply house stocks a unit consisting of a thermostat which is attached to the side of the tank, and a special gas cock which it controls and which is cut into the gas feed line. Any home mechanic can install one of these units by following the simple directions which the maker encloses with them. It must be observed, however, that anyone who installs one on an uninsulated system is in for an unpleasantly large gas bill.

Tempering Tanks

So much for the general problem of inadequate hot water and the cures or degrees of improvement possible with the various types of heaters. Now as to the other aspect of the same problem, which is the matter of the fuel cost for heating the water being too high. Of course insulating the system will cut the fuel cost substantially in every instance, whether gas, electricity, or a summer boiler indirect heater is used; and the conversion of a gas unit from manual to automatic control will help it still more; but there is one other improvement that can be made with very little trouble or cost and with very startling results. (It begins to sound as though we might have to arrange to let a little heat *out* of the system pretty soon, but this device is so simple and effective that it seems a pity it is so little known to home mechanics.)

It is no more than a *second* (tempering) tank interposed between the cold water house pipe and the cold water inlet of the heater tank so that the cold water, instead of flowing directly from the house pipe into the storage tank, first flows into the bottom of the tempering tank and then from the top of the tempering tank into the regular storage tank. No particular type or shape of tempering tank is required. Just any tank which is sound and clean and pressure tight will do, so long as its capacity is about as great or greater than the storage tank's.

How the Tempering Tank Works

As a matter of fact a duplicate of the regular tank is about as good for the purpose as one is likely to find, provided the two side openings are closed with plugs. The location of the tempering tank is the most important factor in its operation. This is the way it works. When water enters the house, it is colder than the air within the house. Consequently, standing in the uninsulated tempering tank in the house, it will be warmed by the air. If it stands long enough it will reach the same temperature as the air. And the warmer it is when it enters the heater the less heat will be required to convert it from warm to hot water. That is all there is to the tempering tank.

In summer time the economy is greatest both because the air temperature is higher and because the air's heat is free, being furnished by the sun. In winter time when the heat within the house is generated by the furnace fire, the tempering tank is strictly speaking no more than a very indirect indirect heater, taking heat from the furnace fire through the air as an intermediate medium; but so long as the fuel used in the furnace is cheaper than the fuel used in the water heater the tempering tank will save money.

Quite naturally the hotter the location found for the tempering tank the better. A hot kitchen, for instance, would be better than a cool cellar; and the almost scorching temperatures of 110 and above so frequently found in uninsulated attics in summer time would be practically perfect except for the long runs of pipe required and the necessity of cutting the tank out and draining it in the winter when the attic would not be warm.

It is interesting, and indicative of the efficacy of the tempering tanks, to note that they were first introduced in domestic plumbing practice on any broad scale by the electric companies in connection with the modern automatic electric water heaters. They are by no means a regular part of such equipment, but in those instances where a consumer miscalculates the cost of heating his water electrically so seriously as to threaten to abandon the heater and revert to a cheaper fuel, it is the almost invariable practice of the company to suggest adding the tempering tank.

Solar Heaters

In the Southern states the idea of fuelless water heating has taken tremendous hold. There a tempering tank is located so as to receive the maximum amount of direct sunlight throughout the entire day, and a small electric heating element (aptly enough called a booster) is used in the storage tank, frugally controlled with a thermostat.

An ordinary cast iron radiator is often used as the solar heat absorption element, instead of a tank, because it presents more surface to the sun in ratio to its capacity. This absorber is connected to the storage tank just as was the ordinary tempering tank. The storage tank is well insulated, and the pipe from the heat absorber can be equipped with a check valve to permit the flow of water so long as the absorber is into the storage tank receiving heat, but preventing reverse flow when the sun goes down and the absorber begins to radiate heat. The cold water inlet pipe enters the solar tank in the usual manner at *A*, and the warmed water leaves the tank through the hot water outlet *D* which is connected with the cold water inlet of the storage tank which contains the booster heater and thermostat. The location of the booster in the second tank is necessary to prevent wasting electricity by heating all the water in the solar heater during the night hours when the solar heater absorbs no heat from the sun.

As anyone who has observed the temperatures common in garden coldframes, or even in well exposed glassed-in sun porches, will realize, the advantages of solar heaters are by no means restricted to Southern latitudes or summer months.

Discolored Hot Water

Almost everyone has had the experience, at one time or another, of opening a hot water faucet and seeing the water come forth not clear and clean but rust colored. Sometimes, but only rarely, the coloring matter *is* rust. More usually it is mineral matter carried by the water from its source and present in the cold water as well as the hot, but colorless and invisible until it is precipitated out by the heating of the water. The cure for this difficulty accordingly lies not in changing the piping or tank of the heating system, which is so frequently done on the assumption that they have become rusty, but either in preventing the precipitation of the mineral or in removing it.

The only way to prevent the precipitation of excessive mineral matter is to avoid heating the water too hot when the presence of such discoloring matter has been noticed.

There are two methods of removing excessive mineral matter. One is by periodically and methodically draining off a few gallons of water from the very bottom of the storage tank. It is for this purpose that the bottom hole is tapped into the tank and equipped with the faucet shown in the sketches. Notice that the tempering tank as well as the storage tank is to be equipped with a faucet for this purpose. The tempering tank (or the solar heating tank) thus acts as a settling tank, and its usefulness for this purpose alone often justifies its cost.

Chemical Treatment of Hot Water

In areas where the first method is not effective, the only cure is the chemical treatment of the water. In the last few years domestic treating devices of remarkable efficiency and modest cost have become available. They are so highly regarded by water engineers that in some cities they are made available to householders at a small annual rental charge which includes servicing them and maintaining the chemicals in them. To keep the operating cost to a minimum they are so connected as to treat only the water which is to be heated, since no particular advantage is gained by treating the cold water.

CHAPTER VI

The Plumbing Fixtures

In Chapter III we followed the water from the point where it entered the house to the ends of the various branches where it would be used, and then in Chapter IV we traced the soil lines from these points to the sewer connection. Here we shall examine the sinks, washstands, and other plumbing fixtures required for using the water, and the faucets and other valving devices which control the flow of water from the pipes at the fixtures.

Design and Construction of Faucets and Valves

The valving devices are known by a number of names, and to suit their particular purposes are made in a variety of styles; but whether they are called faucets, spigots, hydrants, taps, bibbs, cocks, valves, or gates, and whether they have one inlet and one outlet as most of them do or two inlets and one outlet as the kitchen mixing faucet does, and whether their outlets are smooth or threaded to take a garden hose, and regardless of the type of handle they may have, their internal construction must follow one of only four simple plans, and the repair of any of them will require only about as much skill as is needed to screw a nut and bolt together.

In the design of mechanical appliances simplicity and directness are always very great virtues, and these four systems certainly have both these qualities. But, more interestingly perhaps, they just about exhaust the practical possibilities for doing their job. One might devise additional types and arrangements of spouts and handles and change the external decorative details of faucets almost endlessly, but it is difficult to think of any other ways in which the actual work of valving the fluid might be done more neatly.

We shall consider these four basic arrangements and the ways in which they are applied.

The Globe Valve

In Figure 59 at the left is shown a globe-screwed valve, which you will recognize as being not a terminal fitting for drawing water from the system, but the valve used in

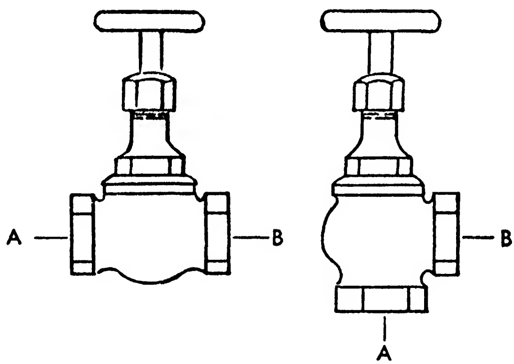


Figure 59—The Globe Valve: Straight Valve at Left, Angle Valve at Right

the main and branch lines of the water pipes to control flow through the pipes. It is called a *globe* valve simply because of its globular outline, and a *screwed* valve because its inlet and outlet (*A* and *B*) are threaded to screw to the pipes.

The word valve is an unavoidably confusing one. Generally a flow control device is called a valve when it is not used as a terminal fitting, but there are exceptions. At *B* in the sketch at the right is shown the same valve as an angle rather than a straight valve, the internal parts of which you can imagine as being identical with those of the straight globe valve. It will not be necessary to show these working parts, since they are the same as in the compression faucet shown in the next sketch. In fact most domestic plumbing valves are of this compression type.

The Compression Faucet

In Figure 60 we have two views of a garden hose faucet, at the left as it actually appears, and at the right cut away to show the working parts. The bonnet is marked *A*, the compression washer *B*, the valve seat *C*, and the stem *D*.

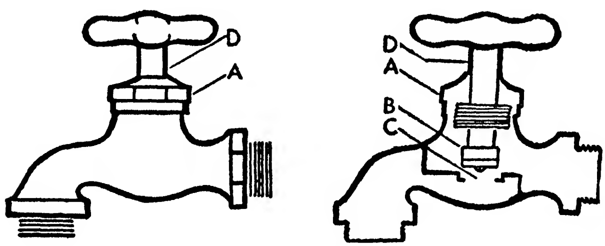


Figure 60—The Compression Faucet

As can be seen, the stem, being threaded, rises or sinks as the handle is turned, lifting the *washer* away from the *valve seat* and permitting the water to pass, or pressing the washer against the valve seat and stopping the flow. When a compression valve leaks it is because the washer is worn or swollen, or because the seat has become scored by gritty matter in the fluid. The cure for a bad washer is simply to insert a new one. Washers are very cheap and are sold in packages of assorted sizes by hardware stores.

To do the job, shut off the water to the branch and remove the bonnet with a parallel jaw wrench, turning it to the left and being careful not to mar the bonnet. When the bonnet is free, turn the faucet handle to the left and the stem will unscrew out of the faucet body. At its lower end will be found the washer, secured by a screw. Remove the screw and washer, insert a new washer of the proper size, replace the stem assembly, and tighten the bonnet down.

If the leak persists it will be because the valve seat is damaged. To repair it will require a special but inexpensive tool called a valve reseater. Directions for its use with various sizes of faucets will accompany it; and it will be found quite simple to manipulate. It resembles the faucet stem assembly somewhat, except that its lower end instead of having a resilient washer is equipped with a hardened paring cutter. Inserted in the faucet and turned, the cutter will resurface the damaged valve seat, restoring its original smoothness.

Now if you study the sketch a moment you will see that in addition to water leaking past the valve seat when the valve is closed, it can also rise along the stem when the valve is *open* and dribble out where the stem passes through the bonnet. To cure this, ignore the washer and seat, and instead examine the underside of the bonnet. There you will find a second washer, much softer and spongier than the other, called the top packing or packing ring. As the bonnet is drawn down snug, this packing is supposed to be compressed so it packs around the stem sealing the joint between the stem and bonnet. To repair a leak here, remove not the bonnet and stem but the handle and then the bonnet, and insert a new packing ring, laying it in place in the bonnet. Replace the bonnet, draw it home not too tightly with the wrench, and replace the handle.

That is all there is to repairing any of the compression type devices. If comparing the sketches with a particular valve does not establish whether it is of the compression type, you can find out in about one minute with a wrench, and complete the repair in about two minutes more. The great majority of faucets in use today *are* of this type, including one known as a self-closing faucet, which is sometimes used to economize on hot water (at the considerable inconvenience of its having to be held open). In this faucet the stem has a very steep pitched thread, and a spring which forces it downward when the handle is released.

The Fuller Faucet

Figure 61 is a cutaway view of a Fuller faucet, now practically obsolete. The sketch suggests its operation, by

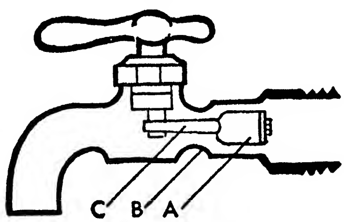


Figure 61—The Fuller Faucet

the conical rubber ball (called the Fuller ball) marked *A* being drawn up against the valve seat *B* as the horizontal connecting rod *C* is moved in and out by the turning of the handle and stem. To replace a Fuller ball requires that the entire faucet be disconnected from the pipe to reach the ball. When one of these faucets persists in leaking or chattering after a new ball has been inserted it is because the rod and stem joint has become worn, in which case the faucet had best be discarded. A faucet can always be identified as a Fuller without being dismantled if the water bursts forth full force and then chokes off suddenly (and possibly with a hammering of the pipe) with a total handle movement of less than a half revolution.

The Ground Key Faucet and Cock

Figure 62 shows two examples of perhaps the simplest fluid valving device ever devised. It is actually a metal version of the familiar wooden spigot cock used to draw sorghum or wine from a cask. It has but two working parts, the spigot (plug or key), and the cock (or seat) marked *A* and

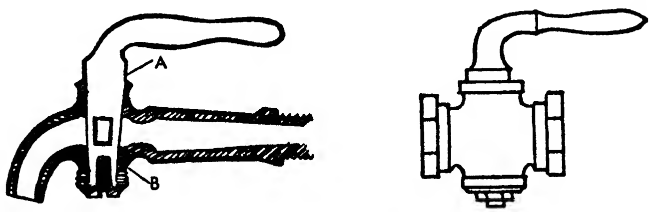


Figure 62—Ground Key Cock Faucet at Left; Gas Cock Using the Same Valving Mechanism at Right

B in the left hand drawing, which shows it cut away and illustrates its operation in a *ground key* lever handled tap. You will notice that the key and cock taper from top to bottom, and that the key is restrained against rising out of the cock by the screw on its lower end. The key and cock are tapered so that in manufacture they can be accurately ground to snug fit. When a cock leaks, whether at the outlet, the stem, or the bottom, it is generally because wear has reduced the key and enlarged the cock, and this is cured by tightening the screw a bit. If this does not remedy the leak it means that the working surfaces have become scored, and need regrinding. This is done by removing the key, smearing it with automobile valve grinding compound, replacing it, and patiently revolving the handle back and forth for several minutes. The grinding compound should then be removed and the key fastened into place with the bottom screw.

It is unlikely that many ground key valves are still in service as water faucets, but you may find the stop cock (shown at the right in Figure 62) used as a shutoff in the water line; and you will find the cock type of valve used exclusively in the gas pipes and gas appliances. Notice about the cocks that they are "faster" than even the Fuller ball faucets, since they change from full-open to full-closed in less than a quarter revolution of the handle. This suggests why they are not too satisfactory for high pressure water service, although they are perfectly practical for gas, where they are universally used both as shutoffs in the pipe line and as "faucets" at the burners. There the all metal construction is an advantage, and the rapid closing action cannot induce hammering in the gas pipes as it might with water. A cock faucet can always be distinguished from a Fuller ball faucet by its having a plug-tightening screw on its bottom, and a stop cock from a globe valve by the fact that its handle can be revolved any number of turns in either direction.

The Gate Valve

In Figure 63 the sketch on the left illustrates the fourth of the manual fluid valving techniques, which differs in one important respect from those so far discussed. This device is called a *gate valve.* It is not often used in domestic pipe fitting, the globe valve being more common for the water system, and a variation of the globe valve known as an angle valve (which is simply the same mechanism with its inlet and outlet at right angles to each other) being used in the steam and hot water house heating systems, as will be discussed in Chapter XII. However, should you encounter a gate valve this illustration will have explained its construction to you. Notice that its movable element is a tapered metal disc marked *A,* set crosswise of the valve. When the handle is turned this disc withdraws from the body of the valve, rising up into the bonnet in a manner which must have been somewhat suggestive of a gate to the person who named it.

Its chief peculiarity and an important advantage is that unlike any of the other manually operated valves so far

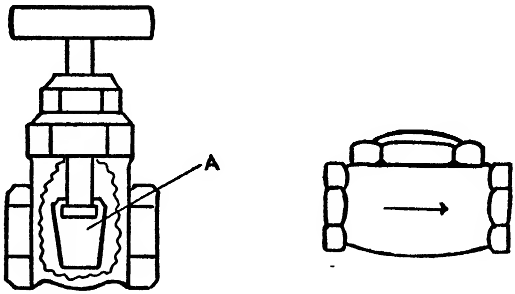


FIGURE 63—At Left, Skeleton View of the Gate Valve; at Right, the Check Valve

illustrated it offers when open a practically straight, unimpeded and unconstricted channel for the fluid to flow through. This can be an important consideration when it is desired to obtain the maximum possible rate of flow with a given sized pipe and pressure, since—as has been pointed out—every constriction or change in direction in a pipe will decrease the rate of flow of the fluid.

THE CHECK VALVE

To the right in Figure 63 is shown a valve not provided with any means of operating it by hand. Its valving element consists of a disc or flap, hinged at the top, operated not manually, but by being swung aside by the flow of fluid, like a gate. But it is not called a gate valve but a *check valve*, and its function is to check the movement of the fluid in the direction opposite its normal flow through the system. You will recall its having been used in the solar heater piping in Chapter V.

Valving Mechanisms in General

These are the commoner types of valving mechanisms for manually controlling the flow of fluids in pipes. You will encounter variations of them again and again in the various mechanical equipment about your home; in the water system, the sewage system, the steam or hot water heating plant, the gas system and gas appliances, in the water pumping system if you are served by a well, and in your automobile. In view of the simplicity of these valves, they should give you no trouble. When a valve is out of order a little patient investigation with a wrench, and a little study of the working parts, are all that will be required to enable you to repair it, replace any defective parts, or discard the entire valve and install a new one. These sketches are deliberately intended not to illustrate any particular manufacturer's pattern, but rather to exhibit the significant mechanical aspects of the various types, so you will not expect your own equipment to be identical in appearance with any of that shown here, but you will certainly find that it operates on one of the principles illustrated, no matter what its particular external design may be.

How the Sanitary Flush Toilet Operates

The advantages of understanding the basic mechanical principles on which a mechanism operates, and the facility this gives one in working on any make of equipment which may be encountered, are well illustrated by a domestic plumbing fixture which has the reputation of being one of the most troublesome ever devised, and yet is perfectly simple. This fixture is the *sanitary flush toilet,* and the troublesome part is the combination of the two simple valving devices by which the flushing is accomplished.

The flush toilet operates by first storing five gallons or so of water in a tank fastened against the wall, without any manual attention, and then releasing this water when the flushing mechanism is tripped, following which the storage tank again automatically fills, ready to be flushed again. Now in the years during which the storage tank flush toilet has been manufactured more than 100 different detailed arrangements of the two valve systems have been devised, manufactured, and marketed; and there are probably nearly half this number of makes now in use. But the problems presented by all of them will be clear if the principles involved are explained, the common troubles recited, and their cures described.

Before discussing the flush box mechanism (the wall storage tank is known as the flush box because in its original and now obsolete form it was actually a wooden box, lined with copper, hung high upon the wall and connected to the toilet with a long vertical pipe), the *toilet bowl* itself can be disposed of very quickly.

The Toilet Bowl

Figure 64 shows a flush box toilet cut away to indicate its internal construction and the path of the water through it and into the soil line. All toilet bowls have the following elements: first a *trap*, shown in the sketch with shading to represent the water which stands in it between uses; second an *outlet* connecting with the soil line shown at *A*, and third an *inlet* connection for the water supply pipe, shown at *B*.

How to Relieve Trouble Due to Freezing

Being exposed to a freezing temperature with water in the trap will break the entire bowl, requiring its replacement. Time will harden both the gasket which forms part of the coupling union at *B* and the ring of mastic putty which seals the outlet joint at *A*, causing dribbling leaks at these points. To repair them, back the coupling at *B* off with a wrench, remove the bolts which fasten the bowl to the floor, lift the bowl aside, clean away the hardened putty, replace it and the gasket at *B*, and fasten the bowl

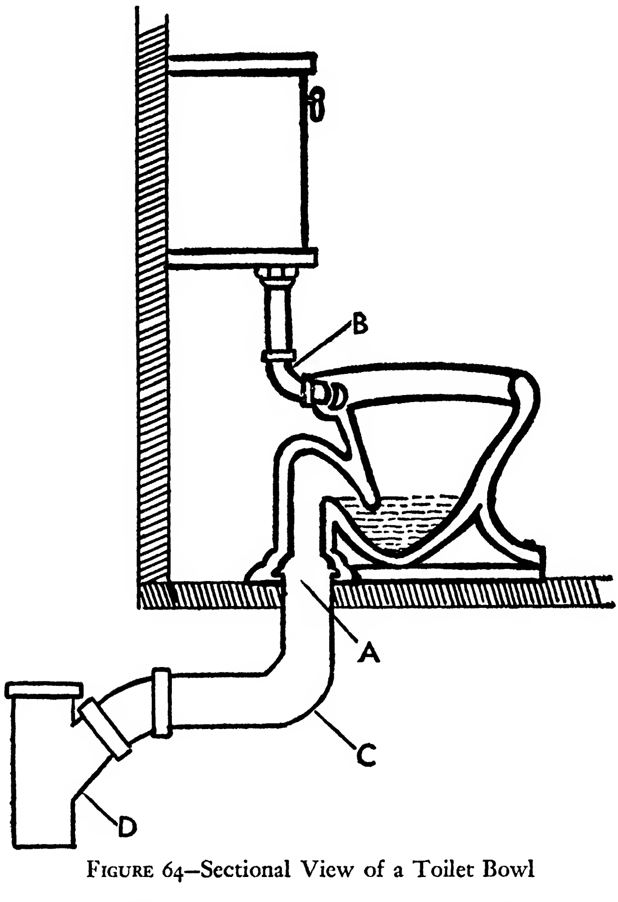


FIGURE 64—Sectional View of a Toilet Bowl

back in place. Begin this job by closing the shutoff valve in the toilet branch water line and then flushing the toilet to empty the flush box, so as to avoid the possibility of accidentally tripping the flush lever while the bowl is disconnected and discharging the water on the floor. Then clear the bowl trap of most of its water with a ***rubber plunger*** to prevent its spilling on the floor as the bowl is moved.

How to Relieve Trouble Due to Clogging

The trap of the fixture itself, the elbow in the soil line shown at *C* in the sketch, the *Y* shown at *D*, or the soil stack at a point below *D* may become clogged if anything of a non-disintegrating nature too large to pass through the system freely is flushed through the toilet. Nine times out of ten it can be dislodged by means of the plumber's snake which is simply a long flexible steel ribbon. A plunger may be effective when the obstruction lies between *D* and the bowl trap, but if it is below this point plunging will be of no help since it will simply force the impounded water up the soil stack, and gravity will bring it down again into the bowl.

With patience a snake can be fed into the soil line a remarkable distance through the fixture trap without the necessity of removing the fixture, and no fear of damaging the sewer line need be felt in using the snake. Plumbers sometimes run snakes the entire length of a house soil line (and electricians do even better in their own field, using the same device, which they call a fish, passing it through small pipes called conduits, to lead the electric wires through the conduits after they are in place in the walls and the walls plastered).

How to Relieve Troublesome Noise

Another complaint about toilets is that they are sometimes offensively noisy when flushed. This is a defect in design and can only be remedied by replacement with a fixture guaranteed by the seller to operate quietly in conjunction with your flush box and soil line. In other words the different designs in which the bowls are made affect the relative silence of their operation as well as their price.

Toilet bowls are not made of iron as almost every other plumbing fixture is, but of glazed pottery. This means that they are more fragile, but the smooth porcelain glaze will be much more resistant to damage by acids or other strong solutions. For this reason toilet bowls can be safely cleaned with the lye base preparations offered for unstopping sluggish drains.

The Flush Box

The real annoyances with flush toilets occur in the *flush box*. One of these is noise in operation. Just as the bowl may emit considerable sound in being flushed, so the flush box in discharging the flushing water into the bowl may give rise to its own noise. The various toilet noise possibilities are: the soil line may rumble or gurgle; the bowl may do the same, whether the soil line is silent or noisy; and the flush box may be offensively audible, possibly alone, or in concert with one or both of the other elements. And added to the din may be still another noise in the flush box, caused not by the flushing water leaving the box but by the water from the pipe line entering the box to replace that discharged. Assuming that the flush box is otherwise operating satisfactorily, its noises, like those in the bowl and soil line, are a matter of poor design, only to be corrected by replacement of its working elements.

Let us examine the interior of the flush box, to see whether its construction and operation justify its reputation of being the most unfixable piece of plumbing equipment in the house. As already explained, it operates by admitting water from the house line through a valve requiring no manual attention, and stores this water until it is released by one's tripping a second valve, called the flush valve, which releases the impounded water into the bowl.

How to Repair the Flushing Valve and Ball

As you will see very clearly if you remove the top of the box and peer into it while tripping the handle, it consists essentially simply of a hole in the bottom of the box which is closed with a rubber ball much as a Fuller ball faucet is. And just as with the faucet, when you move the handle the ball is drawn away from the hole (or valve seat) permitting the water to flow. But when you release the box handle, the ball drops down again into the valve seat automatically; whereas with the faucet, it must be closed, as well as opened, by hand.

So in addition to the common faucet difficulty of the ball failing to fit the seat snugly and thus leaking when closed, trouble may arise out of the failure of the ball to return to the closed position smoothly when the trip handle is released. Also the valve may close too soon, retaining most of the impounded water, or may fail entirely to close, with the result that not a drip or dribble but a steady flow of water continues to flush.

The usual presumption is that either of these troubles is caused by the rod which connects the ball to the trip handle lever being bent or turned out of position, but as a matter of fact this is almost never the case. Rather the ball has deteriorated with use and become elongated, or its bottom has collapsed so that it no longer fits the valve seat snugly, or it has been perforated and partially filled with water, losing its buoyancy. The indication is that a new ball should be obtained; and its method of installation cannot fail to be perfectly obvious upon examination of the mechanism.

Should the cramped quarters afforded by the box prevent a clear view of the valve it can very easily be removed; and if you remove it and find on examination that the valve seat is corroded, or the guide which positions the ball rod is worn, the entire mechanism can be replaced with a new one for less than a dollar. No illustration of this device could allow for the many minor differences in construction between various makes, but examining the actual valve in your own box will make its operation perfectly obvious to you. As a matter of fact, one type of valve still in use does not use a rubber ball but a metal tube which drops over the drain hole, but this is obviously the mechanical equivalent of the ball.

How to Repair the Filling Valve

Now as to the other valve in the box, which admits water from the cold water pipe. It is just a *compression faucet*, and like any other faucet, occasionally needs a new washer, or perhaps a valve seat re-dressing, to prevent it leaking when closed. But its method of closing and opening is unique, and is accomplished by its having a long rod instead of an ordinary handle, to the end of which rod is attached a metal ball about the size of a small grapefruit. The ball is hollow and will thus float in water. And it does float in the water which the box contains. Flush the tank and watch this ball. As the water level in the box falls the ball will fall with it, and as it falls the rod to which it is attached will of course incline downward, and in doing so will open the faucet. Water leaving the faucet will fill the box (if the flush valve has closed properly) and as the water level rises, the ball rising with it will then close the faucet.

Depending on the inclination of the ball rod the valve may either close before the box is filled, or remain a bit open after the box is filled. In the former case, not enough water may be stored to flush the bowl properly, and in the latter case water will run continuously. But it will not overflow onto the floor. It will discharge into the bowl, because a necessary part of every flush valve mechanism is an overflow pipe. No matter how it is arranged, you can check its location and operation by holding the float ball below the surface of the water after the tank is filled (thus holding the faucet open), and noticing that the box fills no further, the excess water draining through the overflow into the bowl. So it happens that the flush valve may be operating and seating perfectly and the water still be running continuously, because the faucet is either failing to close, or leaking when closed.

The first impulse when the inlet faucet leaks is generally to bend the float rod, but this will be no cure for a worn washer. Rather observe first whether or not the float ball is really floating. If it has lost its buoyancy through having a leak and being filled with water, remove it, drain the water, solder the hole, or install a new ball. Removing the entire faucet assembly from the box is just as easy a job as removing the flush valve, and with the device out on a table where you can examine and manipulate it, it can very quickly be determined whether it can be repaired or must be replaced. It costs (complete) less than two dollars, and should be replaced if the valve mechanism cannot be made to close snugly.

Construction of Flush Box Toilets

These two simple repair jobs will keep any flush box type of toilet in order and functioning satisfactorily, and the matter might be left there. But the fact is that the whole flush box with its inlet valve and float and its flush valve and trip handle, and its four or five gallons of water hanging there on the wall, and its noises and leaks, is a woefully obsolete mechanism judged by any modern plumbing standards, notwithstanding that it still remains practically the standard equipment for domestic use and is still being manufactured and installed in new houses. Perhaps you have wondered why the box is needed at all, and why the water could not be sent direct from the cold water pipe into the bowl, with only one simple valving mechanism. To accomplish a flushing action, a large quantity of water must be introduced into the bowl in a short period of time, that is, in about ten seconds. The branch pipe serving the toilet, being very small in diameter (for economy in plumbing cost) could deliver no such volume so quickly. So the storage box with its large drain pipe to the bowl was introduced to do the job; and except for its having been brought down from near the ceiling and hung just above the bowl, it has undergone no real change in its entire lifetime; nor could it be changed mechanically and still do its job.

Years ago, when domestic running water was a new addition to civilized living, a pipe which would deliver water even in a small stream to the upstairs rooms of a house was a wonderful thing, and any device capable of extending its usefulness to the job of flushing a toilet was considered a positive triumph of applied science. But today pipe is not so expensive that we must be content with a size too small to deliver an adequate flow, so that it must be stored in a box a few gallons at a time, and released when we need it to flush the toilet. Pipe has become so cheap that we use much larger sizes than formerly and much greater quantities of it; to conduct heat from the furnace to steam or hot water radiators in every room in the house, for instance, and, of course, for gas, and even as a piping system for electric wires. Yet the use of small plumbing pipes still persists, necessitating the flush box because these pipes cannot deliver a flow of water that will flush a toilet.

A Modern Tankless Toilet

Figure 65 given here shows a modern toilet bowl and a simpler and cheaper means of flushing it than with a box.

Anyone who has been in modern office buildings in the last ten years has seen both these fixtures. The bowl is modern because it hangs from the wall, leaving the floor area beneath and around it perfectly accessible for cleaning. And

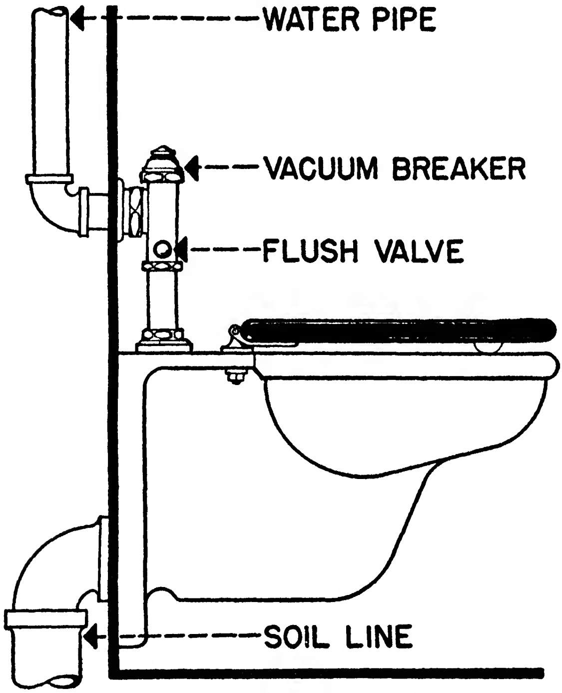


FIGURE 65—A Modern Tankless Toilet

its flushing water comes directly from the water pipe through the special flush valve shown above it, which protrudes only a few inches into the room. It is only required that the water pipe be of adequate size to use this type of valve. The small branch pipe serving a flush box will not do, but replumbing the house with a new pipe added to the old as suggested in Chapter II offers the opportunity to replace a flush box with such a valve. It will use only about two fifths as much water as a flush box, and this is probably its strongest recommendation. It can of course be used with the older type of floor standing pedestal bowl shown in Figure 64 as well as with the modern hanging bowl shown here, and its installation is as simple as that of any other valve or faucet. The hanging bowl, however, calls for a different—though no more difficult or expensive—arrangement of the soil line (as is shown in the sketch), and its use in the home is for this reason not indicated for the replacement of an existent bowl, but should certainly be considered, along with the flush valve, if the plumbing system is to be altered by the addition of another toilet, or toilet and wash room, because of the economy of floor space as well as of water and cleaning labor it effects.

A Flush Valve Requiring No Tank

As with flush box valves, there are a good many different makes of flush valves, and there will undoubtedly be still more as they gain in popularity; but for all their minor differences they operate on the same principle, and by one of two methods. The principle is one with which every boy is familiar because its nature is so neatly and completely illustrated by that toy known as a pea shooter. It is simply this, that a movable obstruction in the bore of a cylinder will remain motionless so long as the fluid pressure is the same throughout the cylinder; and will move in response to a change in the pressure at either end of the cylinder. The pea, in other words, will remain poised let us say midway through the shooter (provided it is just a snug enough fit) so long as it is subjected only to the equal atmospheric pressure from both ends of the shooter. But by blowing into the breech, thus increasing the pressure only at that side, the pea can be made to travel toward the muzzle. And of course, as any practiced pea shooter who has passed the elementary stage of merely continuing to blow until the pea leaves the muzzle can testify, the pea can be stopped in its tracks by the operator's ceasing to blow, and then made to reverse its direction and travel toward the breech by his sucking the air out of that end of the tube so that the atmospheric pressure on the other side of the pea becomes the greater. Then as a third and final variation, the muzzle chamber can be closed by a finger acting as a stop cock and the breech chamber pressure increased by blowing, whereupon the pea will move forward only until the pressure in the two chambers is equal, stopping until the finger is removed when it will resume its motion in the direction of the lower pressure, leaving the shooter preceded by the muzzle air and followed by the breech air.

Now substitute: a captive rubber diaphragm or a metal piston (methods one and two mentioned above), for the pea; a somewhat more refined valving device, for the finger; and the water pressure, for the youngster's lung power; and you have the working elements of the flush valve. At rest the piston is pressed upon equally from both above and below by the water which fills both the upper and the lower chambers. Then when the trip handle is moved, all it does directly is to open a small vent valve from the upper chamber into the outlet pipe leading to the closet bowl. The water pressure in the chamber being greater than the atmospheric pressure in the toilet, the water leaves the chamber through the vent. Now the lower chamber (water) pressure is left higher than the upper chamber (atmospheric) pressure, and of course the piston rises. As it rises it opens a large valve permitting the flushing water to flow from the pipe line into the toilet.

Now notice that up to this midpoint in its cycle of operation, the mechanism has done no more but just exactly as much as might have been done with an ordinary manual valve a good deal more simply and directly. That is, it has opened and permitted the water to flow in response to its *handle having been moved—and had houses been plumbed from the very beginning with pipe of a size adequate to* effect a flushing action without a flush box, it is entirely possible that today the standard toilet fitting might well be no more than an ordinary manual valve such as we use at other fixtures. But the flush box preceded the valve by many years, and it accustomed users to two very convenient features of its operation, which flowed quite unavoidably from its very design. These were: first that it always delivered a predetermined measure of water at each use, or metered it, as it were; and second that when it had done so it stopped flowing (and automatically recharged itself for its next use). Consequently when the boxless flush valve was launched, it was felt necessary to imitate these two characteristics to secure its acceptance as an improvement over the box. This accounts for its peculiar construction, and for its being called a metering valve.

Adjusting and Repairing the Flush Valve

The automatic but delayed closing of the valve comes about by the upper chamber beginning to refill with more water from the pipe line as soon as the trip valve is released and permitted to close, thus forcing the piston back down and closing off the flushing port. The speed of the descent of the piston is susceptible of the nicest adjustment by the variation of the size of the passage from the water line to the upper chamber, and it is by making this intake channel, which is called the bypass, very small in relation to the size of the lower chamber intake that the valve is made to close slowly and smoothly after just enough water has passed to effect the flush. In operation the flushing cycle can be further adjusted to fit the particular pressure conditions and the water requirements of the bowl by means of a small adjusting screw.

The difficulties encountered with the flush valve are only those which experience with the ordinary faucet valve mechanism would lead one to expect. It may refuse to close due to the bypass channels to the upper chamber being clogged with grit, the auxiliary (trip) valve failing to close for the same reason, or through either the flushing or auxiliary valve seats or washers needing replacement. Whatever its make, every metering flush valve is arranged so its working parts are removed through the top, and their actual repair will be found as simple and their proper reassembly as obvious as that of any faucet. The chief difficulty is likely to be the unavailability of needed parts; but the maker's name and catalogue or type number are stamped on the outside of the valve, and he can always furnish a parts list and the name of a dealer or distributor.

Preventing Back Siphonage

There are two other fittings which should always be used with a flush valve, but unfortunately many installations were made—up to as late as ten years ago—omitting one or both of these. The first is a shutoff valve without which it would be impossible to work on the flush valve; and there was never any excuse for omitting this. The need for the other fitting, however, was only brought forcefully to the attention of authorities in 1932 as a result of the breakdown of the Chicago water system under the demands of the World's Fair there. This fitting is a check valving device of some sort which will positively prevent the reverse flow of water from the soil line back into the water line. Such a reverse flow is known as back siphonage, and any plumbing arrangement which permits it to occur is called a cross connection.

This might come about with the flush valve. Assume the water pressure in the line to fail for any reason, for instance by the line being shut off and drained in the basement. Then the water in the line must by gravity drain backward through the branch serving the toilet, and in doing so empty the upper valve chamber, raising the piston and opening the lower chamber outlet to the toilet bowl, admitting air from this source to the water line. Now assume the bowl to be filled not to its usual level but (by its drain being clogged) to its very brim. The retreating water in the pipe line then would through simple siphon action lift water from the toilet bowl into the house water line.

It was to prevent just this that building codes were amended to forbid even the remotest possibility of a cross connection at a toilet or any other fixture. With washbowls, sinks or bathtubs the cure was effected by merely forbidding the installation of any faucet with its spout extended downward below the rim of the fixture, but with the flush valve toilet the only possibility was the installation of a positive check valve in the water line. Two types were at first used which satisfied the legal requirements, but only to create another problem. These were the simple check valve shown in Figure 63 on page 135, inserted in the line near the flush valve, and a special angle valve called an angle check. This valve incorporates both the usual manual closing and opening operation of an ordinary compression valve with the reverse flow checking action of the check valve. With the valve wheel in the open position, flow can take place in only one direction and will be stopped in the reverse direction by the water itself as with any check valve. And of course with the wheel screwed down at the closed position, flow is stopped as with any manual valve.

These check mechanisms are very unlikely to require repairing; but they have been explained in detail because with either of them in the line it is obviously impossible to drain the water from the line. This is so because they provide no means of breaking the vacuum formed between themselves and the drain valve in the basement; and, as a result, a freeze would burst this branch pipe even though the house service has been cut off and all other branches drained by opening the faucets.

The Vacuum-Breaking Check Valve

The recognition of this rather obvious shortcoming of a non-venting check valve in a freezing weather zone has led to the substitution of a type of valve called a *vacuum-breaking check valve*. At first this valve, which operates by opening a port for the admission of air from outside when the line pressure falls (thus both preventing siphonage and permitting the line to drain), was installed as a separate fitting; and then, to prevent its possible omission, flush valve makers incorporated it as part of the flush valve. In either case its construction will be such as to give no trouble at all or else to require replacement rather than repair if it fails.

A little reflection may suggest several places beside the toilet where the meter flush valve might be of considerable convenience—with its rapid action, generous flow, and automatic shut off. Such valves are being used increasingly with a low hung bowl with a large outlet called a slop sink, for emptying scrub water, washing out mops, etc.; and they are popular with photographers at darkroom sinks.

How to Relieve Trouble with Flush Valves

There is one trouble encountered with metered flush valves which is very baffling, and which no amount of working on the valve will cure. That is the habit of the valve suddenly flushing with no apparent cause. It often occurs in a house where more than one such valve is in use, the manual flushing of one valve setting the other off. The explanation is really quite simple:

The flush valve operates by a reduction of the pressure against the diaphragm or piston. This reduction is ordinarily effected by pushing the handle, but any other means of reducing the pressure in the pipes will have the same effect. The valve permits so much water to flow from the pipes so rapidly that when it is flushing there is an appreciable drop in the pressure in the house lines, if the pipes are not of adequate size. Thus, in a house with two valves, operating one manually will bleed the lines enough to set off the other. The same effect can sometimes be produced by opening two or more faucets suddenly and at the same time. The cure is to add enough capacity to the pipes somewhere in the house to overcome the situation. Generally replumbing one of the flush valves will do it.

The Mixing Faucet

The mixing faucet popular for kitchen sinks and laundry trays was mentioned some pages back. Like the flush box, these mixing faucets may give considerable trouble; but not through wearing out after rendering a decent period of trouble-free service, as do the flush box valves, but rather through being so constructed that they never could work well. Under actual working conditions they frequently fail to mix water to the desired temperature and hold the delivery at that temperature. There is no easy cure for this, and as far as the kitchen or laundry fixtures are concerned it is not too serious a matter; but for a shower bath, where exactly the same type of mixing faucet is often used, it presents a positive hazard. If you have such an arrangement serving a shower head, and it is difficult to adjust for temperature, when in use suddenly delivering either scalding hot or straight cold water each time water is drawn from another fixture in the house, the fact is that there is nothing you can do to repair the matter except to replumb the house with larger pipe. This is no secret among plumbers and engineers, who will freely admit that to call this device a "mixing" valve is an optimistic misnomer; but because of the quite substantial cost of a mixing valve which will really do the job, the practice of cross connecting a hot and a cold water valve to a common outlet to serve the shower head still persists.

The Thermostatic Shower Mixer

The type of shower mixing valve which does mix is called a *thermostatic mixer* or thermostatic tempering valve,

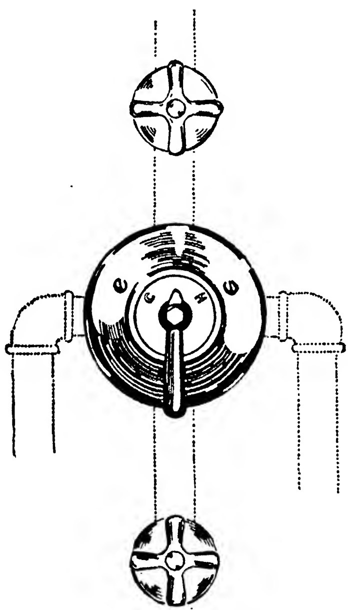


Figure 66—Thermostatic Water Mixing Valve for Shower Bath and Bathtub

and it can always be recognized through having a handle—just one handle—arranged to turn around a circular face plate marked "hot" and "cold" (Figure 66). The thermostatic valve is *not* a flow or shutoff valve. The water is turned on and off and the volume regulated with an ordinary valve either built into the mixer body but controlled by its own wheel or handle, or inserted in the single pipe line which delivers the tempered water from the mixer to the shower head. In tub showers a third control is often added, which is simply a second shutoff valve connected to a single spout and serving the tub instead of the usual faucets, drawing its tempered water through the same mixer as the shower does.

Cleaning and Repairing the Mixer

As with other devices, there are a good many different makes of thermostatic mixers available, each differing in some minor details from all the others, but all contain pretty much the same essential working parts; and every one of them is entirely accessible for parts repairs or replacement simply by the removal of the front cover plate. Within will be found the thermostatic element, which operates to throttle the two water feed lines in response to the temperatures of the water they are delivering. The thermostat may be either metal or a liquid sealed in a metal container. In either case it will swell or shrink as it is heated or cooled, and in doing so will move a lever to open or close the valve ports. It is about as trouble-proof as a thermometer, and also as impossible to repair; so it should not be tampered with. There are, however, two wire strainers, which can be removed, and should be occasionally, to be cleaned. Behind them may be seen two check valves which prevent a cross connection between the hot and cold lines, and that is the sum of the parts. Barring abuse, mixers are really very nearly trouble-proof, and there is little repairing to be done to them aside from cleaning the strainers.

The Shower Head

Cheap shower installations where thermostatic mixers are omitted often utilize a type of shower head borrowed from the old fashioned garden sprinkling can; and an innate defect of this device is that it will deliver a satisfactory spray only under a full head of water, changing to a series of disagreeable dribbles as the flow is reduced. No cure is possible, but such a head can be easily unscrewed and replaced with an improved head which will deliver a spray at any flow.

PART THREE

Gas

CHAPTER VII

The Gas Piping

The Gas Piping and Water Piping Systems Compared

The similarities between the gas piping system shown here in Figure 67 and the water piping system illustrated and discussed in Chapter III are more striking than their differences. Here again we have a simple metal piping system conveying a fluid under pressure (but this time a gas instead of a liquid) throughout the house to points where it will be used.

In the sketch the gas enters the system at *A* (which is a connection to a public gas main); runs underground through the house feed line to the main cutoff cock shown here underground outdoors at *B;* into the house where it enters the gas measuring meter at *D*, after passing through an indoors shutoff cock at *C*. The outdoors shutoff, where one is provided, is the concern only of the gas supply agency, while the one at *C*, although operated with a wrench instead of a more convenient handle, is for the use of the householder in case an emergency makes it necessary to shut off the gas supply. This cock, however, can be locked in the closed position with a padlock, to prevent gas being drawn when the house is unoccupied or when no contract is in effect for the purchase of gas by the householder.

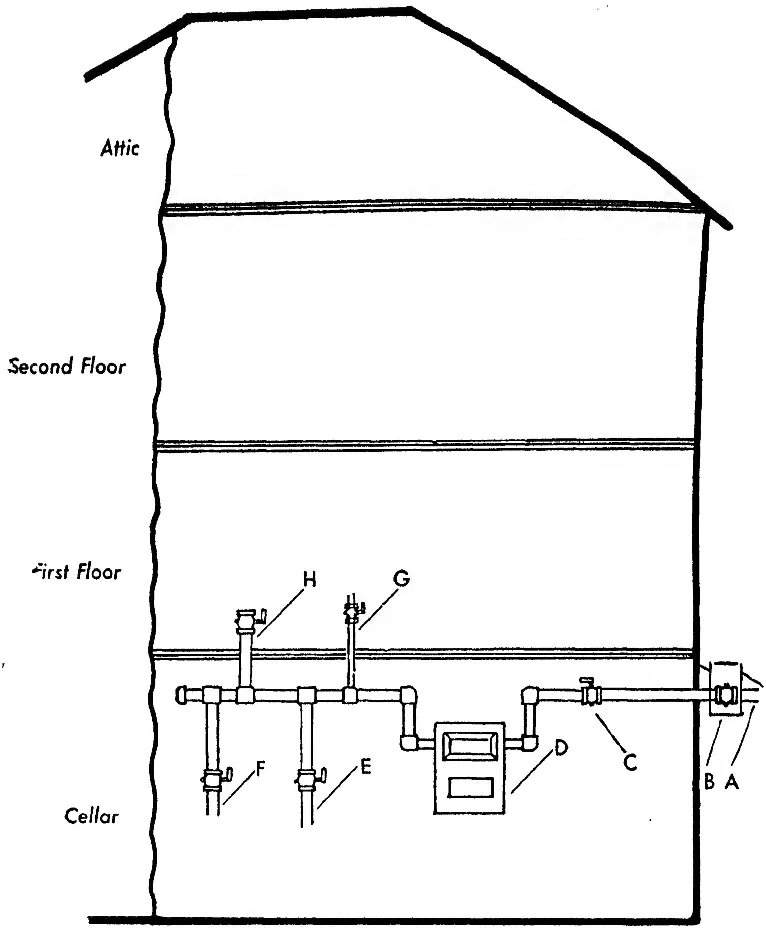


FIGURE 67—House Diagram Showing Arrangement of Gas Piping

THE GAS METER

Like water, gas is sold by volume, and the meter is equipped with a series of dials and pointers calibrated to read in cubic feet, thus resembling the water meter described in Chapter III. However, the internal workings of the two devices are quite different, the gas meter consisting basically of a pair of bellows which alternately fill with gas from the main and discharge the gas into the house line. But, like the water meter, the gas meter is a pretty trustworthy instrument. And as with the water meter, the testing of any suspected gas meter can be requested by the user, with a complete sense of assurance that any inaccuracy found in its operation will be corrected.

The size of the meter will vary with the amount of gas required for the appliances used, a meter serving a gas-fired furnace (for example) being an instrument of imposing size; but otherwise a larger meter is no different from an ordinary domestic sized meter installed where gas is used only for cooking. The size of the pipes used in the gas system will increase too as a greater rate of flow is required, and the gas agency will not serve a system which their engineers find to have inadequate piping capacity.

The type of meter most widely used is one on which the number of cubic feet of gas consumed is read from the meter at monthly intervals, and the customer billed for it on a charge account basis (possibly with a deposit required); but there is another type of meter, notorious for its inconvenience. It is called a quarter meter because gas can only be obtained by purchase units of twenty-five cents, payable in advance by dropping a quarter into the machine (as one would a nickel into a pay phone) each time the system signals the consumption of the last quarter's worth by the flame dying for want of gas. The operation of the quarter meter was based on a very pessimistic and narrow view of the possible usefulness of gas as well as of the average customer's credit worthiness, and luckily the popularity of gas equipment requiring an uninterrupted supply of fuel (such as a pilot light, a gas refrigerator, or an automatic gas water heater or furnace) has practically driven this device out of use. Gone too is the sales arrangement, once popular in districts served by cheap and abundant natural gas, where no meter was used, but the user billed merely on a basis of the number of fixtures connected to the system.

Gas Line Branches and Fittings

Beyond the meter then, the gas line will be found to branch out in the house to serve the various gas appliances, somewhat as suggested in the diagram, where at *E* there is a gas-fired house furnace, at *F* a small gas stove for the laundry work, at *G* a gas-fired mechanical refrigerator, and at *H* the kitchen gas range. Each branch line, as with the plumbing, will have its own shutoff cock in a well piped system, but the cocks will properly be located at the terminal ends of the branches, with the appliances connected just beyond them.

The same couplings, unions, pipes, and thread system as for waterpipes will be used, except that the absence of the problem of rusting will permit them to be ungalvanized; and the same tools and techniques of pipe fitting as explained in Chapter III for water lines will be used in repairing gas pipes, so they will not be dwelt on again here. One difference between the gas and water pipes is in the omission of drain cocks at low points in the gas line, since the gas will not freeze and burst the pipes, and hence they need not be closed, drained, nor insulated.

Blowing Out the Gas Lines to Remove Scale

About the only two troubles to which gas lines are subject are leaking and clogging. Like most every other fluid moved through a piping system, gas carries small bits of foreign matter, dust and scale, along with it; and after a matter of years this settling in the lines or fixtures may impede the flow of gas. Being non-adherent, however, it is easily removed. This is done by the gas company on request, and should not be undertaken by the home mechanic. Besides being done without charge, this job requires special equipment; so there is no point in doing it yourself. To do it, the line is disconnected from the meter and from the fixtures, and a blast of compressed air under considerable pressure forced backwards through each branch toward the meter. When the job is done the mechanic will test the entire system to be sure the high air pressure used has not caused any pipe or joint to spring a leak; and if it has, the leaks will be repaired.

Repairing Leaks in the Gas Lines

Leaks in gas lines are of very infrequent occurrence, but unattended or poorly repaired they present a really terrible explosion hazard. Therefore, should you suspect a leak, you should both investigate it yourself and call the gas company at once. By no means use an open flame or candle, either to light your way or to test a leak on a gas line. Instead use an electric hand flashlight, which is better than an electric extension light for exploring inaccessible places, being self-contained; and to establish the existence of a leak, apply a bit of soapy water with the fingers from a bowl (or more conveniently from a spout oil can) to the suspected part. If there is a leak, the escaping gas will blow the liquid into soap bubbles.

Because the pressure in a house gas line is very low, a small leak can be stopped with a seal which the pressure in a water line would blow out in a moment. This is an advantage in an emergency, since it will permit you to stop a leak by an application of softened soap, pressing and working perhaps half a bar of soap onto and around the pipe, securing it if necessary with a tight bandage of cloth, or of adhesive tape, without the necessity of shutting off the gas. The permanent repair should, however, be undertaken as soon as possible, lest the leak be forgotten until the deterioration or displacement of the temporary patch start it again.

The only proper repair of a gas line leak consists in the replacement of the defective pipe, or fitting, with a good one, correctly installed and tested. And not even temporarily should the low pressure in the line, nor the advice of a thoughtless person, tempt you to plug the open end of a gas line with a wooden plug, or a cake of soap, or a potato. These have already been tried by others, and the explosions resulting have been known to level an entire house.

Danger Due to Possible Gas Leaks

Where a room or a house is closed against a free circulation of air, escaping gas may accumulate until it reaches a highly explosive concentration, whereupon any spark or flame may set it off with a destructive force almost like that of a high explosive military bomb. Because of the hazard involved in a possible leak, gas lines, even more than water lines, should never be installed nor permitted to remain where they might be banged against, or leaned or climbed upon or subjected to any stressing as by hanging anything from or on them which might cause them to spring a leak.

Gas lines should be installed and fastened so as to pass loosely through the walls of the house so any settling of a wall or floor will not be able to tug at them or pull them along as the building settles. Especially should pipes which will be concealed within a partition be carefully installed and the joints made perfect, because it has happened that gas leaks within hollow partition walls have filled the entire hollows between the studs with gas over a period of days or weeks without enough of it escaping into the rooms to be detected by smell; and then a violent explosion has been brought about perhaps by the tiny electric spark caused by an electric light switch set in the wall being turned on.

These cautions about gas are not intended to frighten you but rather to persuade you to observe the few simple precautions which will make gas a docile and harmless as well as a most useful servant in your home. A well installed and cared for gas system is perfectly safe, just as are well made and carefully connected gas fixtures and appliances. It is only ignorance or carelessness which introduces the hazards of explosion or asphyxiation in the domestic use of gas.

How to Disconnect Gas Appliances

In many localities certain gas appliances such as kitchen stoves, refrigerators, and—where they still survive—portable gas room heaters, move with the tenants rather than being part of the house as are the plumbing fixtures.

To permit the disconnection of these appliances without the danger of gas escaping, municipal laws usually require that every branch gas line serving an appliance be provided with a shutoff cock. If you intend to make additions or alterations or repairs to your gas system, or to move an appliance, bear the hazards in mind, and never disconnect an appliance unless you have first shut off the cock. Likewise never connect an appliance to any branch which is not provided with a cock, and never add a branch without providing it with a cock.

If you shorten a line, do not simply cap the end of the pipe, but first add a cock to it, screw a nipple in the cock, and cap the nipple. When any work has been done to the system, test all the joints involved, to be sure they are gas tight; and never use a poorly threaded pipe or fitting, or a battered one. Every joint in a gas system should have clean-cut sharp threads, and should be drawn up tight; and under no circumstances should any cement or plastic or soap be depended on to stop a leak, excepting only the red lead paste with which all pipe threads are treated when connections are made.

Whenever any work is done on the gas system other than the connection or disconnection of an appliance from the end of a branch protected by a branch shutoff cock, the main shutoff (shown at *C* in Figure 67) must of course first be closed to prevent the escape of the gas; and when for this or any other reason the main shutoff cock *is* closed the pilot light flames of such appliances as the gas furnace burner, water heater, refrigerator, and gas cooking stove will of course die. On reopening the main gas cock, the relighting of these pilots must not be neglected.

The Function of Gas in the Home

So much for the construction and repair of the gas system. As to gas itself, and its usefulness to us, or if you please, its functions: It may heat our house, our water, cook our food, and by a paradoxical bit of scientific alchemy, cool the refrigerator. However, it has no monopoly on any of these jobs, and has in fact lost the task which first brought in into the home. Only the facts that we still occasionally refer to it as "illuminating" gas, and that many a utility still operates under the name of the So and So Gas Light Company remind us that gas was once burned not for heat but for light.

The gas jet and the mantle, cunningly designed to burn gas with a maximum of light and a minimum of heat, have joined lead pipe plumbing in the discard; but in the new jobs that gas has wrested from other fuels, or is now competing with them for, it has found a wider usefulness. In the next chapter we shall examine the devices and equipment by means of which gas is burned to release its heat in the various appliances in which it is now being used. These are extremely simple, consisting for the most part of burners with either manual or automatic valving attachments, pilot lights, and thermostatic controls. Complete descriptions of each of the various gas fired *appliances* will be found in the four chapters comprising Part Five.

CHAPTER VIII

Gas Burners

It was pointed out in the last chapter that while gas was formerly used both for heat and for light, it is now used only for heat or as a fuel. It is an interesting paradox that while gas has lost one of its main jobs it has still increased in use from year to year. This increase is more striking when it is realized that it has also lost many of the *heating* jobs it once was called on to do. There was a time when gas heated irons were used, and small portable one-burner gas stoves called hot plates, and small heating stoves called radiant heaters. Then almost every room in addition to having gas jets for lighting, had cocks near the floor to permit the connection of these and other portable gas appliances. Now all these jobs have been taken over by electricity in large measure, and it is unusual to see a portable gas appliance with its rubber hose for connection to the gas line. And yet the total use of gas has increased.

Important Gas Using Appliances

The reason for this is simply that four gas-using mechanisms have come into use which require much more gas than was formerly used for lighting and for all the small capacity heating jobs which the older appliances did. These four are: the gas-fired central heating plant, or house furnace; the domestic hot water heater; the gas refrigerator; and the gas cooking range. Two other appliances less popular than these four but still used fairly widely in certain sections are the gas clothes dryer and the gas garbage incinerator.

Now gas by no means has a monopoly on any of these jobs, because they can all be done by other fuels, and are: by coal, electricity and fuel oil. But gas does enjoy the advantage of being about midway between the cheapest and most expensive in cost, and at the same time as convenient and trouble-free as any.

In fact where difficulty is experienced with a gas-fired appliance it will generally be with some element other than the burner, because a gas burner is structurally so very simple that there is almost nothing about it to get out of order. Basically all burners are alike in that they are arranged to burn the gas in the same way. That is, they burn it mixed with air rather than undiluted as it comes from the pipes. Very much the same burner construction is used in all appliances to effect this mixing, as will be explained later in more detail.

Manual and Automatic Gas Burners

The big difference between the burners on different appliances lies in the valving mechanisms for feeding gas to the burner. Of these there are two types: the manual and the automatic. The *manual burners* are those like the ones used on gas stoves—which are turned on and lit by hand when they are wanted, and turned off again when their work is finished. The *automatic burners* are those which light up and go out, or feed more or less gas to the flame, automatically without any attention from the user.

In the automatic type of burner three elements in addition to the burner proper are needed. The first of these is a heat-detecting device of some kind which will determine when it is necessary to start or stop or adjust the flame. This device is called a *thermostat,* and it has many uses other than regulating gas burners. In Chapter VI we considered the use of the same instrument to regulate the temperature of water flowing from a shower-bath mixing valve. The second element is a *valve* to feed the gas to the burner, arranged to be operated by the thermostat rather than by hand. The third element is a small auxiliary gas burner called a *pilot,* which burns all the time. The function of the pilot is to ignite the main burner when its automatic valve opens.

Now if one had to pick any one factor more responsible than any others for the popularity of gas in any of its major modern applications, it would certainly be the perfection of the automatic burner principle and its replacement of the manual burner, because it was this which made gas an automatic fuel, in addition to its being a convenient and a clean one. It also made gas cheaper to use, because it replaced the variable judgment and the imperfect memory of the user with the methodical regularity of the machine, which once set to maintain a certain cycle of operation found most efficient, would never forget to turn down the flame when the job was done, nor let it burn longer or higher than was necessary.

Importance of Automatic Burner Devices

The development of automatically controlled gas appliances brought down the cost of using gas in another way too. This was by subjecting the entire appliance to the critical scrutiny of the engineers, who in the very effort to make the gas-fired device efficient enough to compete with others using cheaper fuel, developed and perfected parts of the machine other than the gas heating element, so that these used the heat in the most efficient way.

A good example of this was the initiating of the practice of insulating hot water heater tanks against heat loss. When coal-fired furnaces were used more widely than any other kind for heating domestic hot water, the fuel cost had been so low that there was no incentive for anyone to be concerned about the amount of heat wasted by the storage tanks, and even when the first gas heating units were marketed to replace the coal furnaces little attention was paid to this problem, and the storage tanks continued to stand uninsulated, radiating the heat into the surrounding air. But when the self-contained automatic gas water-heaters were launched their design remedied this defect.

Manual and Automatic Pilot Lights

The automatic burners were also an advance in another respect. They were safer. With an automatic relighting pilot such as a thermostatically controlled furnace or water-heater requires, it would be impossible for gas to flow out of the burner without becoming ignited, so long as the pilot is burning, for the pilot lights the gas immediately. This insures that unburned gas will not escape from the fixture with the possibility of its asphyxiating some one, should the valve be opened in some way. (See Figure 68.)

This safeguard has been extended to the burners of kitchen gas stoves, which were formerly equipped with a non-automatic type of pilot light. This light, which burned from four jets in a centrally located burner, had to be operated manually by pressing a button which caused the flame to shoot out and light the burner. It has now been replaced with an automatic pilot, which, though still located equidistant from the four burners, communicates with each of them by means of a metal tube. When a burner cock is turned on, one of its burner openings pours gas into the tube, and this gas is ignited by the pilot and in turn lights the entire burner.

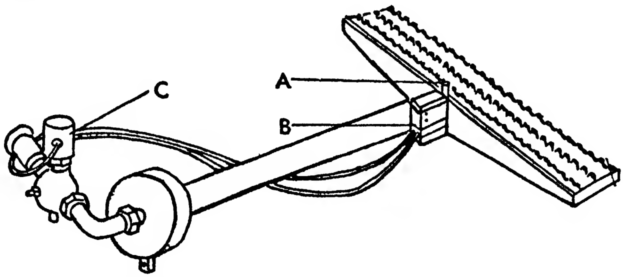


FIGURE 68—Automatic Furnace Gas Burner. If the Pilot Light *A* is extinguished, the Secondary Thermostat *B* will cool and close the Secondary Gas Valve *C*. The main thermostat and valve are omitted in this sketch.

To prevent the main gas burner from being turned on by the thermostat while the pilot light is out, still another safety device is used. This is a second thermostat, which is so located as to be kept warm by the pilot flame. As long as the pilot flame is burning and this secondary thermostat is warm, the main gas line will remain open. But if the pilot flame dies for any reason, its thermostat, in cooling, will close the main gas feed so gas cannot flow to the burner until the pilot is first re-lit.

So much for the generalities of gas burners, manual and automatic.

Repairing and Inspecting Gas Appliances

As to their care and repair, they are all so much alike that most suggestions will apply equally regardless of the appliance to which they are attached, and they are so simple that they will require very little attention. The first good rule about repairing any gas-fired appliance is to inquire of the gas company as to whether they will adjust or repair it without charge before attacking the job yourself. Many gas companies are glad to render this service so as to insure that the equipment will be maintained in good working order and thus used regularly. This is especially true in communities where the gas companies merchandise gas appliances and keep crews of expert mechanics on hand to service them.

The next good rule about gas appliances is to let thermostatic control elements alone unless you are very sure you understand the construction of the one you intend repairing in detail. A real risk is involved in attempting to operate one which is damaged; and they are rather delicate devices which as a rule are better replaced than repaired.

Cleaning and Adjusting Gas Burners

A gas burner which is clean and properly adjusted will burn with a clean, silent, blue-tipped flame, and it will do this at any setting of the burner cock. When the flame misbehaves, it is because the air and gas are not properly adjusted in relation to each other and to the pressure at which the gas enters the cock, or because some part of the burner mechanism is clogged or dirty.

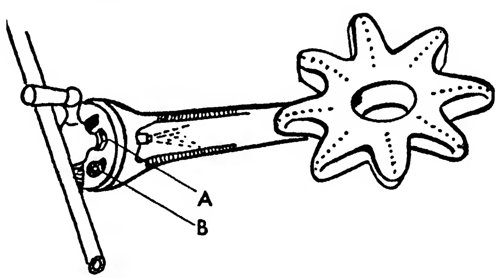


Figure 69—Manually Controlled Gas Burner, cut away to show construction.

Figure 69 given here shows a gas burner cut away to expose its internal arrangement. Note especially the part marked *A*. This is the gas regulator which should be adjusted in connection with the air inlet marked *B* to regulate the flame. Most attempts at adjusting gas burners fail because they are confined to moving the shutter which regulates the air inlet. *Both* the air inlet and the gas regulator should be adjusted to effect any real improvement, and a little experimenting will establish the best settings for them.

Gas burners are not fastened either to the stove or to the cock mechanism, but slip over the end of the gas cock outlet and rest on a bar. They can thus be removed to examine the gas outlet by merely lifting and pushing them back away from the cock. Before any adjustment is attempted, the burner should be removed and cleaned by being vigorously shaken, and brushed with a wire brush if the small gas ports are clogged.

It is particularly important that the burners of automatic appliances be kept well adjusted and clean, both because of the large volume of gas they burn and the cost of the fuel wasted when they are not operating properly, and because they will not ignite or throttle properly when the gas mixture is wrong.

PART FOUR

Electricity

CHAPTER IX

The Electric Wiring System

ELECTRICITY is brought under pressure from the public mains into the house through a large conductor, passes through the meter where it is measured, and from here flows through the main and branch cutoffs and the small branch lines to the outlets in the various rooms where appliances will be attached to use it. Figure 70 shows the house plan with electric wiring, the diagram corresponding to the plan of the water in Chapter III and the gas in Chapter VII.

FUNCTIONS OF ELECTRICITY

As has been pointed out so very, very often, electricity is certainly our most versatile domestic servant. Water we use for drinking, for washing, and as a means of transferring heat. Gas we use only for heat (as fuel). But electricity has a score of jobs, and more are found for it every year. But luckily, and most importantly for our present interest, every one of these jobs will classify into one or more of *four* simple categories. In other words we use electricity to generate *light*, to generate *heat*, to effect *mechanical motion*, and to make and reproduce *sound*. In the chapters which follow we shall examine these functions and the devices required for their performance in detail. First, how-

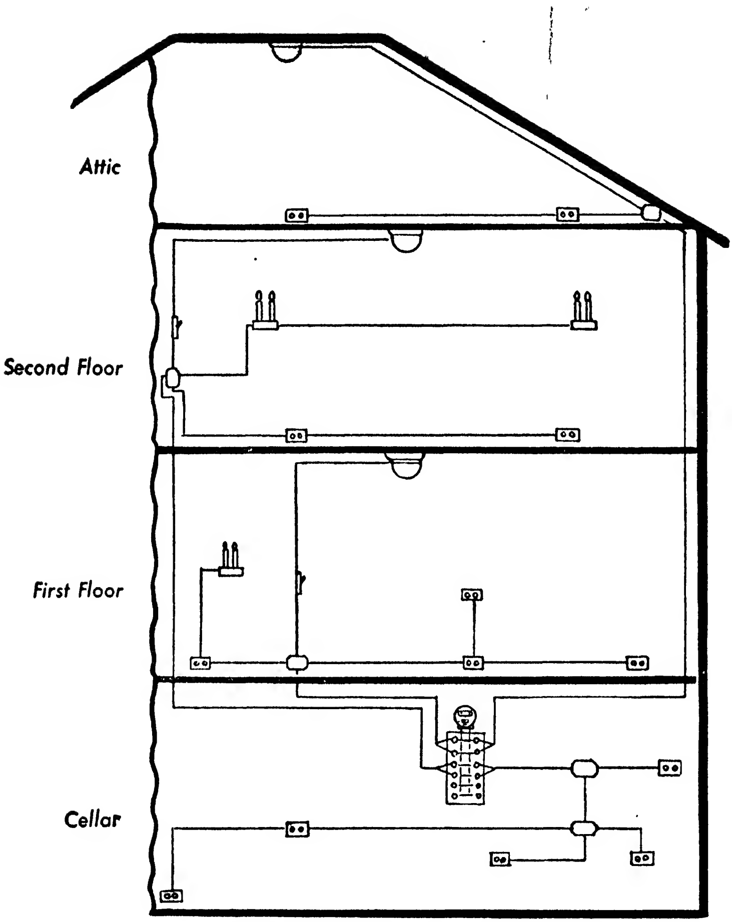


FIGURE 70—House Diagram Showing Arrangement of Electric Wiring Circuits

ever, we must explain how electricity is distributed throughout the house, and that is our immediate task in this chapter.

HOW ELECTRICITY TRAVELS

Electricity travels along metal much as a fluid travels through a pipe. In fact we speak of it as "flowing." Like water or gas, it will flow only so long as it is under pressure; and, again like them, its rate of flow will be retarded quite literally by the size of the line which carries it, and by the length of the line. The metal which is used to conduct the electricity is called the *conductor*, and in the house system it is universally used in the form of flexible wire. It is always copper wire, because copper is a good electrical conductor.

Electrical Conductors and Insulators

In other words, a given size of copper wire will conduct more electricity than a wire of iron, or of any other metal of practical cost. Notice too, the similarity of behavior between electricity and heat. Heat also travels more readily through some materials than others, even to the point of their being classified by the same terms of "good conductors" and "bad conductors." Like heat, too, electricity will flow from one conductor to another unless (and again we use the same word) we "insulate" the conductor to which we wish to confine it.

Thus it is that you will find the house wiring system composed as follows: of metal—because it is a good conductor; in the form of wire—because it is cheap, flexible, convenient and easy to install and work; of copper—because it is a good conductor, invariably insulated to prevent the loss of electricity from the system, and decreasing in size as it spreads out into the branches requiring less flow. You will find the insulation to be of a rubber compound—because rubber is a bad conductor, therefore a good insulator.

The Electric Wiring System and the Flow of Electricity

You will also find a very interesting difference between the fluid and the electric systems. Electricity is conducted not over one line but two. Every branch of any house system (or "circuit") consists of two wires, and so does every public distribution system. A seeming contradiction of this, in the use of the so-called three wire circuit will be explained in connection with the electric stove in Chapter X, and it will be seen that this is in fact two circuits of two wires each, with one of the three wires simply serving doubly as, we might say, the left hand wire of one circuit and the right hand wire of the other at the same time.

Another difference is in the way in which electricity responds to attempts to make it flow through a circuit which is too small (that is, offering too much "resistance"). With a fluid piping system, if the pipe is too small the resistance it offers the flow is purely physical, being accounted for simply by the friction engendered between the fluid and the inside walls of the pipe. The only result will be that the rate of flow will be retarded, so that to get the desired amount of fluid will require a longer time. But, in the case of fluids, unless the pressure is increased to a point where it will burst the pipes no untoward damage to the system will result.

The essence of electric appliances, however, is that they operate by drawing the electricity at a certain *rate*, and if the conductors will not deliver the current at that rate the appliances will not function properly, and electricity will be wasted within the wires themselves in the process. An understanding of the essential part which the element of time plays in electricity will answer many questions about its nature which often puzzle laymen, especially as regards its measurement; since, not being a tangible physical substance like water or gas, it cannot be measured by the gallon or cubic foot.

Volts, Amperes, and Ohms

When water is put into a pipe for distribution, it has, we say, a certain pressure, which we measure in pounds per square inch. So has electricity, but its pressure is measured in *volts*. House lines served from public systems have a pressure of 110 volts, so this factor we can consider as a constant in our calculations. Water has quantity too, and its measure is simply the cross sectional area of the pipe. Electricity too has quantity, but it is expressed in terms of a unit known as an *ampere*. You may think, if you like, of the cross section of the wire as measuring the *amperage* somewhat as the capacity of the pipe measures the quantity of the water, provided you remember that though there must always be enough water available actually to fill the pipe before the pipe's capacity can measure the water's quantity, the amperage is an attribute not of the wire but of the electricity, and practically speaking a little electricity will flow through a large wire just as happily as through a small one. Specifically, an ampere is that quantity of electricity which a pressure of one volt will "push" through a circuit offering a resistance of one *ohm*.

Now amperes and volts should always be thought of together. The electricity, at work flowing from the circuit, or at rest within the wires, has them both, just as invariably as the circuit itself has always two wires. When the number of volts increases, the number of amperes goes down; and when the number of volts decreases, the number of amperes goes up; they are coupled like the two ends of a see-saw.

Watts and Watt Hours

The universal electrical *work* unit is the *watt*. The watt is the real measure of the power used by any of the electrical appliances; the electric "gallon" you might call it, but not to be drawn and stored like a gallon of water, but rather "evaporating" as fast as it leaves the circuit, so that it must be constantly replenished. Which brings us back to time as an element in the measurement of electricity.

You don't buy pressure, that is volts, from the electric company, nor yet amperes, nor even watts. You buy *watt hours* of energy, and a watt hour is simply the amount of electricity which an appliance drawing one watt will consume in one hour. Now to tie these four elements up in useful form. A simple equation does it:

Volts times amperes equals watts,
Therefore – *Volts equals watts divided by amperes*
and – *Amperes equals watts divided by volts.*

This equation is given here because it is basic to an understanding of electricity. Learn it thoroughly.

The Electric Meter

Every domestic electric installation starts just inside the building wall, at the electric meter. Like the gas and water meters it is sealed against the possibility of its being tampered with, and like them its face consists of a series of simple dials and pointers which anyone can learn to read with about ninety seconds study. It is called a watt hour meter, but its dials are calibrated to give the reading in terms of a unit a thousand times as great as a watt hour. This unit is called the *kilowatt hour*, and its use saves dealing with a unit as small as a watt hour, which is a rather small amount of electricity. Every electric appliance is marked to show the characteristics of its current. An electric light bulb is etched with a legend giving the *voltage* (which is standardized in the United States at 110 volts where domestic current is purchased from a utility company) and with its *wattage*. By common usage the wattage marking on bulbs has come to be used as an index of the light intensity of the bulb, but this is not its primary significance.

Calculating Current Consumption

When an electric light bulb is marked "100 watts" or "100 w" it is the maker's indication that when connected to the electric circuit the bulb will draw 100 watt hours of electricity for every hour that it is used. By simple arithmetic its use for 10 hours would advance the watt hour meter just ten times 100, that is 1000 watt hours (or one kilowatt hour); and assuming the electric rates to be five cents per kilowatt hour, the cost would be just five cents for the electricity delivered through the house wiring and consumed by the bulb. It will be obvious that the cost attaching to the use of any other domestic appliance can be readily ascertained in the same way, by merely multiplying the wattage of the device by the time it is used, translating the resulting watt hours into kilowatt hours and multiplying them by the rate charged per kilowatt hour; and this can be done without recourse to the equation about the watt, ampere, and volt, so long as the wattage is given. The current consumed by the various electric devices will be dealt with in detail in the chapters which follow.

Overloading a Circuit

To return now to the equation and the wiring, let us assume that a quite large load be connected to the circuit, say by using so many bulbs, and perhaps an electric bread toaster or other appliance beside, that their wattages totaled 1650. Dividing this 1650 (watts) by 110 (volts) according to the equation would give us 15 (amperes). To serve this connected load (which is just what it is called) would require two things. First it would require that this many amperes actually be available at the meter. If it were not, the result would be very much the same as if too much demand were placed on the plumbing system, but with one important difference. Eventually enough water for the *purpose required could be delivered and accumulated in the plumbing fixture, where it could be used. But with the electricity your needs would never be met.* The toaster and bulbs would go on consuming as much current as was available without ever giving heat enough or light enough to do their jobs.

Second, and even more important, this demand for 15 amperes would require wiring from the meter to the outlets large enough to carry it. Again, comparing the wiring and the plumbing, the water pipes would simply refuse to accept from the main more water than their capacity would permit them to convey. But with the electricity something very different would happen. The wires would accept more current than their size would permit them to carry "comfortably," and more even than the actual requirements of the total connected load. This extra current, however, would not reach the appliances. It would flow through the meter and be measured and charged for, but it would be "consumed" by the wire itself. And more important than the monetary loss involved in the wasting of this current, the wiring would grow hot. How hot? If the wires are only a little too small for the load (or obversely the load only a little too great for the size of the wiring), the wires would become just a bit warm. But increasing the load, the temperature of the wiring would increase until it became literally red hot. And red hot wiring would set the house on fire.

How Electricity Starts Fires

A good many houses are burned every year in just that way. But this can only happen if there is no "weak link" which will get hotter sooner than the wires themselves, and in melting apart break the circuit and stop the flow of current, thus avoiding disaster. For your protection, both wires of every branch circuit, and both wires of the main circuit have such a "weak link." It is called a *fuse.* (Figure 71.)

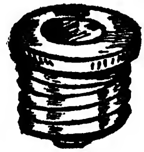


FIGURE 71—The Screw Type Electric Fuse

FUSES

The branch circuit *fuses* then are the householder's first line of defense against the chief hazard which the use of electricity always presents. They will be found in a metal box near the meter. In older houses the fuse receptacles and their wire connections will be exposed by opening the metal cover of the fuse box, while in some of the newer type boxes only the face of the fuses are visible through holes punched in the box cover. But this is a mere detail, and the basic interior construction of the devices is the same. By studying the fuse block for a moment it will be seen that two wires enter the box from the meter, and the way in which these two wires are attached to the individual fuse receptacles—so that both wires of each branch circuit leaving the fuse box will be protected by a fuse—will be quite apparent.

Tracing Branch Circuits from the Fuse Box

It is only by examining the fuse box and unscrewing the fuses one after another while another person visits each electric outlet through the house, turning on the lights, that the various branches can be traced out. This is a tedious job, but it should be done and a simple sketch made showing the layout of the wiring throughout the house, as a necessary preliminary to almost any work on the wiring.

The Main House Switch

Between the fuses and the meter, two other elements will be found. One of these is the main *house switch*, which like the branch fuses may be concealed within a metal box, with only its handle exposed, or it may be entirely exposed to view by opening the switch box. In either event it will be seen to consist of two copper blades hinged at one end and coupled together so that when the handle is moved the unhinged ends of the blades engage and disengage two copper terminals. As all the current used in the house flows through this switch, it is used of course to disconnect the house wiring from the meter and the public power lines *in any emergency*, or when it is desired to work on the wiring without the danger of getting an electric shock by accidentally touching *both* wires of a circuit.

Between the main switch and the meter are another pair of fuses, that is one fuse in each of the two wires leading from the meter into the main switch. But these are not screw type fuses like the others, and they are generally in a box which is sealed against being opened. They are for the protection of the meter and power line in the event that a load too great for safety to these parts is imposed on them.

What Causes Fuses to Blow Out

Fuses are so made that they will fail, or "blow" at a certain load; and they are marked with their capacity. If you will examine a screw fuse you will find it stamped 15 A or 15 amperes, most probably, because this is the usual rated capacity of branch circuits. Multiplying this 15 amperes by 110 volts according to the volts-amperes-watts equation will give 1650 watts, which is the maximum load which a branch circuit should carry. Now assuming four branch circuits and all loaded to capacity, the total connected house load would be 60 amperes, and the main fuses would have to be of this size.

So long as each circuit was in fact protected by fuses of the proper size, the main fuses would never blow out. But this cannot be depended on, because there is the danger that someone may have substituted some conducting material (such as a copper penny) in place of the branch fuse, or the mistake may be made of replacing a 15 ampere fuse with a larger one (and screw fuses are available as large as 30 amperes). With four circuits so fused and loaded to near capacity, the demand on the meter would be doubled, and of course the main fuse would blow, or rather would have blown as soon as the total connected load reached the main fuse capacity of 30 amperes.

It must be emphasized that the main fuses cannot be depended on to protect an overloaded branch from starting a fire, because a penny, or even an oversize fuse, in a branch line may permit that branch to carry an amount of current less than will blow the main fuse but still great enough to heat some weak point in the branch circuit above the danger point.

Repairing the Electric Wiring System

The actual mechanical work involved in repairing electrical wiring of the sort used in domestic installations is very simple, but it is exacting and calls for a willingness to take pains lest some "minor" carelessness or oversight result in tragedy. It is for this reason that the whole field of electricity has been hedged about with local building codes and fire insurance and other regulations which if literally enforced would prevent almost anyone but a licensed electrician from doing much more than changing a bulb.

In examining the meter and the fuses it will be observed that connections made within the metal boxes between wires and fuse receptacles or wires and the switch terminals are effected by means of simple screws with large heads, and that these points are left quite bare of any protective insulation. Touching two wires at the same time would close the electrical circuit in the same way that attaching an appliance would, and the electricity would flow through the body, delivering a shock. Touching the two wires together would also close the circuit, and in this case the wires themselves would take the place of the appliance just as the body did, and the fuses would blow out. This effect is very descriptively called a *short circuit.* The only safe rule to follow to avoid these possibilities is to be sure the line is "dead" before touching any uninsulated part of the circuit, by first removing both branch fuses if a branch is to be worked on, or by pulling the main switch if the fuse box is to be entered.

Likewise any metal which is or might be in contact with the earth, such as a gas, water, or steam pipe, or even one's own body touching one of these or even standing on a damp floor, should always be regarded as one wire of a live circuit ready to deliver current in connection with either of the two wires of the electric system.

The BX, Knob and Tube, and Conduit Wiring Systems

There are three types of wiring systems used, varying only as to the manner in which the wires are protected from mechanical damage. The oldest of these is called the knob and tube system, and it is practically obsolete, having been outlawed because it consists simply of the two conductors protected only by their rubber-compound-and-fabric electrical insulation. These wires were led about the house draped on porcelain insulators nailed to the house timbers. These insulators were called knobs, and they were supplemented at every point where it was necessary for the wires to pass through a timber, by means of a porcelain tube which was slipped over the wire at this point to prevent the insulation from being chafed off.

The knob and tube system was succeeded by the use of a flexible armored cable known as BX, which carries both conductors within its spirally wound metal shell, protected from damage. The BX system has become practically universal wherever any sort of regulation is exercised over wiring installations. It comprises not only the armored cable, but a series of metal boxes into which the cable is led wherever it is desired to effect a branching of the wires, or to attach an appliance or fixture of any sort.

The third system substitutes ordinary rigid iron pipe for the flexible BX sheath. The pipe, called conduit, is installed in much the same way and with the same tools as are used for any other pipe fitting. The conduits are first installed and then the wires are pulled through. To permit this to be done, instead of pipe tees such as are used in plumbing work, boxes are used which are much like the BX boxes. These are inserted in the lines wherever a branching or fixture is required, and the wires are pulled through from box to box by means of a long flexible steel strip which is rigid enough to be pushed through the conduit. This strip is called a fish, and once it has been passed through a length of conduit the wires are fastened to its nether end and pulled into place. Conduit work is not often encountered in domestic installations, being more expensive than BX. Short lengths are sometimes used, however, in a BX system for getting current to such appliances as the electric blower of a forced air heating system where the wires must drop down unsupported from the ceiling or run along the floor.

The sketch in Figure 72, given here, shows the important characteristics of the three systems, but in addition to studying the illustration, you must of course learn about the particular method used in your own house by examining it. However, regardless of the system used, the procedure to be followed in repairing a system will be much the same. There, the main wires *A* enter the meter at *B*, go to the main switch at *C*, and the main fuses at *D*, to terminate at the branch circuit fuse block *E*, enclosed in the metal box *F*. Three branch circuits leave the box, with the fuses at 4 to spare for later installation of another branch. The circuit marked 1 is shown as run in BX marked *G*, with a joint made in the BX box *H*. The number 2 branch is shown as run in metal conduit marked *I*. The number 3 circuit is shown as an old-fashioned knob and tube job, with the wires protected by the porcelain tubes *J* and fastened to the building with the knobs *K*. The ground wire is shown at *L*.

Repairing Overloaded Circuits Which Cause Fuses to Blow Out

One trouble encountered, and by far the most frequent one, has already been mentioned. That is the matter of a fuse blowing out. The causes of this, which are either the overloading of the circuit or the occurrence of a short circuit, have been discussed. When a fuse blows because the circuit is overloaded, you can do one of three things:

1) You can insert larger fuses. But this is *dangerous.*

2) You can carefully total the wattage of the connected load which blew the fuse, and reduce it to an amount which will permit using the same (correct and safe) size fuse. But this is *impractical.*

3) You can increase the electrical capacity of the branch circuit.

The first method is unfortunately often tried; but it

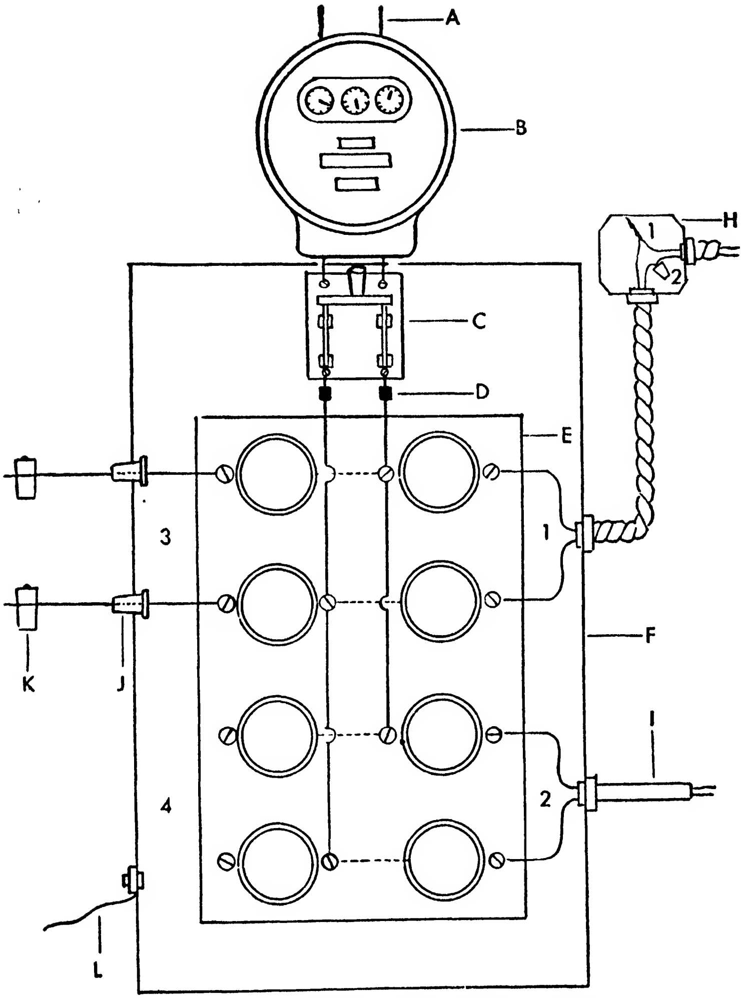


FIGURE 72—The Electric Meter, Main Switch, and Fuse Board.

should definitely be avoided. The second method is difficult to accomplish.

The third method is the recommended one. It would justify its cost many times over even if one hired the most expensive electrician in town to do the job in the most expensive way. This way would, as with the plumbing, be to replace the entire branch line or lines, from every outlet right back to the meter. To this method there are two alternatives, and the sketches in Figure 73 just below suggest

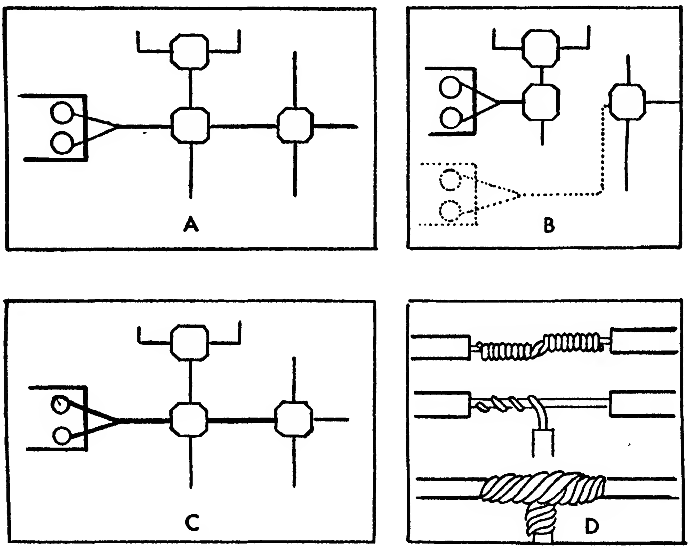


FIGURE 73—At *A* an overloaded Branch Circuit serving six outlets. At *B*, by adding another Fuse Block and Feeder Line, the overloaded Circuit is broken into two Circuits, each serving three Outlets. At *C* heavier Wires are substituted for the Feeder portion of the Circuit shown at *A*. At *D* the proper method for splicing and for tapping wires in a Knob and Tube System.

them. The first is to divide the overloaded circuit, shown at *A*, into two circuits, adding two fuses and a new branch feeder line as shown by the dotted line in sketch *B*, with the new feeder supplying only part of the old branch and the old feeder continuing to serve the remainder of it. The second method is to replace the feeder portion of the branch circuit with larger conductors but still keeping all outlets on the one branch circuit, as shown at *C*. Which method is best in any given situation will depend entirely on the actual arrangement of the outlets.

The manner in which the wires are attached to the building and the connections made in the work already in place will serve as good models of the way in which the repair should be done. In the case of a knob and tube job, the points where you splice or tap in the new feeder must be handled, as shown at *D* in the sketch, by skinning back the insulation from both wires, and winding the new wire around the old one in a snugly fit but open threaded spiral, and soldering the joint. The joints must then be wrapped first with rubber tape and then with the familiar friction tape.

BX Boxes

With BX all connections must be made within a box, which will mean that you will have to cut the old line and install a new box if one which is conveniently located cannot be found already in place. If BX is used, soldering the joints is avoided because the protection afforded by the boxes permits the use of an approved screw-type connector, which is no more than a short metal sleeve with a female self-tapping thread insulated by a bonnet of hard rubber shown at 2 H in Figure 72.

The wires are skinned and twisted together and then the connector is screwed down over the ends. BX is very easy stuff to work with except for one thing. Cutting back the sheathing to expose the wires is a baffling job unless it is done in just the right way by hacksawing it apart.

Knocking out the holes in the side of the box will give you no trouble, nor will the bushing which seizes the ends of the

BX sheathing where it passes through the knockout hole. The matter of fishing the BX through the hollows of the walls and floors will give you a lot of trouble where this is necessary, and almost any amount of scheming and ingenuity exercised to avoid or minimize this thoroughly disagreeable job will prove worth while.

Short Circuits

When a fuse blows, and the circuit is found not to have been overloaded by too many appliances, the overloading must have resulted from a short circuit. The most prolific source of short circuits is the appliance extension cord; and if this possibility is eliminated and a new fuse still blows, the "short" (short circuit) must be in the house wiring. Here indeed is an opportunity to test your patience, by tracing back every foot of wire from every outlet right back to the fuse box, until the short is located. Very fortunately (especially with BX where the conductors are protected from almost any damage but a husky nail driven squarely into the spiral joint, or the entrance of water into the BX), shorts almost always occur at connections between the wires or between a wire and a switch or other line appliance. The big part of the job is finding the short, and the small part is repairing it.

To find the short, first go from box to box, removing the covers and inspecting the wires to see whether vibration may have chafed the insulation on one of the wires where it enters the box, or loosened a screw connection permitting the wire end to spring into contact with the box so as to make a grounded short, or to make contact with the other wire. (The BX sheathing and all boxes are grounded through a ground wire from the meter box to some nearby water or gas pipe.) Then if this investigation does not locate the short, it will be necessary to localize it by detaching one section after another of the circuit and "ringing out" the isolated run of wire. This is done by substituting the safe yet ample energy of a dry cell battery for the house power, connecting the battery to one end of the suspected wiring and a door bell to the other. If the bell rings, the circuit is not shorted across the two conductors.

Then substitute the BX sheathing for first one and then the other of the wires. If the bell rings, the circuit is not shorted to the BX. Repeat this tedious process from box to box, and you will find the short in one of the sections tested. Whereupon, if the short proves to be in some inaccessible spot within a wall, you must decide on how best to restore service without using the defective run of wire by installing a new run of BX to replace the shorted section.

How Water Causes Short Circuits

When a short is caused by water, it will cure itself as soon as the water causing it is removed and the wires dry off; and in the case of an obscure short this should always be considered as a possible cause. BX sheathing (except for an expensive type known as BX L which has an inner liner of seamless lead around the wires) is *not* waterproof, nor are screw connections where the metal is bare of insulation. Even taped splices cannot be depended on to be waterproof, and water might well gain admittance to the BX and run along the insulated conductors to a connection where it would make a short.

Flickering and Dimming of Lights

Blown fuses and short circuits almost sum up the difficulties encountered with the wiring system, but there are three other irregularities in the delivery of the current which arise occasionally. Two of these are made manifest only through the electric lights as a rule. They are a flickering of the light as though the current were definitely but only momentarily being cut off, and a dimming of the light, also only momentarily. The third is the total absence of current without the fuses being blown.

Loose Connections

The first difficulty is just what it would seem, a *loose connection* somewhere in the system; and its cure is the same as was described for a short circuit, except that in ringing out the circuit to locate the loose connection the current may unobligingly refuse to flicker. This is because the natural springiness of the wire is holding the conductors in contact and permitting the current to flow except when the force of some vibration or other shakes them momentarily apart. In ringing out a circuit looking for a loose connection, it will not be necessary to isolate the section being tested by disconnecting it from the remainder of the circuit, but only to penetrate the insulation at the two ends of the section to attach the batteries and bell. Often the difficulty will practically announce its location by affecting only one outlet on a branch; and in such a case suspicion should first be directed at the wall switches. (Remove branch fuses first!)

Significance of Momentary Dimming of Lights

The momentary dimming of a light may occur when some appliance is connected to the circuit on which the light is connected. This dimming happens so frequently that it is often regarded as normal, but it is not. It means that the circuit is being overloaded; and the cure is to increase the capacity of the circuit just as was suggested for the continuous blowing of the fuses. In other words, momentary dimming is a danger signal which should not be ignored.

When all fuses are properly in place and unblown and current is still not available at an outlet, it means that a break in one of the conductors of the circuit has occurred at some point along the line. Generally this trouble is an intermediate stage between a flickering connection and a short circuit which will blow a fuse; and locating it will be found just as tedious but no more mysterious or difficult than dealing with those troubles, the same methods being used.

Wall Switches

A *wall switch* can be taken out of the metal box which protects it by removing the two screws which hold the decorative cover plate in place and then removing the two screws which anchor the switch into the box. The wires connecting it will be found to have several inches of slack so that the switch can be pulled out into view and examined without difficulty, or the screws securing the wires can be loosened and the entire switch assembly removed.

Wall switches are worth a bit of study for two reasons. First because they are such a good example of a practically unrepairable mechanism, nine out of ten of them being so assembled, with rivets instead of screws, that they cannot be taken apart, but must be discarded when they fail; and second because of the ingeniousness of their design, which causes the blade always to snap rapidly from one position to the other regardless of the speed with which the handle or button is moved.

This effect is necessary with any switch which is to be used frequently by laymen, because when an electrical current is interrupted by the circuit being broken the current will continue to flow across the gap so long as the gap is small in relation to the amount of current being drawn.

This flow is known as an arc, and generates heat sufficient to melt the ends of the switch blade and terminals. The spring loading of the switch blades does not entirely prevent arcing, but it reduces it to a minimum. Switches are marked with their electrical capacity, and a good deal of trouble will be avoided by taking care not to overload them.

They are always marked both in amperes and volts, so simple multiplication will (according to the equation mentioned above) give the safe connected load in watts. There is a very easy way to tell when a switch is being overloaded without even comparing the load with its capacity. That is by listening closely to the sounds made when the switch is turned off. Normally loaded, a switch will emit only a metallic clicking sound as the blade reaches the end of its stroke. But if it is turned off under too great a load, it will be heard also to first hiss and then pop as the arc is drawn and then broken.

Wall Switches Which Operate Silently

Noise in operation can be a very annoying fault in switches, especially where they are located in nursery or bedrooms. The sound made by a switch is dependent on the design of the switch, but generally speaking even the best of the kind used as wall switches make a quite audible click as the poles snap into place, and nothing can be done about this inherent defect in the mechanical type of spring loaded switches. (Figure 74.)

There is, however, a switch made which is available in a size and capacity to be used with the standard wall boxes, and which is entirely silent in operation. It is called a mercury switch, and instead of having the usual pole or snap mechanism, its working part consists of a small glass tube into which is sealed a pool of mercury. Two wires enter the tube at its opposite ends and terminate inside.

The tube is arranged so as to tilt back and forth when the switch handle (which is the usual type of toggle) is moved. Since mercury is an electrical conductor, the switch will pass current when the tube is so tilted that both the terminals are immersed in the mercury; and the circuit will be switched off when the tube is tilted so that one of the terminals is not in the mercury. These silent switches are more expensive than the mechanical type, but they are just

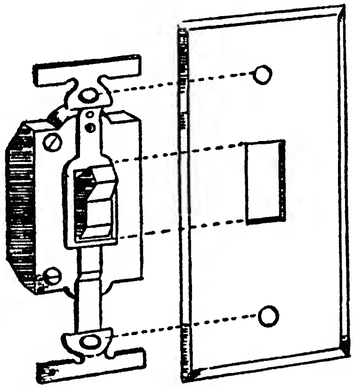


FIGURE 74—The Toggle-Type Wall Switch and Cover Plate.

as simple to install and very long lived and trouble free, unless the mercury tube is somehow broken, in which case the entire mechanism must be discarded.

All the *toggle switches* (shown in Figure 74) are activated by flipping a short handle upward or downward, but many of an older type with two *push buttons* instead of the handle are still in use. Of the two types there are literally dozens of makes, but they are all so simple and so similar that examining any one will reveal their pattern of operation. Where only one switch controls a given outlet, the switch will have only one blade; that is, it will be a single pole switch as against the double pole main switch in the basement which has two blades.

Only one blade is required in the wall switch because opening only one wire of the circuit will cut the current off just as effectively as would breaking the connection through both wires. The diagram at *A* in Figure 75 shows how the switch is inserted in the circuit to do this.

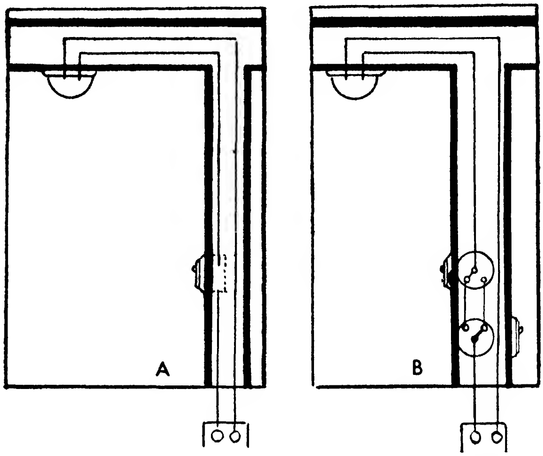


FIGURE 75—At *A*, a Ceiling Light controlled by a Wall Switch, and at *B*, a similar light controlled from either of two wall switches.

THREE-WAY SWITCHES

It is often convenient to be able to control an outlet, especially a hall or stairway light, from either of two wall switches. The way in which this is done is shown in the diagram marked *B* in Figure 75. The special switches required for this service are known as three-way switches. By omitting to use one terminal of a three-way switch, it can be used as an ordinary switch, but of course the ordinary single pole switch cannot be used for three-way service.

CHAPTER X

Electric Fixtures and Appliances

Types of Electric Appliances

As was suggested in the previous chapter, the various appliances and devices in the home which work by using electricity can be classified as belonging to one of four groups in so far as their function is concerned. These are the light-making appliances, the heating appliances, the motor appliances and the miscellaneous appliances such as bells, buzzers and chimes, and the radio. As might be expected, devices of any one of these groups will generally be found to be similar to others of the same type as regards construction and operation as well as function; and further, all of them of whatever type take their electric current from the house wiring in much the same way.

The Extension Cord

Every electric appliance must be connected to the house line by two conductors. We are all familiar with these two conductors where used with all the portable appliances, as the extension cord, or cord and plug set. Sometimes, as with the electric iron or toaster, the cord set is separate from the appliance proper, and is equipped with two plugs, one always a male—to be plugged into the convenience outlet of the house wiring, and the other a female—the two sockets of which slip over prongs on the appliance. Other appliances such as lamps have the cord permanently attached. This is an advantage in that it gets rid of a useless and troublesome fitting the purpose of which no one has ever satisfactorily explained. As a matter of fact the current practice is to omit the appliance plug and make the extension wire a permanent part of the appliance. These plugs were never standardized as all other fittings have been, to permit them to be used interchangeably from appliance to appliance, and they lend themselves too conveniently to being used—or rather misused—as switches, so it is as well that they are on the way out.

Even without the appliance plug, the extension cord is by no means a perfect device, however. The plug which attaches it to the house wiring is so designed that the least tug on the cord will jerk it from the outlet; and the rigorous wear to which the cord is naturally subjected frequently frays the insulation on the wires, causing a short circuit or a break in the wires. Where the first of these troubles is a problem, as with the vacuum cleaner and the electric iron cord, about the only practical cure is to provide a screw hook at the wall outlet over which a loop in the wire can be hung.

Repairing Extension Cords

Repairing a frayed cord or replacing a broken plug are both simple enough jobs. In the case of the cord having gone bad, it will generally be found best to discard it entirely and replace it with a new one because it will seldom happen that the kinking and wear is all localized in one spot. An exception to this is at the point where the wire enters the appliance. Here, if as sometimes happens with cheap appliances, a soft rubber gasket has been omitted, the wires may chafe. A durable enough repair can be made by wrapping each conductor with friction tape to cover the bare spots, or a more sightly repair by cutting the cord off and reconnecting it to the terminals of the appliance. In either case the hole through which the cord enters the appliance should be provided with a bushing to prevent a repetition of the trouble. The extent to which it will be necessary to dismantle the appliance to permit feeding the wires through its interior to reach the electric terminals will depend entirely on the construction of the particular appliance, but whatever this may be will be quite obvious from an examination of the device and no fear need be felt in removing or loosening any screws which seem promising.

In the case of the male plug the two setscrews to which the wires were attached will be found to be quite exposed, so it will only be necessary to slip the cord through the hole in the plug (which requires no bushing because its edges are smoothly rounded and it is a loose fit), trim back the insulation half an inch or so from the ends of the two wires, wind the bare end of one wire around the shank of one of the setscrews, tighten the screw down, and do the same with the remaining wire and remaining setscrew. To take the stress off the wires at the point where they are cramped beneath the screw heads, before the wires are fastened to the screws they should be tied together in a knot too large to be pulled back through the hole in the plug (being careful that the insulation is intact where they are knotted together); or each wire can be passed around behind its prong before being wound around the screw shank, instead of coming directly through the hole and up to the screw.

It will bear repeating that the function of a flexible extension cord is to attach a portable appliance to a convenience outlet. Every extension cord is a compromise between safety and convenience; and to use a cord as a permanent extension of the house wiring to overcome a lack of sufficient outlets is a dangerous practice.

Light Sockets

Electric light sockets are not portable appliances, properly speaking, although they are often used attached to one end of an extension cord. Where a portable extension light is indispensable, it should consist of heavy gauge flexible wire heavily insulated with a rubber sheathing and attached to a socket provided with a switch, a rigidly attached handle, a wire guard completely surrounding the light bulb, and a hook for hanging it up. Such extensions are usually available at hardware and electrical stores and although necessarily expensive are a very worth while investment. (See Figure 76.)

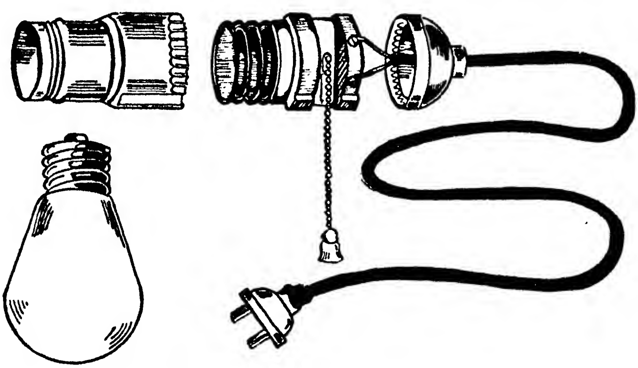


Figure 76—A Brass Shell Socket With a Pull Chain Switch, an Extension Cord, and an Incandescent Light Bulb.

Electric light sockets, like wall switches, are generally not susceptible to repair. They are simple to disassemble or detach, however, once two rather obscure points about them are understood. The commonest type of socket has a brass shell which is made in two pieces, one cylindrical and one dome-shaped. To take one apart to expose the terminal screws to which the wires attach, the cylindrical part must be pinched at opposite points of its circumference at that end which slips into the dome-shaped part. This will free the small concealed catches which secure it to the dome, and the two parts can then be slipped apart thus exposing the porcelain body of the socket carrying the wire terminal screws. Consequently it is not necessary (or in fact desirable) to detach the entire socket from the appliance to get at the wire connections. To detach the socket from the remainder of the appliance, the shell should first be slipped off and the wires disconnected, and the dome then turned to the left to unscrew it after loosening a small setscrew which will be found in the small threaded collar forming the apex of the dome.

Light Socket Switches

This type of socket is made either without a switch, or with a pull chain switch, or a push button switch, or a key handle switch; and when the switching element of a socket fails, the socket can either be used as a switchless type by removing the external switching control and reassembling the socket with the switch in the closed position, or it can be discarded. Most switch sockets fail through being overloaded. These switches are made only to control electric bulbs, and are too light in construction to stand being used for *switching* appliances such as electric irons, or toasters. Sometimes portable electric lamps are provided with a switch separate from the socket, and the same observations obtain regarding the capacity of these switches.

Light Bulbs

About the electric light bulb, which is the heart of the light making appliances, there is little to say. It consists essentially of a short length of very fine wire which offers such resistance to the flow of current that when its two ends are connected to the two wires of the electric circuit it becomes almost white hot or incandescent. Its only serious drawbacks are that for all its shining efficiency and cheapness compared to other lights such as a kerosene or gas flame, it still converts less than ten percent of the electricity it consumes into light (the remainder being converted into heat), and its light source is concentrated in one small spot.

These may seem small objections, but they have led to the development of a substitute for the incandescent bulb. This new type of light, which manages to convert more than twice as much of the current consumed into light, which is distributed from the entire length of a long tube in a softer, less glaring glow, is known as the fluorescent tube light, and in time it may replace the incandescent bulb for domestic as well as industrial use. Its color values are as different from those we are used to from the modern incandescent bulb as is the modern incandescent from the old-time carbon filament incandescent bulb. The fluorescent tube requires a special type of socket which delivers current to both ends of the tube, and a special device to start it when used on direct current.

Heaters, Toasters, Grills, Irons, Pads

Appliances which use electricity to produce heat (Figure 77) operate on much the same principle as the incandescent filament light bulb. That is, the heating element consists of a metal wire which when connected to the electric circuit becomes hot. In the *electric toaster*, the heating element is right out in the open where it can be seen, as is also the case with the radiant bowl heaters and the various types of grills and hot-plates. In the *radiant heaters*, the *grills*, and some toasters, the heating element is in the form of a round wire twisted into a coil just loose enough so that no turn touches an adjoining turn. Thus the air between the turns acts as an insulator (electrical) so the current will be forced to travel the entire length of the element. In some toasters,

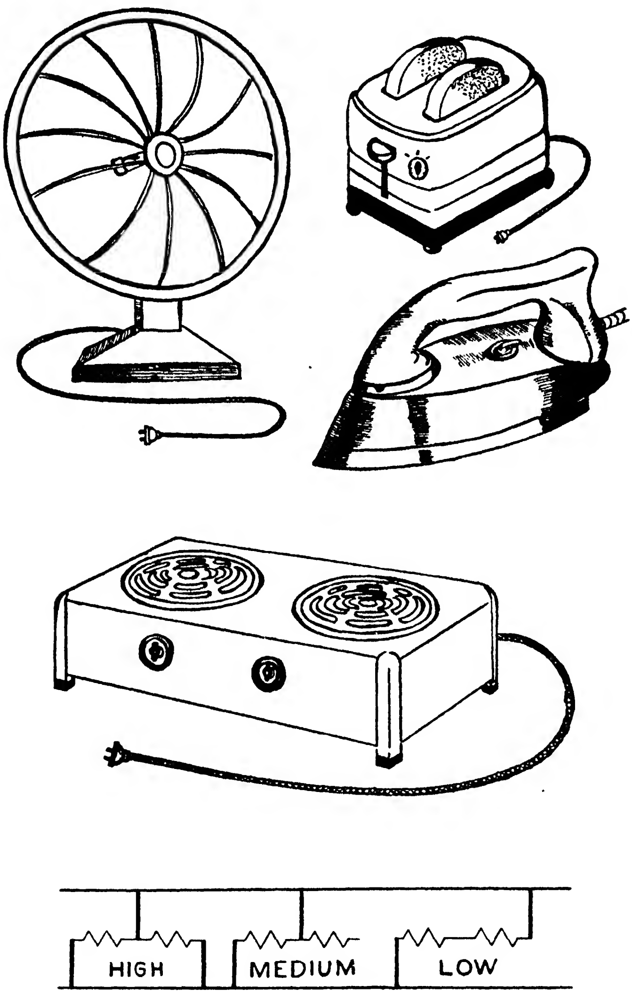


FIGURE 77—Four Home Appliances of the Resistance Heater Type. They are the Radiant Heater, the Automatic Toaster, the Electric Iron, and the 3-Heat Grill. Beneath these four Appliances is a Diagram of the Wiring for a Grill Switch.

and in waffle irons and the older types of electric irons, the element is in the form of a flat ribbon which is wound around a sheet of mica which is sandwiched between two more sheets of mica. This material is both an electric insulator and fireproof, and thus serves the same purpose as the air surrounding the exposed-element appliances, but still permits escape of the heat.

Replacing Heating Elements

When one of these appliances fails, it will usually be because the element has burned apart; and the cure is simply to disassemble the device as far as necessary to get at the element, which should then be removed and replaced with another exactly identical with the original one. This is important. It is not possible to make a satisfactory joint by twisting the wires together, and of course they cannot be soldered because of the heat they generate when in use.

Some of the newer *electric irons* have a type of heating element in which the resistance wire is completely enclosed in a protective metal tube and insulated from the tube by its being packed with magnesium oxide. This element is also used on the higher priced electric ranges. It is sold with a lifetime guarantee, so the fact that the resistance wire itself cannot be gotten at to be replaced is no disadvantage. Should such an element fail, which is most unlikely, it will be replaced complete ready to install, protective tube and all, if the defective unit is returned to the maker.

The *electric heating pad* is one appliance in which the heating element is so much a part of the appliance that replacing it is not practical. The same is true of most curling irons, and the immersion heater as well. The heating pad is made by taking a resistance element of small cross section and considerable length, and winding it about with asbestos thread which is not only an electric insulator and fireproof but flexible as well. The insulated element is then sewed, or rather quilted, into the pad.

Electric Appliance Switches

Now in discussing the repair of these common appliances discussion of their switches has been omitted. Some appliances, especially of the cheaper sort, have no switches at all. Where this is the case, a switch should be provided. This can generally be most conveniently done by using a type of simple single-pole toggle switch which is made to be inserted in the extension cord. Both conductors of the cord pass into one end of this switch and out the other, but just as with the single-pole wall switches, only one of the conductors is interrupted by passing through the switch mechanism. This will be quite apparent on removing the two screws which hold the two halves of the switch shell together, and examining the interior. To insert the switch in the extension cord it will only be necessary to remove an inch or so of the outer sheathing of the cord, cut either of the two conductors, clean the insulation from the cut ends, wrap them about the two setscrew shanks, tighten the screws down, and reassemble the shell.

In buying a switch for this or any other purpose the amperage of the device should first be determined by dividing the wattage (which will be marked on the device) by 110 (volts), and a switch secured which is marked to carry the needed amperage.

Special Switches

Some appliances cannot be controlled by a single-pole switch. They are equipped instead either with a multiple position manual switch to offer varying amounts of heat (as the two-heat grill and the heating pad), a clockwork time switch to cut the current off after a predetermined time (as the automatic toaster), a thermostat to automatically maintain the desired heat (as the modern electric iron, the waffle iron, and the electric range), or a combination of these switching elements.

Multiple position switches are not really complicated, and any mystery about their operation will be quickly resolved by removing the cover from one and studying the contacts and blades and making a simple diagram showing the course of the current from the switch poles to the heating elements.

The switch wiring diagram in Figure 77 shows how a four position switch would operate to give a low, medium, and high heat with a grill or hot-plate. Notice that there are really two heating elements used. In the high heat position each is connected just as if they were two separate appliances. In the medium position only one is used. In the low heat position both are again used, but this time connected end to end so as to form one long element.

As connected for the high heat, the elements are said to be *in parallel*. Assuming each of the elements to draw 550 watts, the total connected load would be 1100 watts. Using either of the elements, but only one of them, for the medium heat, would—as you might expect—draw 550 watts. But using them both connected end to end for the low heat (in which case they would be said to be *in series*), the two of them would draw a total of only 275 watts! What has happened here to cause one element (medium heat switch position) to yield twice as much heat as two elements (low switch position), and two elements (high switch position) to yield four times as much heat as the same two elements (low switch position), but only twice as much heat (high switch position) as one element (medium switch position)?

Importance of Resistance in Applications of Electricity

Recalling the equation given in the last chapter (volts times amperes equals watts) and applying it to the low switch situation we must conclude that if the series connection changed the element wattage to 275 watts the amperage and/or voltage must also have changed to maintain the equation. Assuming that the voltage available at the outlet serving the appliance remained 110, the amperage must have become 2½. (110 V times 5 [A] equals 550 [W], and 110 [V] times 2½ [A] equals 275 [W].) And this is just what happened. Now recall also that the quantity of electricity flowing through a circuit (that is, the amperage) is limited for a given pressure (voltage) by the resistance of the circuit, and it must be apparent that the long element formed by the low switch position offered twice the resistance of the short elements.

In first defining the ampere we said it was that quantity of electricity which a pressure of one volt would push through a circuit offering a resistance of one ohm. We can now perhaps invest the ohm with a little more substance as the electrical measure of resistance without the equation which establishes its quantitative value becoming confused with the equation about volts, amperes and watts. This new equation (which is known as Ohm's law) goes like this:

Ohms equals volts divided by amperes
or *Amperes equals volts divided by ohms*
or *Volts equals amperes times ohms.*

Applying this to the single element used in the medium or the high switch positions, we have 110 volts divided by 5 amperes equals 22 ohms resistance. In the case of the long element used for the low heat we have 110 volts divided by 2½ amperes equals 44 ohms resistance. So the series connection of the two elements simply doubled the resistance of the appliance as it doubled the length of the resistance element.

The importance of this phenomenon is that in connecting up heating resistances (which is practically the only place in home appliances where series connections are used) it must always be remembered that the wattage drawn by the appliance will be changed (and hence it will not deliver the correct amount of heat) unless it is rewired correctly.

Automatic Switches

Where clockwork time switches are used, as with the pop-up type toaster, to shut the current off after a predetermined time, the possibility of repairing the timing element will depend entirely on its construction. Generally they are so assembled that they do not yield to being disassembled and repaired with the simple tools available to an amateur; but they are usually so designed as to outlive the appliance anyway, and in most cases where they get out of order it will be because of something very superficial, such as a bit of dust or grit between some working parts or perhaps a loose connection.

It is sometimes a good thing to approach such a mechanism with the attitude that it probably cannot be repaired, because being thus reconciled to throwing it away and replacing it with a new one, one feels free to do any amount of exploratory tinkering with the defective unit, and very often this will turn up the trouble, permit its repair, and suggest a means of preventing its repetition.

Thermostatic Controls

Thermostatic controls used on electric devices are basically the same as those already mentioned in the chapters on plumbing and gas in that they are thermometers which utilize the mechanical motion of the heat-sensitive element to do work which otherwise would have to be done by hand. In the case of the thermostats on electrical devices this work consists of opening and closing electric switches.

It is mostly the delicacy of their construction and the necessary fineness of the adjustments between their working parts which both puts these devices out of order and makes their repair difficult. About all that can be done for them, once a break in the control wires which connect them to the device has been eliminated as the possible difficulty, is to see that their electrical contact points through which the current is switched are clean, by drawing a piece of paper between them.

With the exception of the electric cooking range and electric water heater dealt with in other chapters, the devices described above are the ones most commonly encountered which use electricity to generate heat. There are many other applications where it might advantageously be used but for the limiting factor of the cost of the current.

Electric Motors

Electrical energy is transformed into motion and thus made to do work in a dozen ways around the house by means of the *electric motor* (Figure 78). As anyone who has ever ventured to dismantle one to find the source of its power will agree, the *motor* is at once a most simple and a most mysterious device. It has but one moving part, which because it rotates is called the rotor, or in certain types of motor, the armature. The other part of the motor, which is stationary and surrounds the rotor like a sleeve, is called the stator, or the field. This forms the outside shell of the motor, along with two end caps or housings which are attached to it with four bolts. By removing these bolts the ends of the motor can be taken off, the rotor slipped out, and the interior of the motor examined.

Caring for Motors

It is said, and with considerable truth, that all any motor requires is current, kindness, and a little oil. The electric current required by a motor is marked on the motor's name

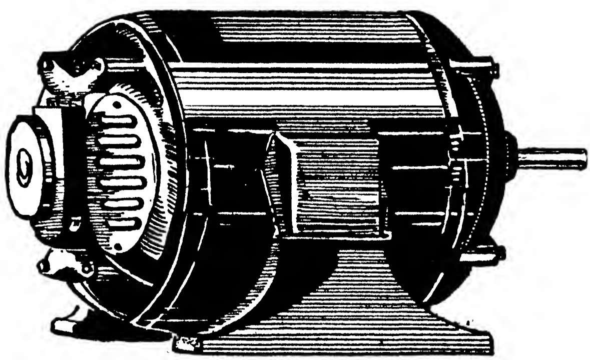


FIGURE 78—The Electric Motor

plate. There are three types of motors: direct current motors, which will operate only on direct current; alternating current motors for alternating current (which is much the commoner nowadays for domestic service); and universal motors which will operate on either type of current. The voltage too must be correct, which means that neither a heavy duty industrial motor made to run on 220 volts nor a six volt motor, such as an automobile starter motor, could be used on a 110-volt house line.

The kindness required consists in keeping the motor clean, keeping it dry, and not overloading it. Every motor is built to consume a certain amount of electrical energy, to turn at a certain speed, and to do a certain amount of work. If in any way the load imposed on the motor is increased beyond its rated capacity, it will do two things. It will slow down (or stop), and it will heat up. Even operating under its normal load, a motor transforms part of the energy used into heat; but it is so designed as to dissipate this heat to the surrounding air. A persistent overload, however, will generate heat faster than it can be disposed of, and thus burn out the motor.

Oil is required by the two bearings which cradle the shafts forming either end of the rotor. Some motors have sleeve bearings, which are just what their name would suggest; and some have ball bearings like a roller-skate wheel. Among the latter type some are packed at the factory with grease sufficient for the life of the motor, and sealed against its loss. These of course will require no oiling, and indeed cannot be oiled since the shell will lack oil holes through which to oil them.

Changing Motor Brushes

On one end of the armature shaft of all D.C. (direct current) and universal motors will be found an encirclement of narrow copper strips called the *commutator*, and pressing against the commutator from opposite sides two small carbon plugs called *brushes*, which are set in sleeves or brush holders attached to the end housing. The brushes are free to slide in the holders and are held in place against the commutator by springs. They are the only parts of the motor which require replacement in the normal course of use; they gradually wear away as the commutator revolves against them. They are removed by unscrewing the plugs which close off the ends of the holders. When this is done the brush springs will expand and extend beyond the ends of the holders so they can be seized and withdrawn along with the brushes to which they are attached. The commutator and brushes should never be oiled, because they are electrical conductors which carry current through the armature of the motor.

Replacing Bearings

After long years of service both the bearings and the commutator may become so worn away that the motor ceases to function smoothly. When this happens it is by no means necessary to discard the motor, although this is often done. Instead the end housings and the armature can be removed without even disturbing the mounting of the stator, and taken to a service man who with the necessary shop equipment can quickly force the worn bearings out of the housings and press new ones into place, and either smooth the surface of the commutator or replace it too with a new one.

How the Motor Works

A motor runs because magnetic impulses tugging at the rotor are set up when current flows through the windings of the machine, as can be shown in very much simplified form with a pocket compass and a small horseshoe magnet.

In this experiment the needle of the compass represents the rotor of the motor, and the object will be to set it rotating. To do this, first place the compass on a table and let its needle come to rest. Now lay the magnet flat on the table some distance due east of the compass and with its poles pointing north—that is with its legs parallel to the compass needle. Now slide the magnet sideways directly toward the compass, and watch the needle. As the magnet approaches, the needle will be seen to effect a quarter revolution, either clockwise so the north-seeking pole of the needle points east, or counter-clockwise so the south pole points east. What has happened is that the horseshoe magnet pole nearest the compass has a) attracted one pole of the compass needle (which is also a magnet) *and* b) repelled the other pole, in accordance with the law which says that like magnetic poles repel and unlike magnetic poles attract (each other). By alternately approaching and retreating from the compass with the magnet, the needle might be made to spin around continuously though a little jerkily, through the combination of the intermittent application of the magnetic force and the inertia of the needle.

An obvious improvement would be wrought by adding a second magnet pole of opposite polarity on the other side of the compass, and by having some means of "turning the magnetic force off and on" (either in the needle or the external magnet) without the necessity of moving the magnet. Likewise of course the small amount of energy represented by the residual magnetism of the elements in this model would be insufficient to do any real work. In a practical motor then, to take a simple direct current or universal motor as an example, the necessary refinements on the basic pattern exhibited by the model are effected as follows.

Structure of D.C. Motors

First, the magnets, both in the armature and the field, are not permanent magnets at all. They are electromagnets. If you will open the case of any D.C. (direct current) motor and remove the armature you will see the two poles of the field magnet inside the stator, and the way in which they are shaped to partially encircle the armature when it is in place. You will also see that around each pole is wound a considerable coil of insulated wire. These coils are called the field coils or field windings. When the motor is connected to an electric line, the current flows through these field coils, and in doing so it transforms the field magnet from an inert mass of soft iron to a powerful electromagnet. But it remains a magnet only so long as current flows through its windings. And that is what an electromagnet is—a core of soft iron wound about with a coil of insulated wire.

Now as to the armature: If you will examine it, you will see more clearly than any diagram or picture could show, how it is made. You will notice first around its entire circumference the repetition of the pattern formed by the copper commutator, that is, a series of strips of exposed metal, arranged like the staves of a barrel. The body of the armature is of iron (as you may have guessed from its weight), and the exposed strips are formed by grooves cut in its surface. Each of these grooves corresponds to one of the segments of the commutator, and the windings of wire in the grooves form half as many separate coils as there are grooves and segments, the two ends of a coil being soldered to the two copper commutator segments exactly opposite each other. All the segments are insulated both from each other and from the shaft of the armature.

So it is that by passing a current through any one of the coils the armature too will become an electromagnet, with a positive and negative pole, capable of being repelled by the poles of the field magnet. Now slip the armature into the frame, insert the brushes in their holders, and notice how neatly the brushes will conduct electricity to one coil after another, successively energizing and de-energizing each of them in rotation so as to make the armature revolve.

A.C. Motors

Motors made to operate only on alternating current (the name plates of which are always marked alternating current, or A.C.; instead of D.C., Universal, or A.C./D.C.) are even simpler in physical construction than the D.C. and Universal motors. They require no commutator and brushes, and certain of them (though not those of the fractional horsepower sizes encountered in household use) dispense entirely with the rotor windings.

Oiling Motors

The oiling arrangements of all motors are very similar, and they all require the same care in preventing them from becoming overheated, encrusted with dirt or dust, or wet. When a motor seems to be overloaded, and slows down or grows warm, and the trouble is not cured by cleaning and oiling the motor, the trouble should be looked for in the machine which the motor is driving.

TESTING MOTOR-DRIVEN MACHINERY

A setscrew is usually used to fasten the driving *pulley* to the motor shaft in *belt-driven* machinery such as the electrical refrigerator, wash machine, some heavy duty ventilating fans, and for fastening the *drive gear* in *gear-drive* machines such as the mangle. This setscrew must be kept tightened, except that to localize any trouble as between the motor and the driven element this setscrew and the drive pulley should be removed and the motor run idle. If it performs well thus without the load being connected, the trouble is in the driven machine.

Worn Bearings

There is one motor trouble the only symptom of which is often quite misleading. That is the matter of the motor bearings having become worn so that the shaft is too loose a fit within them. In high speed belt-drive machines such as the refrigerator (as compared to a low speed gear-drive machine such as a mangle) this may cause a terrific knocking sound, as though the entire machine were about to fall apart, and it is most natural to ascribe the trouble to the driven machine rather than the motor. If such a noise occurs as the motor starts up and stops or is interrupted after the machine gains speed, the cause of the trouble is almost certainly the motor bearings, even though the motor may idle perfectly with the load disconnected. The cure of course is to have the motor bearings changed.

Household Motor Appliances

Food Mixers

Kitchen food mixers operate under widely varying loads, and thus may be damaged by being inadvertently overloaded. A light duty mixer which will whip cream may almost stall if its blades are made to mix heavy dough.

Sewing Machines

A sewing machine motor, too, may slow down if an attempt is made to sew too heavy a material, even though the sewing machine may be well oiled and in good running order.

Vacuum Cleaners

The operation of a vacuum cleaner is discussed fully on page 9, but we shall illustrate the two types (Figure 79) here among the household appliances. Even a vacuum cleaner motor can be overloaded by running the machine with the nozzle closed off for any length of time, as can be seen by holding the hand over the end of the attachment hose and noting the change in the sound made by the motor as it slows down.

Door Bells and Buzzers

Another appliance which converts electricity into mechanical energy, and by means of an electromagnet too, is the door bell or signaling buzzer. Compared to the electric motor, however, its construction and operation are extremely simple. The four necessary elements are: the *push button*, which is no more than a tiny switch whose contacts are held apart by a spring except when the button is pressed, and which is practically trouble-free except for becoming clogged with paint through the carelessness of

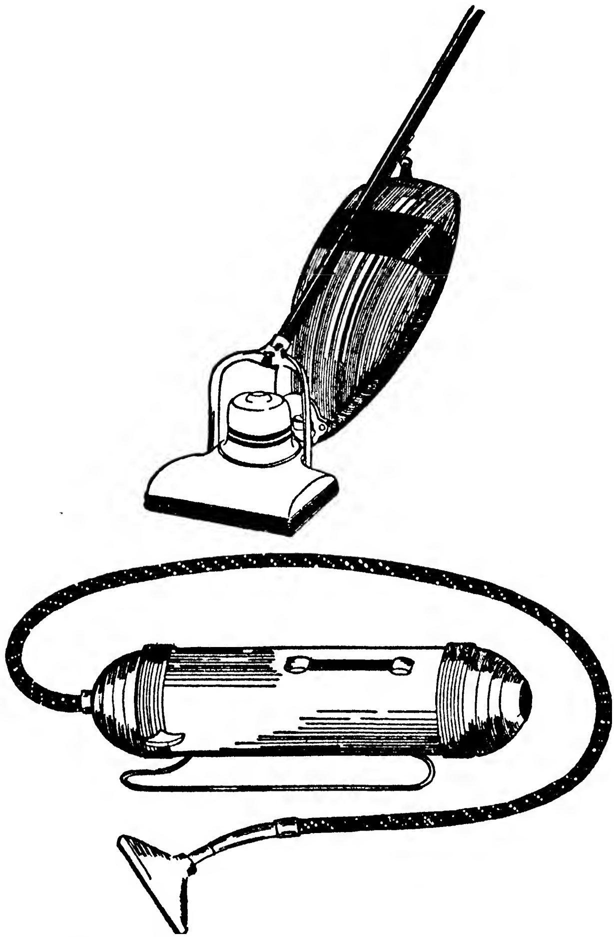


FIGURE 79—Two Popular Types of Vacuum Cleaners. Above, the Bag Model; and below, the Tank Type.

the painter (in which case it can be cleaned out or replaced); the *two wires* which connect the push button with the bell, which if short-circuited will cause the bell to ring continuously and if broken will prevent its ringing; a *connection* with a source of power; and the *bell* itself. (See Figure 80.)

Door bells and buzzers are not to be connected directly to the 110-volt house line. A bell could perfectly well be made to operate on 110 volts but this would be needlessly

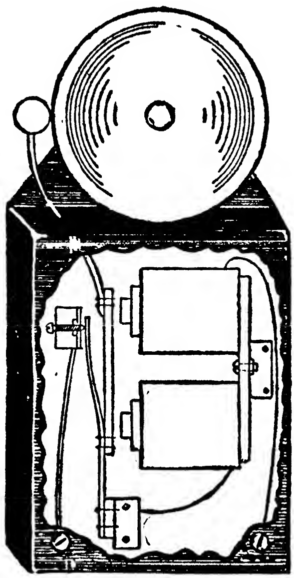


FIGURE 80—The Door Bell

expensive. It would require a heavier electromagnet, the contact points in the bell and in the push button would have to be made so as to prevent harmful arcing, and the same heavy wiring as is used for the house lines would be required to carry the current from the push button to the bell.

Bell Transformers

Consequently the bell is made to operate on six volts; and, in a house where alternating current is used, the bell current is drawn from a device known as a *transformer*. The transformer takes the 110-volt alternating current through two terminals marked P. or Primary, and delivers current at six volts pressure from two other terminals marked S. or Secondary. Usually the transformer is mounted directly on a ceiling outlet box in the basement, and it consists merely of two coils, insulated from each other and from a common iron core on which they are wound, enclosed in a light metal shell. The primary coil consists of many turns of fine wire and the secondary coil of fewer turns of larger wire. A step-down transformer such as this, if mistakenly connected in reverse, becomes a step-up transformer delivering a dangerously high voltage. A transformer uses no current except when the bell is rung, and requires no attention to keep it in order.

Direct current can not be transformed, and where it is used the bell must be operated from dry cells, and these will need to be renewed from time to time.

Structure of the Door Bell

The bell consists of a small electromagnet, a clapper, and the gong. A buzzer simply omits the gong. The clapper is pivoted at one end and held in position away from the gong and the magnet by a spring. When the push button is pressed and the circuit thus closed, the current flows to the electromagnet *through* the clapper. The magnet attracts the clapper, drawing it up smartly against the gong. But this breaks the circuit at the clapper by withdrawing the clapper from a contact on which it rested, and the magnet ceases to attract. The spring can then draw the clapper back, again closing the circuit, so that the clapper is kept in continual vibration so long as the push button is pressed.

Little can be done to harm a bell except to impede its moving parts with paint; and there is little that is worth doing to repair it should it somehow go out of order, since a new one can be secured so cheaply. The tone of a too-loud bell can be harmlessly muted by half a wooden clothespin or a wad of paper wedged between the gong and the frame which supports it, or it can be converted into a buzzer by removing the gong entirely.

Solenoid Chimes

If the core of an electromagnet were not securely fastened in place it would move lengthways through the coil every time the coil was energized, and the device would then be not an electromagnet but a *solenoid.*

This is just the principle of operation used in a type of door bell known as a chime or gong chime. In its simplest form the solenoid is mounted vertically so that its plunger rises to strike the gong when the push button is pressed, and falls back into the coil when the button is released. The gong of the simple vertical single-stroke single-note chime is no more than a short strip of metal loosely cradled in rubber horizontally above the coil. Correct mounting is important to its proper operation because if the gong becomes displaced so as to touch anything but its rubber supports its tone will be muted and distorted.

Two-tone Chime

The chief appeal of the chime is that its makers, unlike the vibrator bell manufacturers, use a gong which renders a pleasant, melodious sound of considerable resonance but no great loudness. Apparently on the theory that two pleasant musical sounds are even better than one, the production of a more elaborate model which rendered this interesting effect followed the successful launching of the single note type. Here the coil is mounted horizontally between two vertical gongs and the plunger moves through the coil both to the left and the right, striking one of the gongs at each end of its stroke. The solenoid action impels it toward one gong, and when the circuit is broken a spring causes it to rebound and strike the other.

These two-tone chimes have a disconcerting habit of "ringing themselves" if they are placed where there is any occasional draft or breeze, because instead of using short flat gongs they are equipped with brass tubes, sometimes almost a yard long, hung from cords. These may sway in the breeze and strike against each other or the wall. The only cure is to snub the lower ends against excessive movement by means of a non-metallic yoke attached to the wall. It should also be noted that these chimes will not operate on the standard 6-volt transformer, but require one with an output of 16 volts.

Musical Chime

The ultimate in novelty and in elaborateness both of construction and appearance is reached in the so-called "musical" chimes. These use more than one solenoid and as many gongs (the long tubular kind of course) as are required to render some particular melody, which is set off and continues to its conclusion merely by the pressing of the push button. Musical chimes require a 24-volt transformer and perhaps a peculiar musical taste, but are otherwise as trouble-free and sturdy as the other kinds, though necessarily more complicated in their wiring. Either a two-tone or a musical chime can be converted to a single tone merely by removing the unwanted gongs.

The Radio

In dealing with the various mechanical devices used about the home it has been our aim to explain the pertinent elements of their construction and operation in sufficiently simple and familiar terms to permit the amateur home mechanic to approach their repair with self-confidence based on a reasonable understanding of their nature.

With the radio (and the radio-phonograph) this is unfortunately not possible. From a purely structural point of view, the radio is both a delicate and an extremely complicated mechanism requiring specialized tools and apparatus to repair. Added to this, moreover, the interlacing of its several elements is such that a given trouble may spring from any of several causes. Thus even the diagnosis of a trouble requires not only special equipment and a fairly thorough general knowledge of electrical theory but a specialized knowledge of the application of this theory to radio circuits.

Connecting the Radio

There are, however, several simple difficulties which the amateur can remedy himself without recourse to the expert. To begin with, as with any electrical device, all *contacts* in a radio should be secure, and where insulation is required it should be maintained. The *antenna wire* should be strung between insulators and prevented from touching or scraping against anything. The *lead-in wire* should be soldered to the antenna, insulated for its full length and securely attached to the binding post of the set. The *ground wire* should make a good attachment to whatever is used as a ground. (See Figure 81.)

The split plug and convenience outlet serving the radio should engage each other tightly. With a direct current radio, it will be necessary always to insert the plug in the same way—that is, with the same prong uppermost—or the set will not work. The correct position can be found by experiment and the plug and outlet cover plate marked with a pencil to avoid future difficulty.

Small sets which are a snug fit in the cabinet should always be located a bit away from the wall to favor the dissipation of the heat which is generated; and if the extension cord grows warm it should not be coiled up but draped

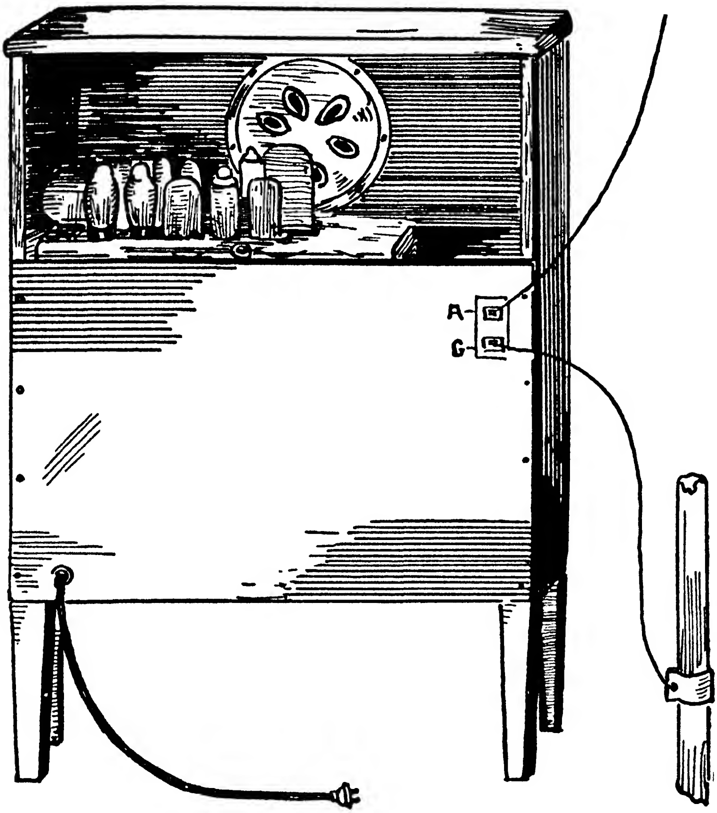


FIGURE 81—Radio (back view), showing Aerial *A*, and Ground *G* connections, and Extension Cord

out full length to permit the heat, generated by a resistance wire which it contains, to escape.

Radio Tubes

The cost of a complete duplicate set of *tubes* for a small or medium sized radio is not excessive, and if a weak tube is suspected of causing poor reception it can be located by replacing the tubes with new ones one at a time until one makes an improvement in performance—thus indicating which was the bad tube.

Servicing the Radio

The host of howls, squeals, hums, rattles, and whistles which a set may suffer may be caused either by adverse weather conditions, man-made static (that is, the interference of a nearby electrical machine), or by something amiss within the set, the tubes, or the speaker. The remedy required will depend on knowing just exactly what it is that causes the trouble, and the service man can often be helped in learning this by being advised when, and how often, and at what dial settings the trouble occurred, and how it sounded, as nearly as can be described.

The Radio-Phonograph

Radio-phonograph combinations, or—as they are also called—phonograph pick-ups, make for one more possible complication to the radio. Electrical disturbances from the phonograph motor (which is a small electric motor) may be reproduced by the radio speaker. The general effect is a humming or a buzzing, and it is easy to identify because it is not present when the motor is stopped. The cure is the addition of a small electrical condenser to the motor wiring, which any competent radio mechanic can install quickly and at low cost.

Television Sets

Television radios are a special class of radio apparatus not yet in wide use. They are tremendously interesting; but their repair is entirely beyond the mechanical facilities of the amateur even more than the ordinary radio circuits.

PART FIVE

Heat

CHAPTER XI

House Insulation

Types of Heating Plants

There is no part of a house which comes in for more complaint and criticism than the heating plant. And there is no type or kind of heating system which escapes the criticism. Whether the fuel is coke, bituminous coal or anthracite, fuel oil, or gas, and whether the system is a hot air furnace, a steam boiler or hot water boiler, manual or automatic, makes little difference. It would seem there is always something wrong with all of them. What is the trouble? Is it possible that no one has ever found out how to make a really good heating system in all the years of practice? That hardly seems reasonable. Are some types of systems innately good and some bad? Apparently not, or the mere process of costly trial and error by which harried householders are always switching from one fuel and one type of plant to another would reveal that.

The fact is that all heating plants (not only all types of plants if you please but practically all makes of plants) are good. They are more than good. They are excellent. They are so good that instead of being the most annoying they should be the least annoying of all domestic mechanical devices. Of course they have their minor defects, and are bound to be troublesome now and then, as every mechanical device is entitled to be. We shall later consider the possible defects and related matters: the fuel troubles; the combustion and heat transfer and distribution and control difficulties; and the question of comparative fuel costs as between different heating devices. But first let us see just what a heating plant can—and ordinarily does—do.

Houses Which Leak Heat

In the great majority of cases the heating plant does heat the house, and not once but a dozen times a day. Over and over the furnace pours out and distributes enough heat to heat the house and all it contains, only to have the heat escape outdoors almost as rapidly as it is generated. So any trouble in heating is often not with the furnace; it is with the house. It is as though one poured water into a sieve, endlessly and hopefully waiting for the sieve to fill; and then criticized the water for not staying inside.

Consequently we shall first examine the house and the ways in which it permits the heat to leak out, and suggest a few cures, and then give our attention to the furnace itself. This is neither the quick nor the easy way to attack this problem, nor indeed the popular one, but it is by far the more effective. And it must be emphasized that while the defects cited against the house will be simple and easy to understand and the cures suggested not difficult of accomplishment, the work must be approached with both patience and thoroughness and a determination to see it through. Unless this is done one might better just skip ahead to page 243 where the part about the heating plant proper begins.

When a pound of coal, or a given amount of any other fuel is burned, heat is given off. That is the first step in the process of heating a house. The fuel is burned, and its heat released. Once the heat is released it follows the simple laws outlined in Chapters III and V. It flows to whatever in its environment is of a lower temperature. Now the object in heating a house is to heat the people in it, and the last step in this process is invariably to heat the air in the house, which always surrounds the people. So the heating system is always arranged ultimately to heat the air in the house so that it in turn may heat the occupants.

Now what amount of heat is required to heat all the air in all the rooms of a house? Surprisingly little, really. But the air cannot hold heat against the appeal of other colder substances. It passes it on, to the occupants, to all the furnishings and furniture and every other thing in the house, and to the floors and walls and the roof of the house.

But the walls and roof pass it right on to the air outdoors. If this were not true, a few shovelfuls of coal would suffice to heat a house. But because the outside shell of a house does transmit the heat from its warmer to its cooler side the furnace must constantly burn more fuel to add more heat to make up for the loss.

Heat Loss Through Conduction

Now the shell of a house, and its materials and construction are not determined on a basis of its rate of heat conductivity. That is an afterthought. Up to a few years ago it was given virtually no consideration, and even now there are other qualities—waterproofness and durability, for instance—to be considered, and construction cost. These were bound to be controlling so long as the person who paid to heat the house did not understand and hence could not appreciate the effect in dollars and cents on the heating cost which the rate of conductivity of a house shell had. So a very large part of the total cost of fuel in a house the insulating quality of whose shell is poor must go just to balance conduction losses through the shell. That is the first loss.

Heat Loss Through Air Leakage

The second loss is through the simple escape of the heated air through any and every opening crack and crevice small and large which the house shell contains. The existence of these losses is obvious for the simple reason that we feel the draft which accompanies such air movements, —but their extent is positively startling. Exact figures are risky things to quote, but air losses amounting to the total air content of a house once every hour are quite ordinary.

Heat Loss by Radiation

The third way in which a house loses heat is by radiation from its outside surfaces, and this too is not inconsequential. Now what would the relative difference between the cost of one fuel and another, even if this were a hundred per cent, seem to be, compared to the proportion of the fuel which was used to heat the inside of the house and that used to heat the outdoors? And what indeed could a furnace maker do in the face of this situation except what he has always done, which is to make a furnace capable of burning much more fuel than a better house would require?

Overcoming Heat Losses

More pertinently, what can the home mechanic do to remedy the situation, that is, to cure that greatest of all heating complaints: "the furnace does not keep the house warm," or "the furnace uses too much fuel"? He can help to remedy the situation by correcting some of the faults in the house construction and ameliorating others. He can attack them all with varying effect depending on his particular situation, or he can ignore some which seem too difficult and attend to others with worth while effect. In other words, he can improve the insulating quality of the shell of the house.

The advantages resultant can be crystallized in any of several ways. Just as the economy gained from adding a jacket to a water heater tank offered the possibility of enjoying a clean fuel and automatic heat at no increase in operating cost, so one might change, after heatproofing a house, from hand-fired coal to gas; or perhaps the reduction in attention and the saving in fuel might make hand-firing become an unobjectionable chore.

Three Ways to Heatproof a House

The overall job of improving the resistance of a house to the transfer of heat through the shell is divided into three distinct operations, and a great deal of rather foolish competition exists between them for the reason that they are as a rule offered by companies which manufacture or sell and install only one of the three. They are: 1) the weatherstripping of doors and windows to reduce heat loss by air leakage around the peripheral cracks; 2) the addition of secondary or duplicate doors and windows known as storm doors and storm windows to reduce the conduction and radiation of heat through these thin spots in the house's skin; and 3) the insulation of the house by the addition of some material within the walls and roof which being of low density has a low rate of internal heat conductivity.

The house whose construction embodies all three of these elements is the very rare exception. The strongest proponents of storm doors and sash are: a) those who sell them, and b) everyone who has ever occupied a house using them. Exactly the same is true for both weatherstripping and wall and roof insulation. From which it can only be concluded that any *one* of these three methods is so effective as to convince a user that his house must be just about perfect, or so nearly so that further expenditure on the other two would not be worth while. And yet this is exactly wrong. It would be just as logical to attempt the repair of a bucket spouting water from three leaks by selecting one of the leaks for plugging and ignoring the other two. This does not mean at all that it is not worth while to do one of the jobs if it is not possible to do all three.

On the contrary experience has shown that any one of them will be most distinctly worth while. Two will simply be more worth while; and all three most worth while. And it is the advantage of the home mechanic that he can do all the work connected with at least two of them—the stripping and sash—himself, with a saving in cost which may permit him to have the third done professionally if necessary.

Weatherstripping

It is not a criticism of doors and movable windows that they leak air. No carpenter ever installed one and none ever will, either of wood or metal, which could be practical to operate, of reasonable cost, and which would still be air tight. The reason is that wood swells and shrinks as it absorbs moisture in damp weather and loses it in dry, with the consequence that a door or window fitted slack enough not to bind in wet weather will leak badly in dry weather. It does not matter what kind of wood is used nor how well painted it is; this will still be true. What is needed is a member which will fill in this space around the edges, but in such a manner as not to interfere with the necessary motion, and so made as to be self-accommodating to the changing size of the space which it occupies.

The scientific attention which the whole problem of house heating and insulation has had in recent years has confirmed these facts, and the enthusiastic acceptance which weatherstripping as an accessory operation has received from users is just now resulting in the marketing of windows which incorporate weatherstripping in their manufacture; but there is still much less than full agreement as to how weatherstripping should be designed.

For both doors and windows there are many makes of weatherstripping available, and many types—of metal, felt, and rubber. Of all these one type is especially recommended. It is known as *spring weatherstrip*, and is made of thin spring tempered bronze.

Weatherstripping for Doors

The principle on which this type of weatherstrip operates is illustrated in the sketches in Figure 82 on page 238. At *A* is shown the form in which it is used on doors, and on French or casement wooden windows, which open on hinges instead of sliding. It will be seen to consist of a substantially flat ribbon about half as wide as the thickness of the door or window, but preformed in manufacture to the shape of a shallow flat-sided trough with one narrow and one wide side. It is applied as shown there by being nailed through its narrow side about every 2½ inches with ½ or ¾ inch solid copper or brass (rustproof!) nails. With the narrow side of the strip held flat against the frame, the wide side will stand away so as to press against the edge of the door or window when it is closed.

Having attached the strip around the sides and top in the case of a door, or the sides, top, and bottom of a hinged window, its fit is then determined by slipping a calling card into the crack with the door or window closed and sliding it along to determine by the resistance offered its movement whether the unnailed edge of the strip is standing away from the frame enough to make contact with the door or window at all points. When spots are found where there is not sufficient contact, they are marked with chalk on the facing of the frame. Then the door or window is

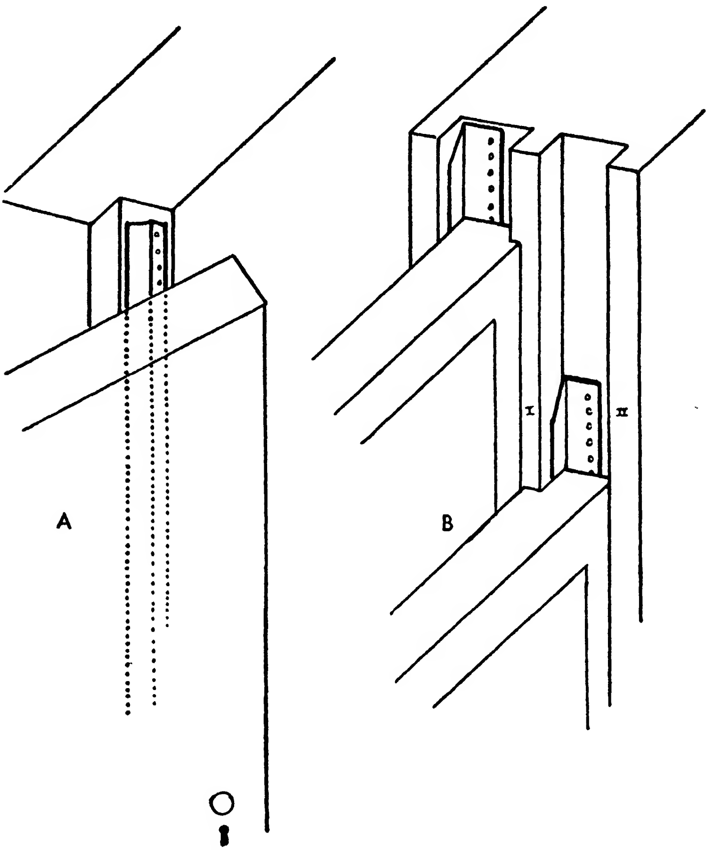


FIGURE 82—Weatherstripping. At *A* as applied to a Door, and at *B* for a Double Hung Window.

opened and the free side of the strip made to stand away from the frame more, but only at these places. This is done by gently stroking the strip exactly along the line of the crease with a dull knife. As this is done, the edge of the strip will be seen to bow outward a bit. Extreme care should be used in this operation lest it be carried too far, and the tool should be guided to travel exactly along the original crease of the metal. Although the metal is so thin and flexible that a very slight pressure will deflect its free edge at any single point, the cumulative pressure exerted against the door by an "overfitted" strip which presses too tightly all around the edge of the door becomes so great that the door will be difficult to open or close. The crack at the bottom of a door can be treated with the same strip, but to protect it it must be applied to the door itself. This will necessitate removing the door, which is best done by driving out the hinge pins.

Weatherstripping for Windows

Two types of strip are used for double hung windows: 1) the same type as for the door on the top and bottom of the window and along the inside face of the bottom rail of the top sash; and 2) the shape shown at *B* along the sides. Although the side strips must be about 2 inches longer than the height of the sash, for both the top and bottom sash they can be inserted without removing the sash, by carefully springing the strip into a very mild bend to get it started.

Considerable care must be used however to avoid kinking the strip too sharply when this is done. Where sash weights and cords are used, the upper strips must be cut out a bit to avoid interference with the cord pulleys. The cross strips will require no fitting. The side strips are fitted where necessary by viewing them from *outside* with the windows closed, and inserting a thin but not sharp blade (the rounded end of a hacksaw blade is excellent) between the sash and the strip and stroking the crease.

Refitting Windows

To be weatherstripped, windows should be fitted quite loosely, and if age and wear have not brought a sash to this condition, and most emphatically if it shows any tendency to bind or stick either through swelling of the sash or retaining mouldings being warped, the sash should be refitted. This is a messy but not a difficult job. It simply requires the removal of the inside and center stop mouldings marked *I* and *II* in sketch *B* and the planing down of one edge of the sash, when the tightness is sidewise between the sash and the window frame; or the removal of some of the encrusted accumulation of paint from the mouldings, when the tightness is between them and the faces of the sash.

Caulking Leaky Frames

Examination of the outside of a door or window frame along the joint where it meets the wall of the building will almost invariably reveal a crack as wide or a good deal wider than the one treated with weatherstripping. The efficiency of a weatherstripping job can be just about doubled, and at very little cost or extra effort, by treating this crack as well. This is done by means of a mastic caulking compound which is applied with a pressure gun not unlike an automobile grease gun. A bead of the compound is laid along the crack and then worked into a more or less smooth fillet by means of a physician's tongue depressor. It retains its mastic consistency for a good many years, and is available in various colors to match or blend with the color of the wall or casing.

Installing Storm Sash

Storm sash and storm doors operate to overcome a heat loss which weatherstripping does not correct in the slightest. They do this by trapping a layer of air between themselves and the regular door or window, thus establishing a temperate zone intermediate between the indoor high and the outdoor low, which retards heat loss through the *glass*. The storm doors and windows are hung just as are screen doors and full length top hinging window screens, usually being arranged to utilize the same hardware. Combination storm-screen doors are available with interchangeable screen wire and glass panels which can be changed with less trouble than changing the entire door; and they offer the added advantage of being much more sturdily constructed than the average screen door.

Storm members will quite naturally leak a certain amount of air around their edges, but they should not be weather-stripped—only well fitted. The very small amount (small when the inner window is weatherstripped) of air exchange which they allow to the outdoors prevents the condensation of moisture or the formation of frost on the glass.

Insulating the Walls and Roof

Insulating the entire outer shell of a house is quite an ambitious undertaking. Whether it can be done at all will depend on the construction of the house being such that the outside walls contain hollows into which the insulating material can be poured; and the degree of effectiveness of the job will depend on the thoroughness with which each hollow is filled.

What can always be done, and with very worthwhile effect, is to insulate the roof area, whether the walls can be insulated or not. Where the attic is unfinished and the roof rafters exposed on the underside, one of the batt or quilt type insulations can be applied between the rafters. Where the attic is finished, the insulation must be introduced from above, as by removing the ridge covering of the roof and pouring one of the fill type insulators into the spaces between each rafter. This is the method used by companies which specialize in insulating already-built houses, both for the roof and wall hollows. These specialists do the work so quickly by blowing the insulation into place through a hose connected to a monster blower which operates like a reverse action vacuum cleaner, that the small difference in cost between the material alone at retail and the price for the complete job done mechanically often favors the latter.

Fireplaces

Although a fireplace is primarily a heating system, its construction is of considerable importance in connection with any effort to insulate or weatherstrip a house.

This is because the chimney of an open fireplace will permit the escape of a very large amount of heat from a house—as much perhaps as all the unweatherstripped doors put together.

The thing to do is to examine the damper of a fireplace when the house is being weatherstripped or insulated, and if it does not close as air-tight as any well fitted door (and few dampers do), its air leakage should be corrected.

This will usually require the installation of a modern, air-tight damper. These devices are not cheap, but they will definitely pay for themselves in fuel saved.

CHAPTER XII

House Heating Systems

The general plan for a house heating system is shown in Figure 83.

The Hot Air Furnace

The very first type of central heating plant, with the fire in one big stove in the basement to replace several small fires upstairs, was the hot air furnace, now known, by unanimous agreement between the various manufacturers, as the warm air furnace. It consists of the stove proper, surrounded by a sheetmetal jacket starting at the floor and covering the entire stove including its top, thus enclosing it and trapping a layer of air between the two. From the top of the jacket radiate metal ducts which rise through the hollows of the walls like so many chimneys, one terminating in an opening in each of the upstairs rooms. One more duct, a very large one, enters the jacket at the floor; and this duct in the early hot air systems communicated through an outside building wall with the fresh air outdoors. (See Figure 84.)

The theory behind the operation of the system was perfectly simple. A fire being built in the furnace would heat the air in the jacket, which on being heated would rise through the heat ducts and enter the various rooms through the floor or wall *registers*, being in turn replaced by more fresh air drawn from outdoors.

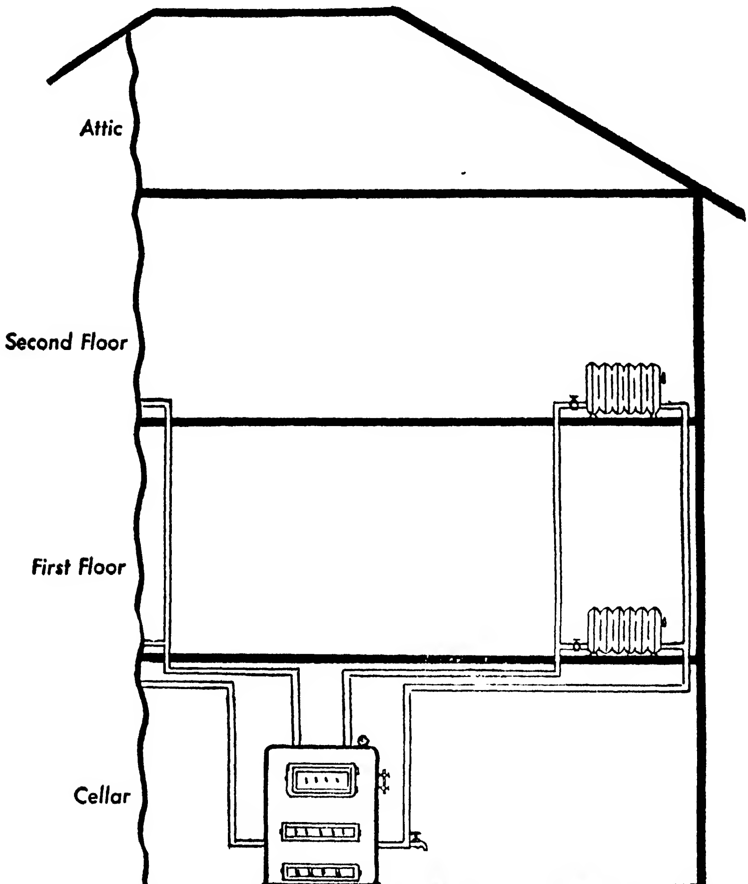


FIGURE 83—House Diagram Showing Arrangement of the Boiler and Radiators

The Re-circulating Warm Air System

That idea of combining the heating with automatic and uncontrollable ventilation by means of the fresh air inlet duct was a serious mistake. We know now that the problem, even with modern tight house construction, insulation, and weatherstripping, is to keep the air within the house (and the precious heat it contains) from being changed too rapidly. That one error in design and the amount of fuel

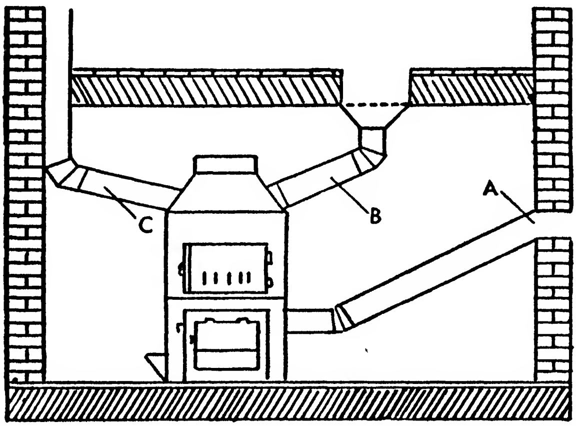


FIGURE 84—Diagram Showing Arrangement of the Hot Air Furnace. The Fresh Air Inlet is at *A*, and Heat Ducts to upstairs rooms at *B* and *C*.

it consumed gave more impetus to the development of the hot water and steam heating systems than any other single complaint against the hot air furnace. For a time indeed it threatened to make the hot air furnace extinct, but today the warm air re-circulating furnace is competing very satisfactorily with the more expensive water and steam systems. These modern furnaces omit the fresh air inlet. The heat registers are placed high on the walls; and from each room a separate return duct is run from near the floor back to the furnace, where these *return ducts* join to enter the bottom of the heat jacket. (See Figure 85.)

The Electric Blower

In the best systems an electric fan blower is inserted in the return duct near where it enters the furnace, to assist the natural convection currents. Thus the warm air system is on an even footing with the steam and hot water systems, which of course draw no cold air from outside the house but reheat the same air over and over except as the house-

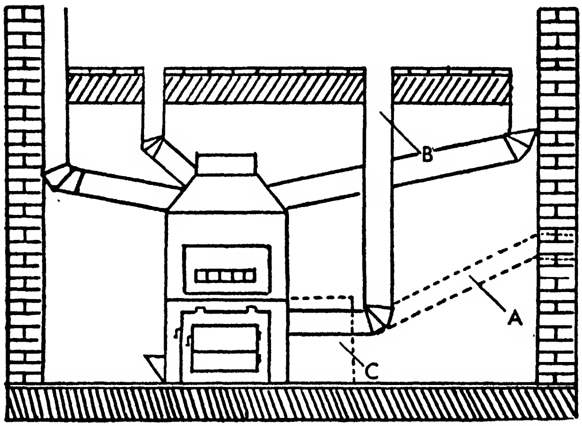


FIGURE 85—House Diagram Showing Conversion of a Hot Air Furnace to Re-circulate Warm Air. The Fresh Air Inlet Duct *A* is relocated to draw air from a First Floor Hall Register *B*, and if desired a Blower and Air Filter can be added by housing them in a Sheet Metal Box at *C* between the Return Duct and the Furnace Air Inlet.

holder admits fresh air deliberately for ventilating purposes. As a matter of fact the warm air system has an advantage in that an inexpensive air filter can be inserted in the return duct just back of the fan so that all the air in the house is filtered every time it makes a return trip to the furnace.

The indication then for an old fashioned furnace which seems inadequate to its job is to abandon the fresh air inlet. The installation of return ducts from all the rooms is an expensive job but this is seldom necessary. Usually the relocation of the duct so that it draws its air from the first floor hall is satisfactory; and where a two story house has a heat register in the second story hall this can be converted into a return duct by extending its lower end down to join the regular inlet duct, with very good effect.

The Air Filter

The addition of the electric blower at the same time the duct is changed will be little more trouble, and the use of both it and the air filter is recommended. Where air filters are used they must be removed when they become clogged, and either cleaned or replaced. The most popular type of filter is made of spun glass supported in a light cardboard frame; and ordinarily when the filter becomes clogged it is thrown away and a new one purchased. Similar filters used industrially are not discarded when they are soiled, however. They are immersed in a bath of gasoline or any other liquid which will clean them, and reused for years and years.

To increase the effectiveness of the filter it is treated with oil which clings to all the strands of glass and traps the dust. After cleaning a filter it should accordingly be dipped in light oil and well drained before being put back in use. It is safer to use a non-inflammable oil. Where the size or dimensions of the duct does not permit the convenient insertion of the regular filter, an equally effective one can be made and at less cost by using the same spun glass, which is available in quilt form as wall insulation, and mounting it in a simple frame which can be slid in and out of the duct. In this case two filters might be made and one kept always clean and ready to replace the clogged one.

Balancing the Warm Air Furnace

Sometimes a furnace will persistently overheat one room or one part of the house and underheat another part. This situation may be aggravated by changes in the duct work, or by the addition of a fan. To remedy it, the system must be balanced, or re-balanced to change the distribution of the air throughout the house. The air flow is controlled by two valves in each duct. One is at the register and the other

—which is simply a turn damper—is in the duct just beyond where it leaves the furnace. The register should normally be either fully open or fully closed, and the system should be balanced by means of the dampers.

To do this, open all the registers wide and all the dampers half, and notice over a period of time (preferably with the assistance of an inexpensive thermometer in each room) which particular rooms seem to be getting too much heat and which too little. Then close the dampers controlling the ducts leading to the warmer rooms just a bit *and* open those to the cooler rooms the same amount. Continue this, adjusting the dampers only slightly at each visit, and always balancing the opening of any dampers by a like closing of others. The idea is not to get the same temperature in each room, but the most comfortable temperature for each room; and when this is done and the system properly balanced the dampers will by no means present a symmetrical appearance. Some will be almost wide open, some almost entirely closed, and others at various stages between. The correct location of the handle of each should then be marked on the ducts, and the family advised not to disturb the settings.

The Hot Water Heating System

The basic difference between the warm air and the hot water heating systems is in the medium used to transfer the heat from the fire in the basement to the rooms upstairs. The warm air system, as we have seen, uses the air itself, warming it by passing it over the hot surface of the furnace fire chamber in the air jacket, and then sending it upstairs through the ducts and discharging it into the various rooms.

The hot water system attains the same final result but in a less direct manner and with a much more elaborate and expensive set up. It uses a special furnace, called a *boiler*, which is like the warm air furnace in having a jacket around the fire chamber, but one made to contain water instead of air. From the top of the boiler a pipe rises and branches out

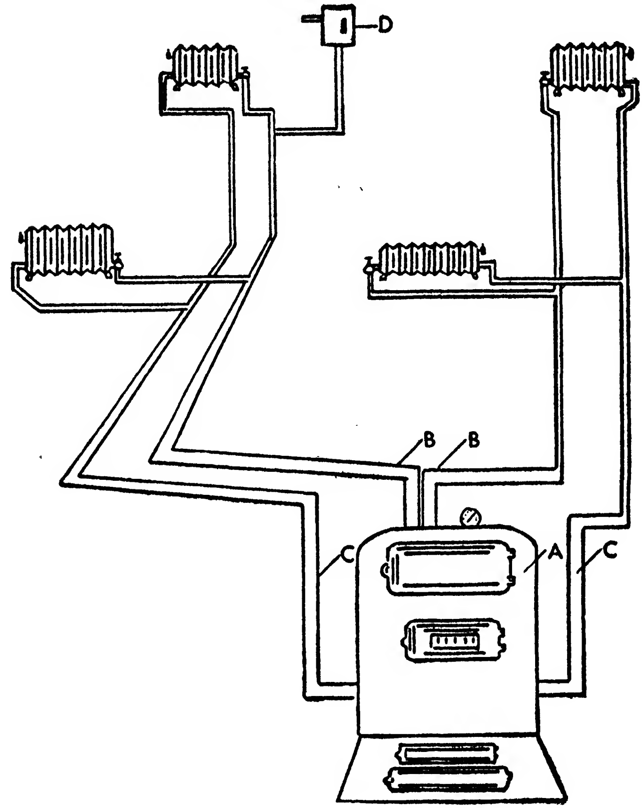


FIGURE 86—Diagrammatic view of a Hot Water System, showing the Boiler *A*, the Hot Water Pipes *B*, the Cold Water Return Pipes *C*, and the Overflow or Expansion Tank *D*.

to each room of the house, and in each room is an iron *radiator* which is connected to the pipe. Another pipe is connected to the opposite end of the radiator and this runs back to the bottom of the boiler, joined by the return pipes from the other radiators. (See Figure 86.)

How the Hot Water System Operates

In operation, all the parts of the entire system—the boiler, the pipes, and all the radiators—are completely filled with water. The water is secured through a feed pipe from the house cold water line, but the heating system is not under the same pressure as the water line. In fact it is not under pressure at all except the pressure resulting from the weight of the water in the radiators, pipes, and boiler. Located at some point higher than the highest radiator—usually in the attic—is an open tank called the expansion tank. This serves as a reservoir; and when the water level in it drops, the valve in the cold water feed line must be opened to refill it.

When a fire is built in the boiler, a convection current is set up in the water and the heated water rises through the upper boiler pipe and its branches into the radiators. As it does so, the cold water in the pipes and radiators falls back through the return pipe, and enters the bottom of the boiler. This continues as long as heat is added to the water in the boiler and transferred to the air in the upstairs rooms by the radiators.

The most frequent reason for the failure of a hot water system to heat up properly is the gradual dropping of the water level due to small but inevitable leaks, and evaporation from the expansion tank. It is not necessary, however, to examine the level in the tank. A gauge on the boiler marked "Altitude," and graduated in feet, shows the altitude of the top level of the water in the system. The gauge has an extra pointer, generally colored red and manually controlled. This pointer is merely for the convenience of the user, to remind him of the altitude at which the expansion tank begins to overflow, and to suggest that more water be added (by opening the valve in the feed line) when the black pointer falls more than a few feet.

Even keeping the water level up to the expansion tank will not alone assure that the system will be filled with water, however, because air—freed from the water as it is heated the first time—will rise and accumulate in the radiators. The heating efficiency of a radiator will be reduced to just the extent that entrapped air in the radiator prevents the entrance of the hot water. For this reason each radiator is equipped with a small *key operated valve* near the top, and the occasional bleeding of these valves is an invariable part of the routine of operating a hot water system.

Variations in the Design of Hot Water Systems

There are three variations in this basic design of the hot water system. First the open expansion tank may be omitted from the system if other provision is made for the expansion of the water as it is heated. If the system were closed *and* every part of it filled with water, something would have to burst if the water were heated because a) water expands when heated and b) it is an incompressible fluid. The alternate to the open expansion tank in the attic is simply a closed tank located above the boiler in the basement and connected to the system by a pipe which enters the bottom of the tank. Inevitably such a closed tank must contain air as well as water, just as would an unvented radiator (or the air cushion illustrated on page 93), and no attempt should be made to completely fill the tank with water. The small valving mechanism located atop the closed tank is not for this purpose. It is an *automatic pop-off* valve, preset to release air only if either through overfilling the system or overheating it the internal pressure becomes too great.

The second variation is the use of an automatic valve in the feed pipe which removes all necessity for watching the water level in the system. This valve is in effect a pressure reducing valve which will allow water to flow from the house line into the boiler whenever the boiler pressure (that is, the weight of the column of water in the system above the boiler) falls. These valves are available at all plumbing supply houses, are as simple to insert as any ordinary fitting, and are easily adjusted—at the time they are inserted—to open and close at just the pressure required by the particular system with which they are used.

The third variation is the use of only one pipe from the boiler to the radiators instead of the hot feed pipe and cool return pipe. This so-called one pipe system is now rather rare for hot water systems. It was developed in an attempt to bring the cost of hot water systems down nearer that of steam systems which operate quite successfully with only one pipe.

Balancing a Hot Water System

It sometimes happens that one room or one section of a house may consistently get either too much or too little heat. This is usually the result of the pipe sizes and radiator sizes or their locations having been miscalculated in the original designing of the system, or of the addition of radiators (and possibly long runs of piping to serve them) not originally planned for. Extensive piping changes to an existent system to correct this difficulty are quite expensive; but there are several minor changes which any home mechanic can make first in the hope of overcoming the trouble.

Proper Adjustment of Valves

To begin with, the manually operated *angle valves* with which all the radiators are equipped need not be set either full-open or full-closed. Rather they should be used as throttling valves, and all of them in the system adjusted simultaneously as was done with the damper controls of the warm air system, to balance the water flow through the various radiators to favor those which do not heat enough and reduce the heat transfer from the overly warm ones. In every instance this will help, and should be done first. Often it will reveal a small radiator inadequate even with its valve fully opened, and a large radiator still overly warm with its valve almost closed; and this may offer the possibility of reversing the positions of these two. This is a considerable nuisance, however, because it requires draining the system to the level of the lower radiator and some pipe fitting to attach the radiators in the new locations.

Rebalancing Two Riser Systems

In systems with two pipe risers from the boiler, another method of redistributing the heat within the system is to reduce the water flow to the section which is overheating by inserting in the line a washer especially made for the purpose. These washers are available with holes of various sizes, and operate by constricting the pipe and thus reducing the flow beyond the point where they are placed. An ordinary globe valve would do the same job and offer the possibility of subsequent adjustment, but the washers are considerably cheaper.

Rebalancing the system will not help much when the problem is one of more heat being required at all the radiators than the natural convection currents in the pipes can deliver.

The Automatic Electric Impeller Pump

In this case the circulation of the water in the system can be speeded up by means of a centrifugal pump run by a small electric motor, inserted in the return line at any convenient point near the boiler. The use of such a pump should be considered before it is assumed that the boiler is inadequate to the heating needs of the house; and particularly is it indicated when the addition of a new radiator impairs the performance of the system.

These pumps, called impellers, are very similar to the water pumps used to promote water circulation in automobile cooling systems. They come complete with unions for easy installation, and with a thermostatically controlled electric switch to start and stop the motor.

Steam Heating Systems

A steam heating system does not differ greatly from a hot water system in general construction. It uses exactly the same kind of boiler to generate the heat and very similar radiators to transfer it to the air in the rooms to be heated. The usual domestic steam system, however, is a single pipe system with only one connection to each radiator. Only the boiler contains water; and when they are cold, the pipes and radiators are filled with air. When the plant is fired up, the boiler water—being unable to lose heat by circulating through the radiators—reaches the boiling point and is converted into steam. As rapidly as steam forms it rises through the distribution pipe into the radiators. Here it surrenders its heat, condenses back into water; and the water—by the simple force of gravity—flows back to the boiler through the same pipe, to be again reheated into steam. (See Figure 87.)

The Air-Vent Valves on Radiators

The two prime conditions necessary to the satisfactory operation of a steam plant are first that the air be removed from the system to permit the steam to circulate, and second that the piping be so arranged that the condensate can flow back from the radiators to the boiler unobstructed. The air escapes from a steam system—just as it does from a hot water system—through small *air-vent valves* attached to each radiator (see Figure 88). The valves operate automatically, however, by means of a small thermostatic device coupled to the plunger of a needle valve. When the system

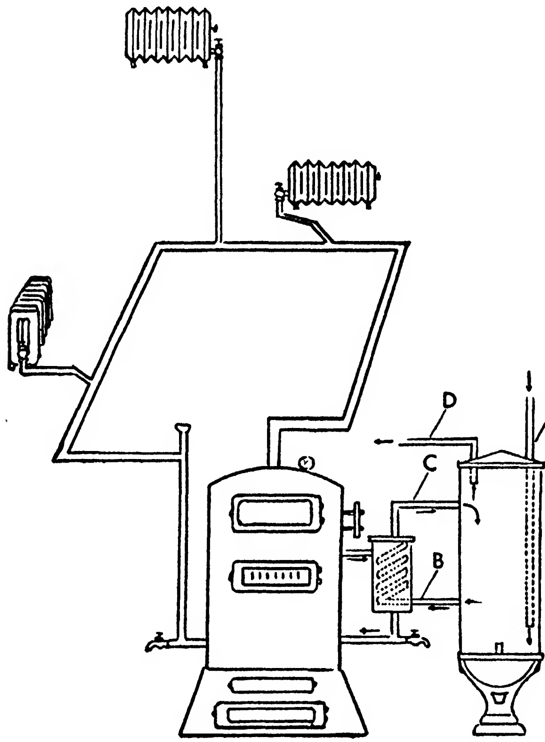


FIGURE 87—Diagrammatic view of a Steam Heating System with a Domestic Water Heater attached

is cold, the valve is always open; and it remains open until the advancing steam has driven all the air out of the radiator. Then as steam strikes the thermostat, being hotter than the air, it causes the air-vent valve to close. When the fire dies down and the steam in the radiator loses its heat and is condensed into water, the valve cools too and opens to admit air back into the system.

Sometimes a radiator refuses to heat up because the air-vent valve has stuck in the closed position, due to a bit of grit lodging in its working parts. This can often be cured by removing the valve (it screws into a tapped hole in the body of the radiator) and rinsing it in gasoline. More rarely the valve may remain in the open position, in which case

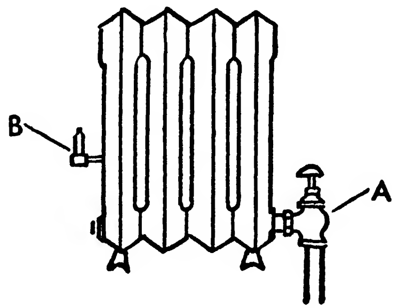


FIGURE 88—Steam Radiator, showing Manual Cut Off Valve *A*, and Air-Vent Valve *B*

steam will escape continuously. When this happens it is generally because the thermostat has broken; and this calls for a new valve.

Balancing the Air-Vent Valves

It is obvious that when air-vent valves on radiators near the boiler (where the steam pressure is initially higher as the fire is "brought up") and on radiators in distant or upstairs rooms (where the advancing pressure is at first lower) all have the *same size* vent openings, the distant radiators will heat up less quickly. What is needed to cure this difficulty is generally not to clean the vent valves but rather to equip the distant radiators with valves having *larger* openings, just as one would have to have a faucet of larger opening at the end of a long run of pipe than near the water meter in order to get an equal flow through both.

When a radiator distant from the boiler is slow in heating up, first switch its vent valve with one taken from a radiator nearer the boiler, which has been performing satisfactorily. If the nearer radiator continues to behave, the valve is all right; and buying another like it will not help. Therefore, it is well to get the type of vent valve whose opening can be adjusted manually so that the rate of escape of the entrapped air can be throttled to suit the requirement of the radiator on which it is used; and after installing it on the distant radiator adjust its opening as far as necessary to balance the system.

Curing Hammering in the Pipes

When a steam system sets up a loud hammering noise it is an indication that the water circulation is impaired. There are two causes for this. One is the habit of using the manual cutoff valve at the radiator as a throttling valve, attempting to control the temperature of the radiator by adjusting the valve to a partly open position. Ordinary angle valves used on domestic one pipe steam systems are not properly designed for such adjustment and may trap water in the bottom of the radiator unless they are either fully opened or closed. When the entering steam reaches this entrapped water, it is cooled and condensed, and forms a partial vacuum, which in turn sets the water into violent motion, slamming it noisily against the nearest elbow. So long as it does not induce hammering, however, there is no objection to throttling with the valve, and a little experimentation will establish the limits within which this can be done with each particular radiator.

When the system hammers elsewhere than at a radiator the cause is the same; that is, water is being trapped. The only cure is to locate the place or places where the line deviates from an even slope (just as was suggested on page 105 for the water piping) and to rearrange it so as to obviate the low spot in which the water is trapped. Such traps usually occur through the settlement of the building frame carrying the pipe along, or by springing a run of pipe out of alignment to overcome poor pipe fitting in the attachment of a radiator. Luckily as little movement of the pipe is required to cure trapping as to cause it, so it is often possible to remedy the trouble without pipefitting.

Boiler Fittings

In a steam system the level of the water in the boiler is read by means of a gauge glass, which is simply a vertical

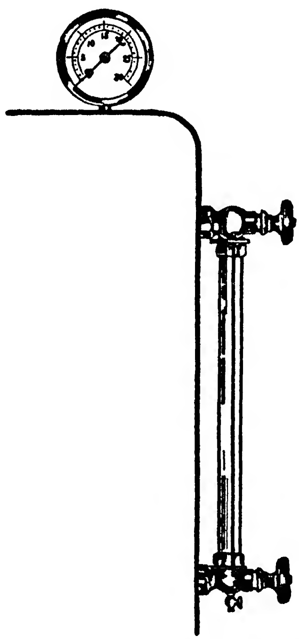


FIGURE 89—Boiler Trimmings: The Water Level Gauge and the Pressure Gauge

glass tube attached to the side of the boiler by means of two pipes similar to the outlet and inlet of an indirect heater; but the gauge glass is so placed that its lower connection is below and its upper connection above the normal water level so water will always stand at the same level in the gauge as in the boiler. The boiler is also equipped with a pressure gauge which will be seen to rise as steam is generated, and with a pop-off or safety relief valve located on the top of the boiler. This is pre-set to open at a pressure below the bursting strength of the boiler, should heat be generated faster than the radiators and pipes can dissipate it.

Reducing Heat Loss From the Pipes

The rate at which either steam or hot water pipes lose heat can be of considerable importance in the satisfactory operation of the plant. With a well insulated house, short runs of pipe, a boiler of adequate size, and no compelling need to reduce fuel cost, the uncontrolled losses from the pipes may be discounted as contributing to the general warmth of the house, which they certainly do. In the great majority of cases, however, it will be found much better to insulate the pipes thoroughly and to distribute the heat only at the radiators, where it will heat the air in the living portions of the house. The boiler too should be jacketed, and when these two things are done there is almost invariably a saving in fuel cost because it is cheaper to heat only the upstairs than both the upstairs and the cellar.

Improving Radiator Performance

It often happens that radiators rather than pipes are insulated, but inadvertently by being enclosed in radiator enclosures calculated to improve them esthetically. Modern covered or recessed radiators and their concealments are carefully designed so as to interfere with neither the radiation nor the convection heat transfer; but the usual sort of radiator cover built by carpenters, with a solid top, back and ends, and a perforated metal front grill, which is only 27% openings, is a different matter.

Such covers can be used, however, and the performance of the radiator improved by adding a small inexpensive electric fan within the enclosure, so aimed as to force air across the fins of the radiator and out into the room. Radiation of heat toward the room from the front of the radiator can be improved by painting the front of the radiator with flat black paint; and where the radiator stands against an outside wall radiant heat loss to outdoors through the wall area behind the radiator can be reduced by painting the back of the radiator with aluminum paint and by covering this wall area with reflective metal foil so attached as to form a dead air space an inch or so thick between the foil and the wall. While the concealment offered by a cover makes these three improvements particularly applicable, they can be used with any open radiator with like good results.

Repairing the Steam Heating System

Both steam and water systems suffer the same gradual accumulation of sediment and rust as was discussed in connection with the domestic water heater and the plumbing system, but to a greater degree because of the higher temperatures to which the water is heated and because the average householder never realizes the importance of removing the accumulation which interferes both with heat transfer to the water and with its circulation. This is corrected just as with the water heater, by opening the drain valve with which every boiler is (or should be) equipped and permitting the discolored water to drain off when the system is cold and the water at rest.

Draining the Boiler

When it is for any reason necessary to drain the system, it will be worth while to use this opportunity to flush it out thoroughly by introducing the nozzle of the garden hose at its various openings; but normally the system should not be drained, even for the summer, because water which contains air (as the water used to refill the system would) is decidedly more corrosive to iron than water which has lost its air through previous heating. Where the boiler feed water is drawn from the domestic water heater this trouble will be somewhat reduced. The added burden on the water heater will be small because either a water or steam system in good condition will require the addition of only a very small amount of water from time to time.

Trouble Due to Leaks

When the water level does continually fall more rapidly than is normal, it means that there is a leak somewhere; and its location and repair will require the same sort of effort as was suggested for the plumbing in Chapter III. A leak anywhere in the exposed piping, or even within the walls, will usually reveal its location quite readily; but when the return pipe of a steam system is buried in the cellar floor it will either be necessary to tear up the floor, or—what is usually more practical and cheaper—to abandon the buried run of piping and repipe above the floor. Generally speaking any type of repair which would hold against the pressure of the house plumbing will be more than adequate when applied to the heating system.

Trouble Due to Excess Water

Sometimes, quite rarely but most bafflingly, a system will suffer not from losing water but from gaining it; and not through a defective water feed valve but by a puncture in the indirect heater coil forming a cross connection between the water storage tank and the boiler.

Should this occur with a steam plant and the entire system fill with water, it is probable that in addition to the safety valve opening, most of the valve stems and possibly some of the threaded joints in the system would drip water. This would not mean, however, that the water had damaged the joints but simply that, while tight against the very low pressure developed by the steam, the system was not tight against the much higher house water pressure; and no fear need be felt of the system leaking steam after draining off the excess water (and of course mending the leak which caused the overflow).

The Vapor-Vacuum Steam System

There is a type of domestic steam system in which all the joints must be very tight for satisfactory operation. This is called a vapor-vacuum system. The practical difficulties of keeping the system really tight have interfered with its wide use. The vapor-vacuum installation, aside from being tighter than the usual low pressure steam system, differs from it only in having one-way vent valves on the radiators and a special type of pressure gauge. The valves open to permit the discharge of air as the steam rises, but remain closed when the steam pressure falls, with the result that the cooling steam on condensing back to water forms a partial vacuum in the system.

Now with this partial vacuum, when next the fire is built, the water in the boiler, instead of boiling when its temperature reached 212 degrees as it would in an ordinary system subject to atmospheric pressure, would boil at a lower temperature (provided of course that the vacuum "held" in the meantime). Thus the distribution of steam to the radiators would begin as soon after a fire was built as with a hot water system. The special gauge used with the vapor system is arranged to show both the extent of the vacuum realized when the boiler is cold and the pressure of the steam when the fire is up.

For satisfactory operation the system should show a vacuum reading of about fifteen inches on the gauge when cold, and should lose no more than an inch every two hours. Failing this the leaks can either be patiently sought out and mended or the advantages of the low temperature vaporization abandoned and the system operated as an ordinary low pressure system. In this case two-way vent valves should be installed on the radiators to prevent the sucking in of air at any point below the water level where the air would to some extent be absorbed by the water, thus promoting corrosion.

Automatic Controls

It will be seen from what has been said about the heat transfer and distribution elements of the various types of plants that there are at least several heating troubles which should not be blamed on the fire. And there are several more which, as we shall now see, grow out of the faulty operation or mishandling of the semi-automatic and automatic controls which the various plants use to retard or increase the rate at which the heat is generated. The detailed arrangement of these controls will vary from one system and one fuel to another, but basically they are very similar.

The Thermostat

The heart of every heat control is the thermostat (Figure 90). It should be located at a point in the living portion of the house convenient for adjustment. It measures the temperature at this location, and—according to the setting which is given its manually controlled dial—sends an impulse to the fire which stops the heat when temperature *at the thermostat* has reached the desired point, and then starts it again when the temperature at the thermostat has fallen a certain number of degrees. The commonest complaint about the thermostat is that it fails to control

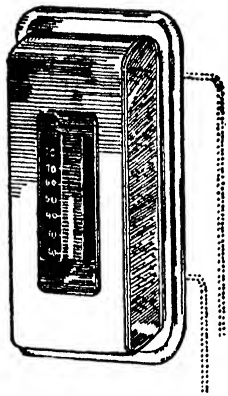


FIGURE 90—The Wall Thermostat Used to Control the House Heating Plant

the temperature of some other room, or of the entire remainder of the house satisfactorily. This it will most emphatically fail to do. A thermostat set to maintain a temperature of say seventy in the room where it is located, will do just that, quite regardless of the temperature anywhere else. In other words the satisfactory operation of a thermostatic heat control is predicated entirely on the system being first balanced so as to deliver such varying quantities of heat to various rooms as may be required to make up the differing heat losses of each room. When this is done, by any of the methods already suggested, the thermostat will do its job—generally for years—with no repairs.

With hand-fired coal, all that the thermostat will be able to do will be to increase or decrease the flow of air to the fire pot by activating the draft doors. With a coal stoker, it will regulate both the fan forced draft through the fire and the rate at which the fuel is fed to the fire. With an oil burner, it will turn the burner off and on. And with a gas burner it will do the same, just as a water heater thermostat does for the burner of an automatic side-arm heater.

When a thermostat really breaks down, the quickest remedy is to call a local service man, and the cheapest is to disconnect and remove the thermostat from the wall and mail it back to the maker.

Combustion Difficulties

When a hand-fired coal fire fails to respond to the draft controls properly, whether they be automatic or manually operated, there are two things to do. The first is to regulate the damper located in the smoke pipe so that with a brisk fire burning and the check draft closed and the ash door draft open, a piece of paper placed over the slots in the firing door will just be held in position by the suction. The fire door draft should then be closed and left closed. The second thing to do is to stop firing the furnace (or boiler) improperly. There is a technique by which any grade or size of any fuel which reaches the domestic heating market can be satisfactorily hand-fired in any furnace or boiler now in use. The producers' trade associations of the bituminous coal, anthracite, and coke industries have prepared and done their best to distribute—both directly and through fuel retailers—free booklets which contain precise and exhaustive instructions on this subject, and to a large extent the furnace and boiler manufacturers have done likewise.

Both coal stokers and oil burners will require the attention of expert mechanics when they fail, except for such minor matters as a broken wire or loose connection which the home mechanic can discover without disturbing the working mechanisms. It is now quite generally agreed that oil burners should have the regular attention of a service man who by periodic inspections and a little minor but expert tinkering can keep the device in good operating order and prevent serious troubles. Progressive oil dealers who have lost customers through the conversion of plants to gas for no better reason than the repeated breakdown of neglected oil burners now quite frequently offer burner maintenance service on a contract basis, and at a price which is a real bargain.

Gas is assuredly the most convenient and trouble-free of all the fuels. It is literally possible to light the burner in the fall and forget it until spring; and even these two jobs (and the incidental inspection of the burner and pilot and thermostat to see that they are in proper adjustment) the gas company will gladly do.

Cleaning the Combustion Chamber

No matter what type of heating plant is used, nor what type of fuel or burner, the combustion chamber will accumulate a layer of soot, dust, and fine ash, which must be cleaned out periodically to keep the plant operating efficiently. This accumulation not only obstructs the smoke passage but acts as an insulator preventing the heat from the fire from being transferred readily to the air or water.

In summary, it should be noted that the difference between the satisfactory and unsatisfactory operation of a heating system is very rarely dependent on any one factor, but rather on the combined effect of a number of them. Some in themselves are small matters, but taken together they are important. A little accumulation of sludge and scale in a boiler might alone be unimportant, and so might a slight imbalance in the system, or some unnecessary heat loss through an uninsulated area of exposed wall, or a few leaky windows, or a deposit of soot, or a defective circulating pump, or a run of uninsulated pipe in a cold part of the house; but taken all together their effect would be tremendous. And the only way to handle them is to go after them methodically, correcting one after the other.

PART SIX

Ventilation and Air Conditioning

CHAPTER XIII

Ventilating the House

THE TERMS "ventilation" and "air conditioning" are both somewhat misused and misunderstood, and the nature and operation of the machines employed to accomplish them have been surrounded with a bit more mystery than seems necessary.

As a matter of fact all the mechanical elements involved are familiar ones which have been dealt with already in previous chapters, so it will only be necessary here to explain a bit about the way in which they are combined to do these jobs.

VENTILATION AS AN EXCHANGE OF AIR

To *ventilate* is to open to the free passage of air. Accordingly, any opening in the shell of a building is a part of its ventilating system, whether that is its primary function or not; and it is important to keep sight of this because a good many of the problems of modern "controlled" (that is forced and regulated) ventilation revolve around controlling or preventing such inadvertent ventilation as occurs through leaky windows and door openings, fireplace chimneys, and so forth. This inadvertent ventilation and its control was covered in Chapter XI in connection with insulation and weatherstripping.

The only reason for wanting to ventilate a building (that is, exchange the air which is inside for some of that which is outside) is because the physical characteristics of the outdoor air—its temperature, odor, humidity, and cleanliness—are presumed to be better.

The three simplest devices for promoting this exchange of air are: 1) an ordinary electric fan placed at an open window; 2) a heavy duty electric fan called an "attic fan," which draws fresh air into the house by exhausting the heated air from the attic; and 3) the electric force fan described in Chapter XII, which will move air past the warm air furnace and through the heating ducts to the room registers, provided the intake to the fan is connected to the outdoors through a ventilating intake duct.

The Electric Fan

The ordinary electric fan (Figure 91), being a motor driven device, may have any of the troubles found in motor devices, which have been discussed in Chapter X. Apart from the motor, however, the fan has two other points where trouble may develop. The blades may be bent and cause the machine to vibrate unduly. This can ordinarily be corrected by carefully straightening them back to their original alignment. Also, the setscrew which fastens the blades to the motor shaft may become loose. The construction is such that you need not hesitate to tighten down the fan setscrew with a screwdriver, as you would any other setscrew.

Ventilating Fans

The effectiveness of a *ventilating fan* (Figure 92) is determined first by the volume of air it is capable of moving, and second by the superiority of the outdoor air over that inside. A great deal of money has unfortunately been spent for electric ventilating fans which are of no real use simply because to keep their price low they were made too small

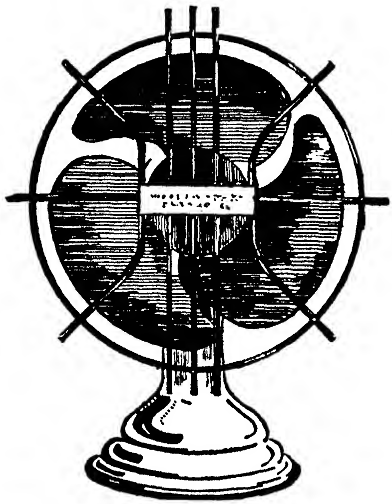


FIGURE 91—The Electric Fan

to move any significant volume of air. The name plate, or at least the catalog description, of every ventilating fan will undoubtedly carry the rated capacity of the fan in terms of the number of cubic feet of air which it will move per minute.

For effective summer ventilation a fan should change the air in a room every 30 minutes. By determining the volume of the room or rooms which you wish to ventilate and comparing this with the rated capacity of the fan which you are considering, you can predict the results. Generally speaking when this is done the result of the calculations indicates a ventilating fan with a motor so large and expensive that it seems unwise to attempt to ventilate the entire house.

However, this is no reason for abandoning forced summer ventilation altogether. You can obtain a ventilating fan capable of serving one or a few of the rooms, preferably downstairs ones on the shady side of the house; and you can use these rooms as much as possible during the hot daylight hours.

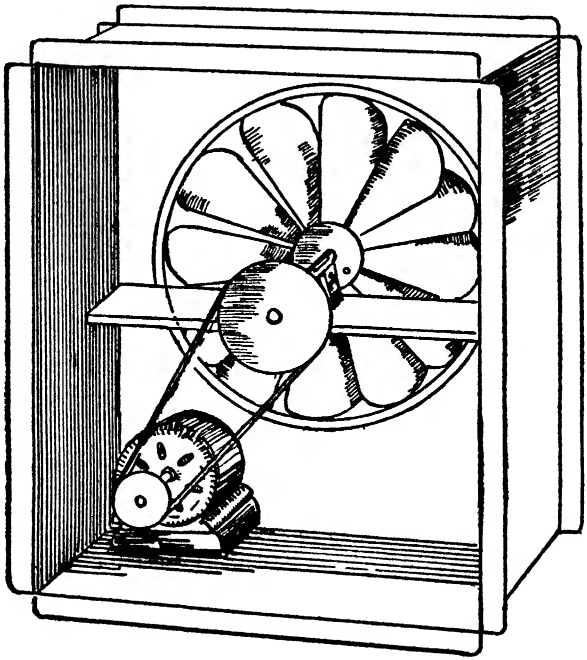


FIGURE 92—The Electric Ventilating Fan

USING THE BLOWER FAN OF A WARM AIR PLANT FOR VENTILATING

If your home heating equipment is one of the modern forced warm air heating plants equipped with blower fan, you can have forced ventilation at only the cost of the electricity required to run the fan. It is too bad that so many of the warm air heating systems are installed without an auxiliary air inlet to the fan to permit their being used for summer ventilating, because any such fan of a size to heat the entire house adequately in winter will move more than enough air to ventilate a downstairs room in summer.

To use this fan it is necessary only to close all the return duct registers in the house, all the heat duct registers except in the room to be ventilated, and to provide an air inlet to the fan by removing a section of the sheet metal return duct near the fan. The fan will then draw cool air from the basement into the duct system and blow it into the room upstairs.

Adjusting Windows, Doors, and Openings for Ventilating

The ventilated room should then be kept closed except for one opening to permit the escape of air. This opening can be either a window, or—when the arrangement of the rooms permits it—the door leading to the stairway upstairs. In the latter case all the other doors to the stairway and upstairs hall should be kept closed *and* the attic scuttle (which must of course be located in the upstairs hall) left open. Then, with an attic window or ventilator left open, the attic air will also be changed and the upstairs rooms thus also kept cooler.

This arrangement is just about the practically ideal one for simple fan ventilation, and the improvement produced is ample to repay the cost of cutting an attic scuttle if necessary. Where a warm air heating system without a force fan is in use, the basement is still the best location for the ventilating fan, using the warm air duct, as before, to convey the fan draft upstairs. In either case the basement windows and doors should all be closed except one window furthest from the furnace. By doing this the fresh air drawn into the fan will be made to travel the length of the basement; and in doing so, because in summer the basement is ordinarily cooler than the air outdoors, the air will be cooled appreciably before going upstairs.

Where no warm air duct system is available for this use, the fan can be put in the usually recommended location, in the attic, and the air drawn as before through the hall. In this case, however, instead of drawing air into the room direct from outdoors through an open window, consideration should be given to the possibility of cutting a register through the floor to the basement (or of having a mechanic do it), to get the advantage of the basement pre-cooling.

CHAPTER XIV

Air Conditioning

WHEN MORE is done to air than merely move it from outdoors to inside the house, the system which handles it begins to take on the nature of an air conditioner.

THE MEANING OF AIR CONDITIONING

Air conditioning is the supplying of air automatically controlled and regulated as to its temperature, humidity, and cleanliness; and while ventilation is a part of this job, it is only a small part of it. Intermediate between simple fan ventilators and full air conditioning systems are a host of systems called partial conditioners which perform one or more of the conditioning functions, but not all of them. A full conditioner must have a fan to move the air, a furnace to heat it in cold weather, a cooling apparatus to cool it in hot weather, a filter or washer to clean it, a humidifier and a de-humidifier to control its moisture content, and—to avoid the dank odor which plagued the early conditioners —a ventilating arrangement to continuously dilute the air with fresh air from outdoors. (See Figure 93.)

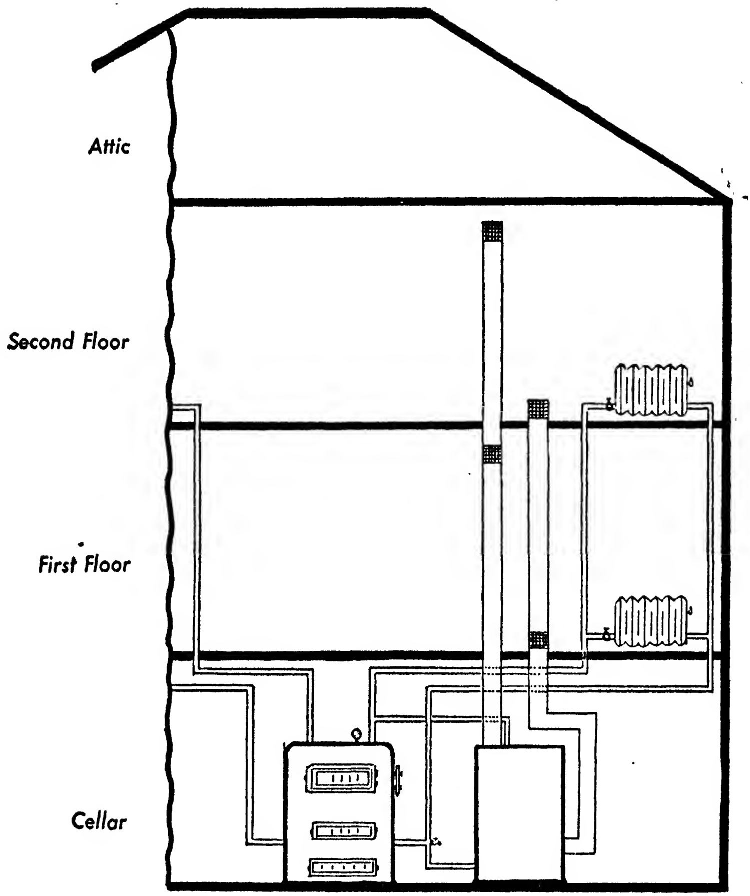


FIGURE 93—House Diagram showing an Air Conditioning System using both Radiators and Air Ducts

THE EQUIPMENT NEEDED FOR AIR CONDITIONING

The furnace is of course familiar already; the air filter was explained in the section of Chapter XII describing the installation of a force fan in the warm air system; ventilating has just been dwelt on; and this leaves the washing, humidity controlling, and the cooling apparatus as the only unfamiliar elements. The cooling apparatus is no more than the electric mechanical refrigerator mechanism which is described in Chapter XVI, but built to a scale to cool a whole room or house instead of a refrigerator. The cost of full air conditioning equipment is such that as yet it is seldom applied to an entire house.

Conditioning the Temperature and Moisture of the Air in the House

Generally speaking the air in summer is not only too warm but too humid, or moist, for human comfort, while in winter it is too dry (that is, its relative humidity too low) as well as being too cold. This is just another way of stating the physical law that warm air will support, as vapor, a great deal of water, and cold air but very little. Naturally then, the way to extract the water from the warm summer air is to cool it. The air conditioner does this without any special dehumidifying equipment other than the expansion coil of the cooler. As the air is blown over the coils by the fan and cooled, it deposits its moisture on the coils exactly as the air in the mechanical refrigerator does (*see* Chapter XVI, page 294); but because the conditioner unit is set to operate so as to prevent the coils falling below the freezing point of water, the condensed water does not cause annoyance by forming frost on the coils as in the refrigerator.

In winter when the conditioner furnace has warmed the air to a point where it will carry the required moisture, a humidifying device must be used to supply the moisture. This is either a pan of water replenished by a connection to the plumbing line, from the surface of which the air—in passing over the pan—evaporates the needed water, or a system of wicks hung in the pan, or a fountain emitting a very finely divided spray of water past which the air is blown.

Keeping the Air Conditioner in Order

In a well designed system which is not overloaded by being made to serve too large a living area, all the elements of the conditioner will function with no more attention than is suggested in the maker's instruction book which details the minor variations in design peculiar to his arrangement; and the necessary delicacy of the automatic controls required suggests that the home mechanic should go no further without expert assistance.

The Humidifying Ventilator

There is one device which lies between the fan and the air conditioner for summer use which is worth mention. It is a very simple summer cooling, filtering, and humidifying ventilator, which is of great utility in those semi-arid areas where the summer air is hot *and* dry. It consists of a ventilating fan of the sort already described, directly in front of which is placed a vertical rack of excelsior kept wet by a constant dripping of water from a faucet, and also any necessary duct work. The excelsior filters the air; the air—being hot and dry—evaporates the water and is thus humidified; and the evaporation of the water cools the air (because—as is pointed out in connection with both the steam heating plant and the mechanical refrigerator—the conversion of a fluid from a liquid to a vapor is always accompanied by the absorption of heat). This neat and inexpensive device is known as a desert cooler. By an interesting paradox this same setup can be used to de-humidify and cool the air in those very rare situations where a practically unlimited supply of very cold water is available. Then the cold water so cools the warm humid air passed over it that the air surrenders its moisture as its temperature falls, and is thus both cooled and dried.

Humidifying Devices for Steam Heated Homes

In homes using steam heat there are two inexpensive devices which are often tried to humidify the air, with uniformly poor success. One is a pan of water placed on the radiator; the other is a radiator vent valve which is kept open and spurting steam. The pans fail because they present

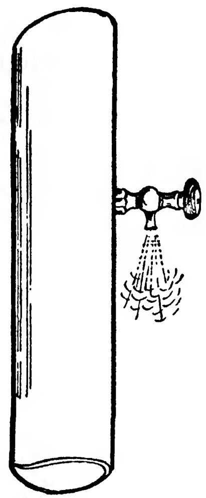


Figure 94—Manual Vent Valve attached to Steam Pipe to spray humidifying steam into the room

too small a water surface to effect any material amount of evaporation, which incidentally would have to amount to about a pint per hour per room to be helpful; and the steam vents fail because to get the steam through the radiator to the vent keeps the room too warm. This latter device too is dangerous to use unless an automatic boiler water injector is used to keep the water level up to replace the water loss through the vent. A pan with a very large water surface and a fan blowing air past it might be partially effective except for its unwieldiness and the nuisance of refilling it; and the steam jet vent would be fairly good if only it were screwed into a hole drilled and tapped into the steam pipe instead of into the radiator vent valve hole, so that it could spray steam without the radiator having to be turned on full blast. (See Figure 94.)

Chemical Absorption De-humidifiers

For de-humidifying too there is currently a device being marketed which is perfectly sound in theory but ineffective as now presented. It is no more than a metal basket containing a few pounds of calcium chloride, a chemical which has the strange characteristic of absorbing moisture from its surroundings much as table salt will, but much more so. The difficulty is that a mere few pounds of the calcium chloride will soon reach its saturation point and become ineffective until the weather cycle has revolved through a spell dry enough to permit the air to reabsorb some of the moisture from the chemical and restore to the chemical its capacity for absorbing moisture.

Now a home mechanic with a bent for building things might use the calcium de-humidifying idea very effectively by arranging *two* baskets or beds of about 100 pounds capacity each (the calcium is even cheaper than salt when bought from a building supply dealer), and inserting them in the duct system of a warm air recirculating furnace of the type that has an electric blower to move the air through the ducts, and adding another duct communicating interchangeably to an outdoor vent and a small gas burner. The air in the house would then be de-humidified by passing through one of the calcium beds until the calcium had become saturated with moisture, whereupon by connecting it to the burner and the vent, and lighting the burner, the heated air passing through the calcium would evaporate the water and dry the calcium. Meanwhile the other calcium bed would be in use, absorbing more moisture from the air in the house.

PART SEVEN

Kitchen and Laundry Appliances

CHAPTER XV

Cooking Stoves

Types of Cooking Stoves

Cooking stoves are manufactured in many types, varying in the fuel they use, which may be: wood, coal, kerosene, gas, electricity, or a combination of two fuels. Just as with house heating plants, there are some ailments and difficulties common to all types of cooking stoves and some peculiar to the particular type of fuel used.

Before the advent of central heating it was an important function of the kitchen range not only to cook the food, but to help heat the house as well; and even today too many stoves still generate heat in quantities sufficient for the latter job, so that the chief complaint against them all is that they "give too much heat," especially in the summer.

Wood and Coal Stoves

In this respect the wood and coal stoves are worst, and there is little that can be done to remedy the matter except to develop a technique of firing which will keep as small a fire alive as possible and to be sure that the oven heat control (by opening which the hot gases from the fire are detoured all around the oven before escaping up the stove pipe) is kept closed except when needed.

Kerosene Stoves

To avoid the unwelcome heat of a wood or coal range in areas where gas service is not available, kerosene stoves are used. There are two kinds of burners in use, the wick and the wickless type. They both operate in the same way, however, by picking up kerosene through capillary action from a circular trough at the base of the burner, the wickless type by means of an asbestos ring. Fuel is fed to the burner troughs through a pipe line running below the burners and fed from a reservoir behind or at one end of the stove, the flow being controlled by a needle valve at each burner.

Kerosene stoves will work improperly if they do not stand level, the fuel either failing to reach the burner or flooding it; and if the fuel is not of a good grade and free from water, the flame will splutter. The wicks or burner rings should be lightly cleaned each day to remove charred material, and the troughs should be cleaned out to remove the particles which will accumulate there. This is about the only attention required except to flush out the pipe line occasionally; but if these things are not done no kerosene stove will operate satisfactorily.

Gas Stoves

Gas stoves operate exceptionally well even under adverse conditions. However, there are two matters which may need attention. The first is the misadjustment of the burner or—what has the same effect—its being dirty. (The construction and adjustment of gas burners was explained in

Chapter VIII.) The second is the stove heating the room much more than is necessary when the oven is in use.

Some years ago practically all ovens were uninsulated, so the walls radiated heat into the room at a great rate. Modern gas ranges overcome this by insulating the oven; and there is an appreciable difference when this is done. In stoves whose construction permits it, you can help an uninsulated model by packing the wall hollows with non-inflammable insulation, and jacketing the bottom and back. (You will have to have the stove upside down while doing this.)

The insulation of the oven is only half the job, however. Every gas stove, because the oven burner is within the oven, must be vented at the bottom and have a flue at the top to afford a supply of air to the flame and to allow the escape of the hot gases resultant from combustion. Formerly the flue was connected to a small stove pipe which entered the house chimney thus carrying off the gases, the heat they contained, the inevitable vaporized grease, and a good deal of the odor. To extend the usefulness of the gas stove to apartment buildings without chimneys, the stove pipe was abandoned. At first a bit of pipe was left, stuffed with steel wool and optimistically called a condenser. Then as users became accustomed to a stove without a pipe, without realizing its disadvantages, even the condenser was omitted. Stove pipe of the proper size is, however, still generally available.

Electric Ranges

Electric ranges (Figure 95) are even more trouble-free than gas stoves, if that can be. Only the very rare failure of a heating element is likely to disturb them, and should this happen it can be replaced quite readily. The wiring circuit of a range is somewhat complicated. To supply the large amount of current required, a three wire 220-volt service is used, and the heat control switches are of the multiple pole type. In addition, the oven heat is regulated by a thermostat, sometimes in combination with a clock. The

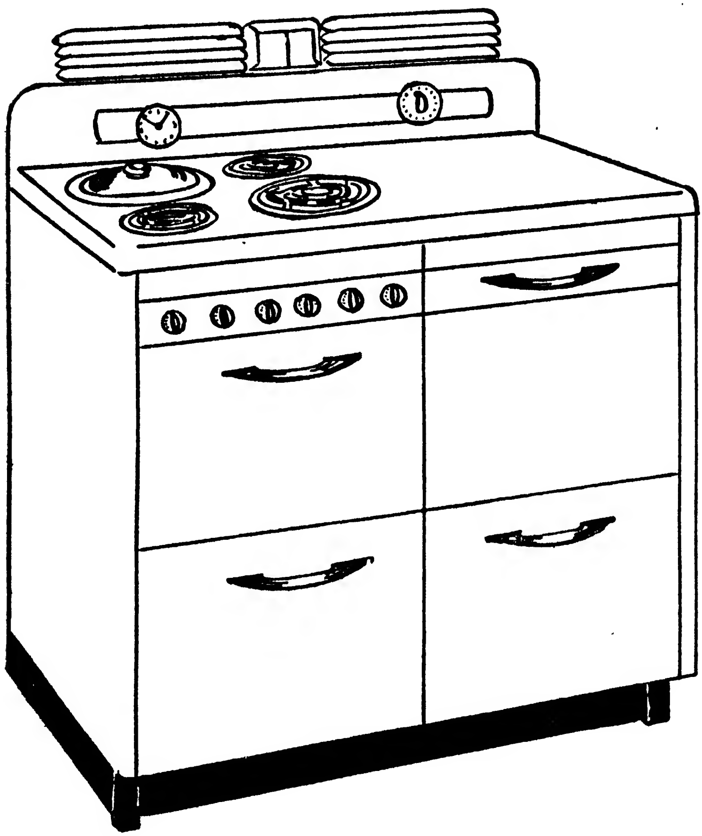


FIGURE 95—The Modern Electric Kitchen Range

general procedure governing the connection of resistance heating elements through switches is covered in Chapter X, and this information plus an understanding of the complete wiring diagram of the stove which is contained in the service manual and parts catalogue are all that is needed.

Hot Plates and Broilers

There are two other types of electric stoves which are rapidly gaining in use. They are the familiar old electric hot-plate mentioned in Chapter X and a new portable enclosed electric broiler which is essentially a chafing dish with a toaster element in the lid. The popularity of these devices is an expression of dissatisfaction with the innate inconvenience of the orthodox stove with all its heating elements grouped in one spot. Functionally they are just about a perfect answer to this limitation, but it should be remembered in using them that the current they draw may cost ten times as much as a like amount used through the cooking stove if the favorable rate granted to users of power for electric stoves and water heaters does not extend to the lighting circuit of the house from which these appliances work.

CHAPTER XVI

Refrigerators

THE REASONS for using a refrigerator of any type are: first, that some foods and beverages are more agreeable when taken cold; and second and much more important, that storage at a low temperature inhibits the growth of bacteria which cause most foods to spoil if they are kept in a warm environment.

FUNCTION OF A REFRIGERATOR

The function of a refrigerator then is first to remove the heat from the food, and then to prevent its absorbing more heat. Any refrigerator which does these two things is a good refrigerator, and the one which does them at the lowest cost and with the least inconvenience to the user is the best.

TYPES OF REFRIGERATORS

There are in current use no less than a hundred makes of domestic refrigerators, but there are only three basic types. These are: the ice box, the electric compression refrigerator, and the absorption refrigerator. The three types of refrigerators are not so different as one might think. The shells of all of them are made in the same way to retard the flow of heat from the room into the box; and they all dispose of the heat that does get in in the same manner; that is, they remove it from inside the box and

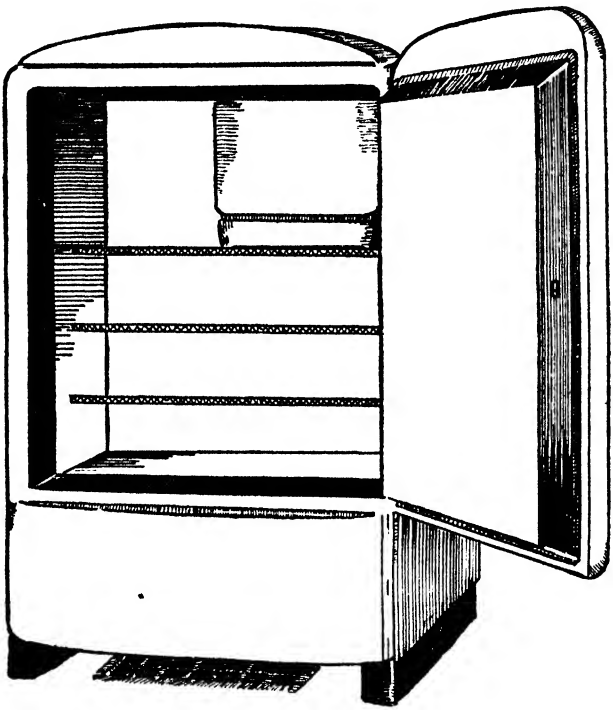


FIGURE 96—Electric Refrigerator Positioned Over an Air Register Cut in the Floor to Admit Cool Air from the Basement.

deposit it outside. (See electric refrigerator in Figure 96.)

Now disregarding for a moment the exact ways in which the three types of refrigerators effect the removal of the heat, and considering only the matter of the heat's constantly leaking back in, the troubles likely to be encountered with the shell of the box will be fairly obvious, and likewise their cures, from what has already been said about other problems of undesired heat transfer.

Heat Transfer Through Air Leakage

First, if the joint around the edge of the door or doors is not practically airtight a great deal of cold air will find its way out through the crack, to be replaced by warm air from outside. Manufacturers go to a good deal of trouble and expense to prevent this by weatherstripping the doors with a soft rubber gasket and providing a special type latch which when closed will draw the door snugly in against the jamb so as to compress the gasket and seal the joint. The tightness of the joint can easily be tested by closing the door on one end of a calling card and trying to move the card along against the pressure of the gasket. If looseness is found, the gasket should be replaced or the latch adjusted. Second, in ice refrigerators a possible air leak is through the pipe which drains the water from the box, if the water trap which seals off this opening is accidentally displaced.

Heat Transfer Through Conduction

Even with a refrigator virtually airtight against heat transfer through the actual exchange of air, there will be a continuous conduction of heat through the walls of the box. The rate at which this takes place will depend not only on the quality of the insulation in the shell, but on the temperature outside the box as well. This simple fact needs emphasizing because it has been so completely lost sight of since the introduction of mechanical refrigerators. What it means in actual practice is merely that the cooler the location found for the refrigerator, the less ice (or electricity or gas) will be required to operate it.

The Effect of Outside Temperature

The difficulty is that there is a conflict here between economy and convenience. The kitchen is almost invariably the hottest room in the house, but it is also the most convenient place for the refrigerator; in many small houses without a pantry or a cool shady covered kitchen-porch, the kitchen is the only place for the refrigerator. Consequently it is a regular summertime routine for the refrigerator service men during every spell of hot weather to get call after call complaining that the refrigerator is out of order because it runs all the time, or fails to maintain the customary low temperature inside. The householder might just as well save his money, because the mechanic's tinkering with the machine will not lower the temperature of the kitchen. Nor would it help much to suggest that the cost of operation might be cut in half by moving the refrigerator to the basement where the air is cool.

Ventilating the Refrigerator

What can often be done, however, is to get some of the cool basement air up to where the refrigerator is, simply by cutting a hole a foot square or so in the kitchen floor beneath the refrigerator and inserting an old-fashioned hot air register in the opening. With a kitchen temperature near ninety and a basement temperature in the fifties, the improvement will be striking, especially if the convection current thus induced is encouraged by keeping the kitchen doors closed and opening the top of a window or the outside door transom to permit the escape of the hotter air from beneath the ceiling of the room. (See Figure 96.)

So much for the troubles which both ice and mechanical refrigerators may suffer. The latter have in addition a few which can be understood and helped only by understanding something of their construction and operation.

How the Icebox Works

It was said that all types are similar in that they remove the heat from inside the box and deposit it outside. In the icebox the heat within the box is absorbed by the ice, in conformity with the natural law already mentioned that heat will flow from a warmer to a colder body. As the ice absorbs heat, it is changed thereby from a solid to a liquid state and becomes again what it was before it was frozen into ice—water. This water, containing the absorbed heat, is drained from the box and it carries the heat along with it.

How Mechanical Refrigerators Work

In the mechanical refrigerator, instead of frozen water a different refrigerant is used; and instead of its being drained off and thrown away it leaves the box with the heat, it is made to surrender the heat outside and return to the box for more. The diagram in Figure 97 on page 295 shows in simplified form the circulation of the refrigerant in an electric refrigerator. Here, as with the icebox, the refrigerant occurs in two states—but as a liquid and a vapor instead of as a solid and a liquid—and the whole operation of the system consists in changing the refrigerant back and forth from one state to the other.

In explaining the operation of the steam heating system it was said that as heat was added to the water, the water was converted into steam; and that as the heat flowed from the steam (to the air surrounding the radiator) the steam was converted back into water. In the mechanical refrigerator the same natural law operates. That is, just as the addition of heat to a liquid will convert it to a vaporous state so the conversion of a liquid to a vaporous state will be accompanied by the absorption of heat; and, likewise, just as the removal of heat from the vapor will convert it to a liquid, so the conversion of the vapor to a liquid will cause it to surrender heat.

In the electric refrigerator then it is only necessary to do these things: 1) convert the liquid refrigerant in the evaporator, or cooling chamber shown at *A*, into a vapor, to make it absorb the heat within the box; 2) conduct the vapor (and heat) through the pipe marked *B* to the ex-

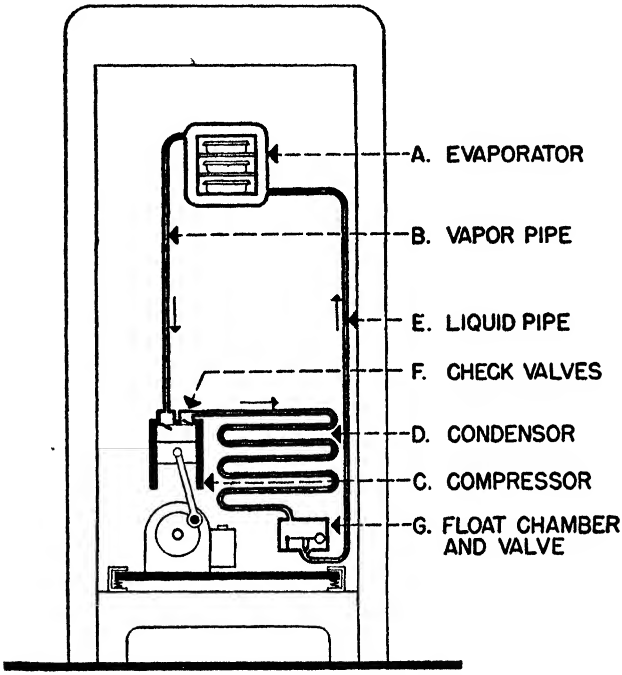


FIGURE 97—Diagrammatic View of the Electric Mechanical Refrigerator

pansion coil *D* outside; and 3) there reconvert it back to a liquid so as to cause it to give up the heat to the air surrounding the coil; after which, 4) it must be drawn back into the cooling chamber through pipe *E* to continue the cycle of operation.

Condensation and Evaporation of Refrigerant

To convert a liquid to a vapor it is only necessary to expose it to a pressure sufficiently low; and obversely to convert the vapor back to the liquid state it is only necessary to expose it to a pressure sufficiently high; and when these things are done heat will be absorbed from the surroundings or given off to the surroundings, even though doing so may require that the heat be made to flow *from* the cooler *to* the warmer place.

The Compressor

To set the refrigerator working, then, requires some means of reducing the pressure on the refrigerant at *A* and increasing it at *D*. The same device does both jobs. It is the *compressor* whose internal operation is shown at *C* in the diagram. There is really nothing in the least complicated or mysterious about its construction or operation. In fact it is no more than a glorified bicycle pump, but arranged so that its piston is moved back and forth in the cylinder by the turning of an electric motor.

The check valves (*F*) prevent the reverse flow of the vapor; and the float chamber and valve *G* permit only liquid to enter the liquid pipe, *E*.

Not all electric refrigerators use this reciprocal type of compressor, nor are all of them arranged so that the compressor and motor are out in the open below the box where they can be seen, but this is of no great importance to the user because the likelihood of the closed or "sealed" units suffering any mechanical trouble which an amateur could diagnose and repair is slight. Of more practical importance is the way in which the motor, compressor, and condensing coil are attached to the refrigerator, because of the direct bearing this has on the cost of operation.

As the temperature of the air surrounding the condenser coil rises, the amount of pressure required to condense the entering vapor back to liquid will rise; and this will mean that the motor must run for a longer period in order for the compressor to build up this pressure. This is just what happens on a hot summer day. With the enclosed type of unit whose shell forms part of the housing of the refrigerator, all that can be done is to either turn an electric fan on the condenser coil or move this entire refrigerator bodily to a cooler location. With the type of machine which has the motor, compressor, and condenser coil mounted in a metal cradle beneath the box the entire unit can be removed and placed in the basement. In the early days of domestic mechanical refrigerators this is what was done, and the practice was abandoned only to make a more convenient portable "sales package" of the refrigerator.

Moving the Unit

To make moving possible, it is necessary to extend the refrigerant lines *B* and *E* connecting the cooling chamber with the compressor and the condenser coil with the cooling chamber, by the insertion of additional lengths of flexible copper tubing, and also to extend the wires connecting the controls with the motor. Any service man can do the job in a few hours, and the cost of the materials required is small. A noticeable improvement in the temperature of the kitchen will follow the job, but not because of the removal from the room of the heat taken from inside the box, but because the motor of every mechanical refrigerator is in effect a small stove converting only part of the electrical energy used into motion and the remainder into heat.

Absorption Type Refrigerators

The *absorption type* refrigerator is not so different from the compression mechanical type. It too uses a refrigerant which is circulated from an evaporating chamber in the box to a condensing coil outside, being changed alternately from a gaseous to a liquid state. However, the changes are not effected by subjecting the refrigerant to a low pressure to evaporate it and a high pressure to condense it, as in the compression type. Instead the refrigerant is vaporized by being heated, either by a gas or kerosene flame which is substituted for the compressor. The construction of the absorption, or thermal type as it is also called, is much more complicated than the compression refrigerators. It requires the use of water, methyl chloride, and hydrogen gas, in addition to the refrigerant, and a more elaborate method of heat exchange to make it operate.

The result is that for practical purposes the machine must be regarded as unrepairable by the amateur, and the service man depended on should it go out of order. However, repairs are seldom needed; and with the type which uses gas for heating, the gas companies usually service their customers' boxes.

Operating Controls

In all mechanical refrigerators, two indispensable elements are a manual switch to start and stop the machine and an adjustable thermostat to maintain the desired temperature in the box. In the electric refrigerators the thermostat and switch start and stop the motor, and in the gas refrigerators they control the gas flame. The exact arrangement of these controls varies with each make of machine, but there is a complete explanation in the maker's service manual or instruction booklet.

Defrosting Mechanical Refrigerators

There is one trouble suffered by mechanical refrigerators which ice-boxes do not have. This is the constant condensation of the moisture in the air in the refrigerator, and its freezing into frost on the expansion coils. It is inherent in the nature of the devices that this should happen, because whenever air is cooled its capacity to support moisture as a vapor is reduced.

The three objections to this condensation are: 1) that the frost is an insulator (in spite of its low temperature) and thus cuts down the operating efficiency of the machine if it is allowed to accumulate on the coils; 2) that when the machine is "defrosted," the melting frost is a nuisance; and 3) that the air, having been dried by the coils, then picks up moisture from the food thus drying it out objectionably.

The newer machines contain an automatic electric time switch which cuts off the current for a period each night to permit the coils to warm up enough to melt the frost. This switch, however, is available as an accessory which can be attached to any make of machine simply by plugging it in; and it will cure the accumulation part of the frosting problem.

Reducing the Dehydration of Food

The drying out of the food (or its "dehydration" as the ice refrigerator makers call it) can be guarded against by keeping the food in closed containers, though even so some evaporation and condensation of the vapor on the cold walls of the container itself will still take place.

Eliminating Food Odors

Both ice and mechanical refrigerators sometimes impart objectionable flavors to the more delicate foods, but this is easily cured. When it happens in an ice refrigerator it means that the drain is stopped up, because when the drain is open so the melted ice can leave the box the odors go along with the ice water. In fact the air in an ice box is actually "washed" in a very real sense of the word each time it passes downward over the surface of the ice, and deposits its odors in the melting water. A well designed ice refrigerator should handle any but very pungent foods without objectionable cross-flavoring so long as they are properly segregated in the box, the strong and the delicate ones wrapped up, and the drain kept open.

The Charcoal Odor Absorber

In a mechanical refrigerator, an odor absorber must be used to meet the problem. An entirely satisfactory one is plain ordinary wood charcoal, which has the ability to absorb odors in much the same way that some chemicals (such as calcium chloride mentioned in the chapter on air conditioning) will absorb moisture. However, the charcoal does not consume the odors, it only absorbs them; and after a time it becomes saturated. Then the odors must be removed or the charcoal will be useless. This is easily done by subjecting the charcoal to a mild baking at a temperature below the point where it will begin to glow or burn. If two perforated metal baskets of the type used to contain vegetables are secured, and both filled with charcoal, one can always be on duty in the refrigerator while the other is somewhere handy to the stove ready to be baked whenever the oven happens to be warm.

CHAPTER XVII

Laundry Machines

Economy of Home Laundering

Laundry machinery occupies a curious position in the American home. On the one hand its makers have so perfected it that most of the connotations of drudgery formerly associated with the chore have been removed, while on the other, commercial laundry service has been so improved and its cost so reduced as to raise a question as to the worthwhileness of home laundering.

That home laundering is still less expensive even with the wage of hired help figured in than buying the service outside, or that it has become a job within the endurance of the housewife, seems to be the opinion of most housewives—provided the work is done with modern home laundry machinery efficiently arranged and kept in good mechanical condition.

Arranging the Laundry Room

The ideal laundry room seems to be a nice cool basement; cool but not dank or clammy, well ventilated and well lighted, and with a smooth dry concrete floor, and by all means clean and free of ashes, dust, or soot.

Because of the proximity of so many electrical grounds —all the exposed plumbing and heating and gas pipes, and the floor (possibly damp during the laundering operations), particular care should be exercised to prevent the danger of an electrical shock in using any of the equipment. Electrical outlets should be located—or relocated—overhead or where they are high enough to prevent any extension cord drooping to the floor. There should be sufficient outlets to avoid the necessity of using long extension cords or serving more than one appliance from an outlet; they should be wired with conductors heavy enough to carry the required load; switches should be of a type having the control well insulated from the action; and outlet cover plates should be non-metallic.

Improving the Efficiency of the Laundry Tray or Soaking Tub

Every laundry should include a plumbing fixture known as a laundry tray or soaking tub. It is really a deep double-compartment sink with a swinging spout mixing faucet with a screw nozzle, for attaching a length of hose and (sometimes) with large drain openings to permit rapid draining. Two difficulties occur in connection with these trays:

First, they are made of dense Portland cement and sometimes the interior surface becomes roughened and pitted with wear and tiny leaks develop, and sometimes they crack when very hot water is turned into them on a cold day. When cold they should always be "tempered" by being sprayed with a light stream of warm water from the hose before being filled with hot water. Luckily either small holes or cracks can easily be mended with a wash of straight cement and water about the consistency of cream, or with any of several other easily secured preparations.

The second difficulty is that the hose mentioned above, which is usually used to fill the washer, must be unscrewed from the faucet spout every time the spout is to be swung from one tray to the other, because the faucet is mounted by being clamped to the back of the tray so near its top edge that the spout just barely clears the partition. The best plan is to raise the faucet six inches or so by extending the water lines upward and abandoning the clamp attachment, or better yet, is to extend the lines beyond the present faucet with tees, and to mount a duplicate about 12 inches above the first. In this way the hose can be used attached to the upper faucet without interfering with the simultaneous filling of the trays.

The Washing Machine

The pattern in washer design varies from that observed so often with other devices where there are many makes but only one or two types to choose from. In washers there are not only many makes but many types as well. But they all have two things in common. They all use electric motors, which need to be kept clean and dry and in some cases oiled occasionally; and they all come accompanied by an instruction booklet which sets forth in the greatest detail, and in simple and understandable terms the total of all the things the user must and can do to keep the machine operating properly, and to adjust it not only while it is new but as the wear inevitable with use loosens its joints a bit and alters its operation characteristics. There is little further to be said, except perhaps this—that the recommendations which a manufacturer makes as to the proper loading of the machine and its time of operation and so forth are calculated to make that particular design of machine behave best. It is better either to follow *those directions or to get another type of machine than to wreck the machine by overloading it in imitation of another user's experience with a different type of machine.*

The Automatic Washing Machine

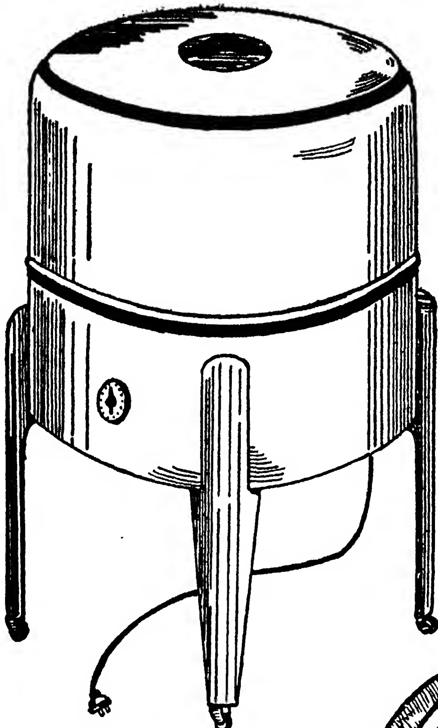
For practical purposes most washers are pretty close together in actual performance, with the exception of a new type which is so different that it might properly be described as a soaker, washer, rinser, bluer, and damp dryer (Figure 98). It does all those things and does them automatically without the operator having to touch the machine once it is started. With this machine, in combination with a mangle, many users with large families find it practical to abolish wash day by running through a machine load or so each day while other work is being done. For this service the favored location for the machine is in the kitchen rather than the basement. As might be suspected of any machine capable of such a combination of actions, it is an expensive machine and its construction is, if not delicate, at least complex enough to suggest the wisdom of the amateur's avoiding repairing it.

THE ELECTRIC MANGLE

The electric mangle, or ironer, and the electric hand iron are both so simple that there just isn't anything much in them to get out of order. Should the heating element of either fail, it can like most all heating elements be easily removed and replaced. The same is true of the thermostatic heat control which the newer models have. The mangle motor must be oiled.

THE MECHANICAL CLOTHES DRYER

Probably the least widely used of all the mechanical aids to home laundering is the indoor clothes dryer. It is



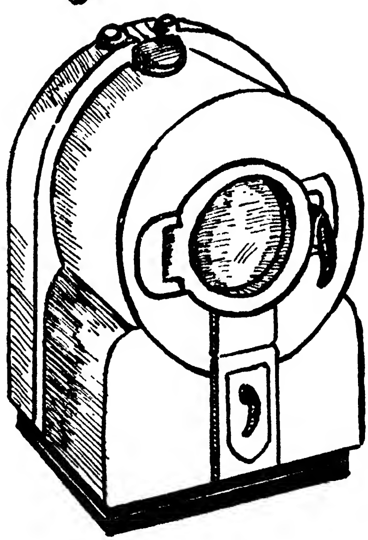


FIGURE 98—Two popular types of Washing Machines. Above, the Extractor type of washer, which removes the washing and rinsing water from the clothes by centrifugal action; and, to the right, a Modern Laundry Machine which soaps, washes, rinses, blues, and damp-dries the clothes automatically.

certainly a time- and labor-saver but its relative unpopularity must be the result of its saving that part of the total labor of laundering which is the least objectionable to the housewife. No amount of argument is likely to affect that widespread feminine preference for the "clean, sweet smell" which being dried in the sunshine imparts to clothes, nor will any showing of the actual labor hours needlessly involved in hanging out and bringing in the laundry. Thus it is that the greatest sale of dryers has been to apartment houses lacking a nice grassy drying yard.

However, the dryer is a worth while machine if only for those days when the weather is inclement or the housewife too rushed or fatigued to justify indulging her preference for sun drying.

In operation, the dryer is usually found to save practically the entire labor effort formerly devoted to hanging out and bringing in the laundry and the elapsed time required for the outdoor drying as well. This the dryer does by converting the three separate laundering operations of washing and then drying and then ironing into one continuous process, the laundered clothes being put through the dryer as rapidly as they come from the washer, and through the mangle directly from the dryer. Thus the three machines can be in operation at the same time and the work can often be finished all in one day instead of in two.

The dryer is essentially no more than a confined space enjoying an atmosphere of such low relative humidity that the moisture is removed from the clothes very quickly. This low relative humidity is accomplished merely by heating the air, and it is maintained by changing the air as rapidly as it absorbs the moisture from the clothing.

Cabinet and Rotary Type Dryers

There are two types of dryers: the cabinet type and the rotary type. The cabinet dryer is the simpler, being a large sheet metal closet with wide doors, hooks or rods to hang the laundry from, a gas burner to heat it, and a cold air inlet and a hot air outlet. It may or may not have an electric fan blower to increase the air circulation and a thermostat to control the gas flame. The rotary dryer, or drying tumbler as it is also called, consists of a horizontal metal drum which is revolved slowly by an electric motor, while air (heated as in the cabinet type) is blown through it by a fan.

The construction of both types is so simple that breakdowns are very infrequent. Their chief drawbacks, which often result in their being abandoned or used only in emergencies are the inordinate amount of fuel they use and the fact that they seem to deposit all the moisture extracted from the clothes all over the basement as dew.

Reducing Fuel Waste and Moisture Condensation

The fuel consumption can be materially reduced, especially with the cabinet type which has such a large surface area exposed to the cooler atmosphere of the room, by insulating the entire machine. In an older type of machine with no thermostatic control to keep the internal temperature within safe limits (that is below the scorching point of dry cloth), it will be necessary to watch the gas burner setting closely after insulating the cabinet. The solution to the condensation problem is to conduct the moisture-laden exhaust air from the dryer outdoors through a flue. This can be made of sheet metal if it can be installed permanently, or of heavy cloth sewed into a tube and stretched over a number of hoops made of light wood or heavy wire where it is necessary to vent it through a window. In this way it can easily be moved away to close the window.

Where any appreciable amount of laundering is done at home, the construction of a well insulated sheet metal cabinet type dryer with an electric blower and a thermostatically controlled gas burner is interesting and worthwhile, and not a difficult construction job for a home mechanic. Rustproof copperbearing sheet metal should be used.

PART EIGHT

Outdoor Mechanical Equipment

CHAPTER XVIII

Outdoor Wiring, Plumbing, and Garden Equipment

Special Care and Design of Outdoor Equipment

Mechanical equipment of any sort which is used outdoors almost always requires special care to protect it from the extremes of temperature and moisture to which it is naturally subjected. More than this, it is usually especially designed so as to be weatherproof. Otherwise it does not differ greatly from comparable equipment designed for indoor use; and repairing and maintaining it will present no particular problem.

Weatherproof Electrical Equipment

In Chapter IX it was mentioned that electric wiring and appliances must be protected from water (and even extreme moisture). In outdoor electrical installations this problem is so much more acute that a whole series of weatherproof devices is used instead of the regular indoor ones. Because they must contain all the working elements of the indoor type plus a special armoring of superinsulation to make them waterproof, they are necessarily a good deal more expensive than the ordinary type, and also bulkier and huskier and more utilitarian in appearance. Because of their use on shipboard they are often known as marine-type fittings.

Whatever the job to be done outdoors by electricity, there is a special marine or weatherproof type device made to do it; and these should be used. There are weatherproof switches, lamp sockets, split plug convenience outlets, floodlights, electric motors, and of course conductors to carry the current to the fixtures.

Outdoor Wiring

There are three general types of outdoor wiring, not unlike the three types used for indoor work. One of these, the BX lead sheathed type, or BXL, has already been mentioned in Chapter IX. It is used where the line must be buried in the earth or where it can be supported at frequent intervals by being fastened to some permanent support. Like regular BX, it must never be draped—as wires can—so it sags from one point of support to another. All connections in the system must be made in special weatherproof boxes.

Instead of BXL, rigid conduit is sometimes used where there is danger of physical damage to the wires. Here too the important thing is to maintain the continuity of the waterproofness throughout all the parts of the system subject to the weather. Both these systems are expensive, however, and troublesome to install and protect; and most domestic applications use either the third system, which consists of exposed insulated wires hung from insulators and protected from brushing or rubbing against anything, or a combination of the three systems.

Paired conductors twisted together like indoor extension or drop cords are sometimes used outdoors instead of two separate wires. Such conductors have especially heavy insulation, and ordinary twisted wire should not be used in this way.

Overloads and Fuses

Two points in connection with all outdoor wiring are worth particular mention. The first is the matter of the circuit being overloaded. This often happens through too small a size wire being used for a long run, or by building up the connected load at the end of the line beyond that which it was originally expected to carry. The second is that any outdoors circuit must always be properly fused just like any other branch line, and this is important because of the added danger of damage to which outside wiring is always subject.

Outdoor Lighting

Wherever electricity is required for the operation of a motor or some other appliance at a point remote from the house, outdoor wiring will of course be required to get the current to the device; but most frequently its only usefulness is for lighting, and in this case the entire job of wiring can often be avoided, or the amount required greatly reduced. This is done by using one or more powerful weatherproof floodlights. These are attached to the house as inconspicuously as possible and aimed to throw their beams out over the grounds. These lights are expensive, but even so the cost of one or two of them plus the small amount of wiring required to serve them is generally substantially less than the outdoor wiring and the smaller old-fashioned weatherproof lighting fixtures which they will replace (Figure 99).

Switch Controls for Floodlights

The convenience of floodlights is greatly increased by using a special switch to control them. This is called a time switch, and it contains a small spring clockwork mechanism coupled to the toggle handle, and a small lever to engage and disengage the clockwork. Usually you want outdoor light only for a short time, as to guide you to the

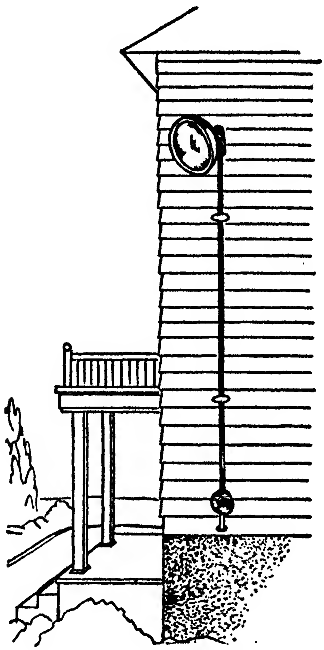


FIGURE 99—A Floodlight used to illuminate the yard or driveway

garage or gate; and in this case the switch is thrown with the clockwork engaged, whereupon the motion of the switch toggle lights the light and winds the clockwork up and sets it to ticking. It runs for a definite time depending on its adjustment and then automatically throws the switch back to the off position. Or by disengaging the clockwork and throwing the switch, the switch will remain on like any ordinary manual switch until it is turned off.

The bulbs of floodlights draw considerable current but as they are used only for short periods this does not add up to any appreciable amount in kilowatt hours. Where they are switched manually and there is a tendency to forget to turn them off, a small pilot light located in some conspicuous spot in the house will overcome this. The pilot light is wired so that the same switch controls them both.

Outdoor Plumbing

Most homes have at least the beginnings of an outdoor plumbing system in the form of a hose bibb or garden faucet to supply water for the garden hose, to irrigate the lawn, and perhaps to wash the automobile. The faucet itself is fairly trouble-free but it is an inadequate sort of device, inconvenient to use and really not equal to its job.

Frozen and Leaking Faucets

First, as to its troubles, it may freeze in winter, and may develop leaks which in turn cause further trouble. To prevent the faucet being damaged by freezing, the branch line which feeds it must have a shutoff valve and a draincock, and at the approach of cold weather the line must be shut off and drained, and the faucet left open. When the faucet develops a leak the water may run back along the pipe through the wall and into the house, or down the outside of the wall to the foundation. Either is bad, and the faucet should be repaired as suggested in Chapter VI, or replaced.

An Adequate Number of Garden Faucets

Too many homes, especially with large yards and perhaps a vegetable garden, have only one outside faucet, when two or even three well located ones would be much more convenient—and sensible. This is simply a hangover from the early days of plumbing when even the inside of the house had far too few faucets. It is not, however, a real economy, because buying and maintaining long lengths of garden hose is more expensive than the small amount of pipe-fitting usually required to serve faucets on opposite sides of the house.

Sprinklers

As every serious gardener knows, growing vegetation (and this includes grass and trees as well as flowers and vegetables) requires a good deal more water than sprinkling it for a few minutes will supply; and to develop healthy

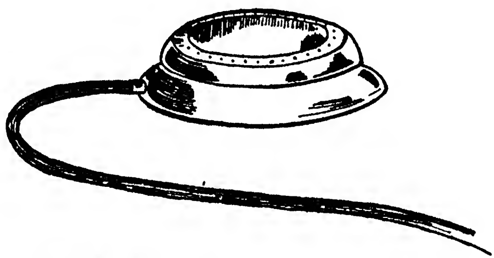


Figure 100—The Garden Hose Sprinkler

roots the water is needed down deep in the soil, not on the surface. Generally speaking it is now considered better practice to give the ground a thorough soaking at intervals of several days than to sprinkle it lightly every day. This is mentioned to suggest that the usual type of lawn sprinklers, which throw an impressive spray of droplets up into the air to simulate "the gentle rain from heaven" but really deliver a comparatively small flow of water, have definite limitations (Figure 100).

Garden Hose

Garden hose is damaged by extremes of temperature and by prolonged exposure to sunlight, and of course by being kinked. The first two difficulties can be overcome by always hanging the hose on a wall reel when it is not in use, rather than leaving it on the ground or looping it over a peg which would cause it to hang in sharp bends. Several types of metal coupling unions are available for mending kinked or broken hoses, and these can be applied without special tools. When a hose is kinked or otherwise damaged so that the fabric cords show and the hose leaks, it is always best to cut the hose in two at this point and splice it back together with a coupling (or fit the cut ends with unions to form two shorter lengths) before the damage spreads.

Lawn Mowers

The lawn mower is a peculiar tool in that to keep it running and doing its job properly requires almost constant

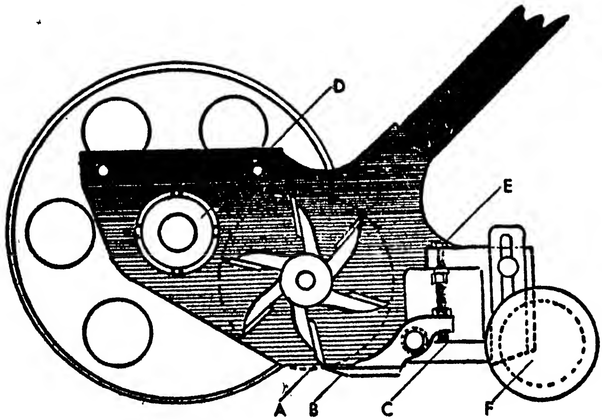


Figure 101—Lawn Mower, showing Revolving Blades at *A*, Fixed Blade at *B*, Setscrew for Adjusting Fixed Blade at *C*, Adjustment for Aligning Revolving Blades at *D*, and Adjustment *E* for Raising and Lowering Roller *F*.

attention and adjustment. The failure to realize this is responsible for almost all the troubles which plague the average user. It is something like a butcher's knife, which the butcher spends almost as much time sharpening as using.

In the case of the lawn mower, however, it is not the mere sharpening of the blades (which as a matter of fact require very infrequent sharpening) but the constant readjustment of the moving parts which is required, to maintain their proper engagement. (See Figure 101.)

Adjusting Cutters

To begin with, a lawn mower is a shearing cutter, and a very ingenious one, with four movable blades and one fixed one. The neat way in which these engage with each other will be perfectly apparent from a moment's study of the machine, as will the way in which the fixed blade is held at its ends by means of setscrews. The setscrews must be kept so adjusted that the revolving blades just touch the fixed blade as they brush along its edge. This is the first important adjustment. Even the cheapest lawn mower makes provision for this adjustment, and even the finest mower will not hold the adjustment without occasional attention.

Adjusting Bearings

No adjustment of the fixed blade will insure the revolving blades brushing past it evenly from end to end if the bearings which support the ends of the shaft carrying the revolving blades are worn or loose. Therefore the second adjustment is provided. In cheap mowers with sleeve bearings, this is a setscrew which tightens the sleeve around the shaft (that is one setscrew at each end of the shaft); and in ball bearing machines it is a threaded tapered collar forming part of the bearing. The collar, or cone, is secured by a setscrew; and by loosening the setscrew and turning the cone a bit, the bearing is tightened. (There are two of these cones, one at each end of the shaft.)

Now, with the cutters properly adjusted the mower will cut the grass as it is pushed forward; but a third adjustment is required to permit cutting the grass to the desired length. The cutters in other words can be raised or lowered, but this is not done by moving the cutters but by moving the wooden roller at the rear of the machine. It is this adjustment which is most often entirely neglected. It is effected just as simply as the other two, and in much the same way, by means of setscrews at the ends of the roller.

Ordinary good judgment will guide one in making the cutter adjustments, but the correct roller adjustment will depend on the kind of grass to be cut and on the particular method of culture being followed. Formerly a very close cropped lawn was most popular, and every mower was equipped with a grass catcher into which the clippings flew. With close cropping the removal of the clippings was necessary because they were unsightly as they changed from green to brown, but their removal represented a constant loss to the soil.

Also such a lawn was found less hardy than one with a taller stand of growth, and so the technique of cutting the grass taller was developed, leaving the cuttings to fall among the standing grass where they protect the roots by forming a light mulch, and in time fertilize the soil. Much less energy is required using this technique of mowing; but the time thus saved by being able to push the mower more rapidly is often used to go over the ground twice instead of once. The second cutting theoretically shouldn't touch the standing grass, but it does pick the cuttings up and chop them up finer so that they drop more readily to the base of the standing grass and rot more quickly.

Aside from these adjustments a lawn mower will require only frequent oiling and cleaning, and proper protection from rain and dew, until the blades become dulled. There are three accepted methods of sharpening mowers. One is by means of a precision grinding machine of which there are actually few in use except at the mower-manufacturers' plants. When the blades are ground on one of these machines, and the mower adjusted by an expert the result is practically equivalent to a new machine, provided the other working parts of the mower are not worn out. A good machine grinding job amounts to a thorough overhaul of the mower and is not cheap. It is definitely worth while with a good quality mower and just as definitely a waste of money on a cheap one.

The next method is to lap the blades. This is done by first adjusting the cutters to engage very evenly from end to end, but a shade too tightly. The cutters are then coated with a lapping compound of emery dust and oil and revolved by running the machine. In the hands of an expert a good machine in condition to take and hold a precise adjustment will be helped by this treatment, especially if the machine is designed so the direction of rotation of the revolving cutter can be reversed to lap the blades from both faces.

The third method is to grind the revolving blades against a sheet of fine abrasive cloth held in a patented frame which is attached to the machine in such a way that the blades brush against the cloth as they ordinarily would against the fixed cutter.

An important part of any lapping or cloth sharpening job is to search out any nicks in the blades and file the corners bounding the nicks down very lightly with a fine file. Do not touch the nick proper. This particular point on the blade is irrevocably lost to any further cutting action, but usually the metal is not chipped off but displaced to the sides where it forms two tiny elevations which in turn make nicks in the other shear blade.

The users' instruction book which accompanies every good lawn mower contains valuable information on caring for the machine and specific and detailed instructions for cleaning, adjusting, and oiling it. This should be read several times and the illustrations studied carefully.

PART NINE

The Automobile

CHAPTER XIX

✓ The Mechanism of the Automobile and Its Care

Mechanical Devices Constituting Parts of the Automobile

This chapter on the automobile is not placed here, at the very end of this book, to set it apart as a different sort of mechanical contrivance from the others which we have discussed, but to save a bit of unnecessary repetition—because that beautiful collection of interlocking devices which we call the automobile really contains little that will be new or strange to anyone who has a general understanding of home mechanics.

It is really surprising how very many familiar elements you will find in the automobile. Its nuts and bolts, of course, and the other mechanical fastenings which hold its parts together are the same as those used with other machines.

Its electric system has bulbs and switches and wires and fuses, and an electric motor (to start the engine), all very similar to those used inside the house.

The cooling system has a radiator which operates very much like an ordinary hot water radiator, and the flow of water through it is controlled by a thermostat and a circulating pump. And there are many other familiar mechanical elements which can be understood by referring them back to some household device or other.

Caring for the Car

While it is true that a car contains many elements which are practically speaking unrepairable by the amateur be-

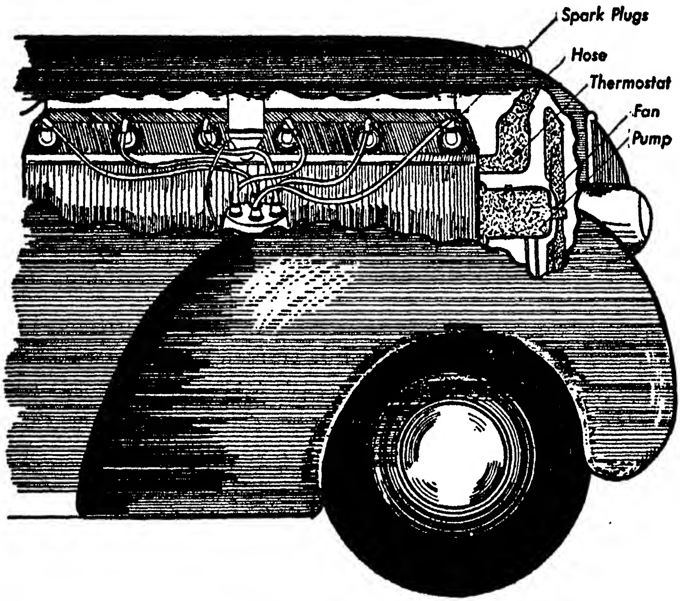


Figure 102—Automobile Engine showing the Distributor, the Wires leading to the Spark Plugs, the Thermostat, Water Pump, and Fan

cause the complexity of the machine is such that localizing and diagnosing the difficulty is impossible without special equipment, it has enough other elements which will yield to the simple tools and limited skills of the amateur to make some understanding of them worth while. Then too, the automobile perhaps more than any of the other simpler machines which we use, suffers from misuse and neglect, and pays large dividends for a little minor tinkering of an understanding and preventative kind. By giving it a bit of attention now and then, a car can definitely be kept out of the repair shop except for those major repairs which are unavoidable in the life of even the best machine.

The fuel system, the cooling system, the electrical system (and the ignition system which is part of it), for instance, may all misbehave occasionally without anything really serious being wrong with the car.

Even if you do not care to perform the slightest repair to your automobile, it is a good idea to know enough about it to be able to avoid misusing it. (See Figure 102.)

The Fuel System

The fuel system consists of the gasoline tank, the feed line which carries the gasoline from the tank to the engine, the gasoline pump which sucks the gasoline uphill from the tank to the carburetor, and sometimes a combination settling tank and filter through which the gasoline passes just before it enters the carburetor. The only attention which the fuel system requires is an occasional cleaning to remove such grit as may get into it with the gasoline and clog it up, and water which is condensed in minute quantities from the air in the gas tank.

There are three provisions for cleaning the fuel system: 1) The filter is made with a glass bowl which is held in place by a simple yoke. The bowl is removed, rinsed out, and replaced, whenever it is seen to contain sediment and water as well as gasoline. 2) In the bottom of the gas tank, at its lowest point, there is a small drain plug. This is removed with a wrench, and a half pint or so of liquid permitted to escape. 3) Some carburetors have a similar drain plug, and it is removed in the same way to drain the carburetor.

The cooling system of a car bears considerable resemblance to a domestic water heater, although here the operation is reversed since the idea is not the generation and storage of heat but the dissipation of heat which is generated unavoidably. The engine is built like a coal-fired water heater, in that it has hollow walls; and these hollows, called the water jacket, are kept filled with water. The water absorbs heat from the engine, rises and flows through a rubber hose connection to the top of the radiator, and as the heat is dissipated through the radiator the water falls to the bottom and circulates through another hose back to the bottom of the engine.

There are four elements used in the automobile cooling system which may be lacking in a domestic heating plant: The first is a thermometer which warns the driver if the temperature of the cooling water (and hence the engine) gets too high. The second is a fan located directly behind the radiator, which increases the heat dissipating effectiveness of the radiator by sucking a strong blast of air through its fins. The third is a water pump which converts the system from a thermosyphon to a forced circulation operation, keeping the water moving much more briskly than would its convection current alone. The fourth is a thermostat in the system which opens at a high temperature and closes at a low temperature to prevent the water from circulating until the engine is properly warmed up.

So long as the last three of these is operating properly, the cooling system will do its work automatically until it begins to become clogged with mineral deposits from the water, and bits of rust from the engine jacket. Then the engine will be seen to operate at a higher temperature than normal. To prevent this the system should be drained out at least a couple of times a year, and vigorously flushed by removing the lower hose connection and running water into both the engine and the radiator with a garden hose, or better yet by running the engine with any of several readily available cleaning compounds added to the water, and then flushing it out.

The Electrical System

The electric system of a modern car has three main functions. These are: to start the engine, to furnish the electric sparks or ignition which ignite the gasoline in the engine, and to operate the lights, horn, radio, and other electric appliances.

The electricity which a car uses is generated by a dynamo or generator which is attached to the engine and revolved by it. The operation of the generator should regularly be checked by looking at the ammeter, which is a small meter mounted on the dashboard. The generator is connected with the storage battery, and the battery with the various electrical devices. Whenever the engine is running, the generator should charge the battery and furnish current for the car's needs; and when the engine is not running, any current required comes from the battery. The flow of electricity in the system is shown by the ammeter, either as a *charge* flowing into the battery when the generator is working properly and generating more current than is required, or as a *discharge* when the battery supplements or substitutes for the generator.

Caring for the Battery

The only attention required by the *battery* is that it be kept filled with distilled water and properly charged, and have the corrosion removed from its terminals occasionally.

The wiring system suffers chiefly from loose connections, broken wires, and short circuits resulting from the constant vibration. Tracing these troubles out and remedying them calls for much the same sort of patience as does repairing house wiring, plus a wiring diagram of the car such as is contained in the owner's handbook.

The Ignition System

There was a time when the greatest complaint of owners against the automobile was the refusal of the engine to start, but improved fuel, the automatic choke, and half a dozen other improvements in the carburetor and ignition system almost guarantee that the engine will start unless the gas tank is empty or the battery dead. There is one exception. That is when the car has stood outdoors or in an unheated garage during a prolonged rainstorm. In such a situation, moisture from the air will condense, often in such small quantity as to be invisible, on the ignition wires leading to the spark plugs. These wires like the rest of the engine often become coated with a film of oil, and this oil holds particles of dust. This dust becomes saturated with the condensed water vapor, and the result is that the spark plugs are shortcircuited just as effectively as though with a piece of wire.

The cure requires three pieces of clean dry cloth. With one piece, all the spark plug wires are wiped from end to end, and also the porcelain portion of the spark plugs and the distributor cap from which all the wires radiate. The second cloth is then dipped in gasoline, wrung quite dry, and the wiping repeated. One more wiping with the remaining cloth to dry off any traces of the gasoline, and the engine will start. It will even start *during* a pouring rain; and once started, it will generate the heat needed to keep the wires sufficiently dry to permit enough electricity to reach the plugs to keep the car running.

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